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ALL DOCUMENTS REFERENCED

BY THE APPENDIX

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NOISE EMISSIONS STANDARDS

#4

4A:

BACKGROUND DOCUMENT FOR MEDIUM AND HEAVY TRUCK NOISE EMISSION REGULATIONS

4b:

REGULATORY ANALYSIS OF THE NOISE EMISSION REGULATIONS FOR TRUCK-MOUNTED SOLID WASTE COMPACTORS

#4

United States
Environmental Protection
Agency

Office of Noise
Abatement and Control
Washington DC 20460

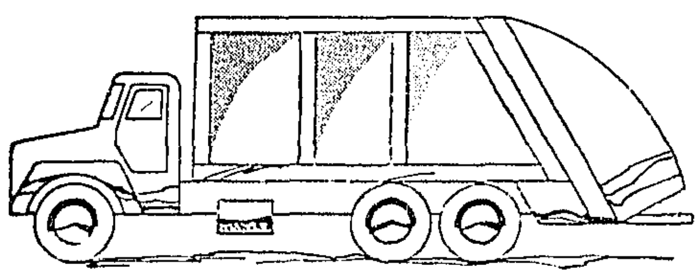
EPA 550/9-79-257
Aug 1979

Noise

EPA

Noise Emission Standards for Surface Transportation Equipment

Regulatory Analysis of the Noise Emission Regulations for Truck-Mounted Solid Waste Compactors



EPA 550/9-79-257

NOISE EMISSION STANDARDS FOR SURFACE TRANSPORTATION EQUIPMENT

REGULATORY ANALYSIS OF THE NOISE EMISSION REGULATIONS FOR TRUCK-MOUNTED SOLID WASTE COMPACTORS

August 1979

U.S. Environmental Protection Agency
Office of Noise Abatement and Control
Washington, D.C. 20460

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

FIGURES

FIGURES (Continued)

TABLES

TABLES (Continued)

TABLES (Continued)

TABLES (Continued)

SECTION 1

INTRODUCTION

BACKGROUND

This regulatory analysis presents the basic information relevant to the development of noise emission standards for newly manufactured truck-mounted solid waste compactors (refuse collection vehicles). For brevity, these products are also referred to in the text as RCV's, or trash compactors, or compactors. The topics of major concern are: the noise emissions of compactors and the technology for controlling the noise; noise measurement methodology; the environmental noise impact caused by operation of RCV's in the community; the reduction in noise impact expected from the establishment of noise limits for newly manufactured RCV's; and the economic status of the industry and the potential costs and economic effects of a noise regulation.

As a result of studies conducted under the authorities and duties given to the Administrator of the Environmental Protection Agency by the Noise Control Act of 1972 (the Act), truck-mounted solid waste compactors were identified as a major source of noise on May 28, 1975 (40 FR 23105). In order to ascertain the basic data required to promulgate a noise regulation conforming to the requirements laid down in the Act, a program of detailed studies was undertaken by the Agency, with the help of qualified contractors. These studies dealt with the areas of concern outlined above, and entailed a search of the pertinent industry and government statistics and the available technical literature, measurements of the noise emissions of a substantial number of refuse collection vehicles, both new and in service, and associated analyses. Many contacts were made with all segments of the affected industry, governmental units at various levels (Federal, state and local) and the general public, in order to develop the factual data and gather the opinions of concerned persons and organizations which were germane to the regulatory provisions and process.

Based on the results of this information gathering process and under the requirements of Section 6 of the Act, the Agency published a proposed regulation on August 26, 1977 (42 FR 43226). A docket to receive comments was opened and hearings were held in New York and Salt Lake City. Numerous comments were received in the docket and at the hearings, and additional information was acquired through communications with industry associations, as well as by further testing and analysis. The Agency reviewed this information thoroughly and, based on the results of this review, developed a number of revisions in the regulation text, with the aim of clarifying the Agency's intent and simplifying some of the measurement and enforcement procedures. The docket comments and the Agency's analyses and responses are summarized in Appendix A of this report. The revisions to the regulation are detailed in the preamble to the final regulation, which is published contemporaneously with this Regulatory Analysis.

PUBLIC PARTICIPATION

Throughout the development of this regulation an effort has been made to allow all groups, organizations, and individuals who have an interest in, or who may be directly affected by truck-mounted solid waste compactor noise emission standards, the opportunity to participate in the rulemaking process. This public participation effort has included meetings with concerned state, county, and city officials; refuse truck user groups; refuse collection industry associations; compactor and truck chassis manufacturers; and compactor distributors. A list of the organizations and individuals contacted in the development of this regulation is included as Appendix C to this document.

As another step in the Agency's continuing public participation program, an extensive effort is underway to inform the public of the benefits and impacts of the noise emission standards for truck-mounted solid waste compactors. This effort will include direct mailings of information packets to the major groups affected by the regulation and briefings to selected groups. Appendix D to this document lists the groups that are to be contacted in this informative public participation effort.

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 part of this essential Federal action, Subsection 5(b)(1) of the Act requires that the Administrator of the U.S. Environmental Protection Agency, after consultation with the appropriate Federal agencies, publish a report or series of reports "identifying products (or classes of products) which in his judgment are major sources of noise." Section 6 of the Act (Subsection 6(a)(1)) requires the Administrator to publish proposed regulations for each product identified as a major source of noise and for which, in his judgment, noise standards are feasible. Four categories of products are listed as potential candidates for regulation; one of these is transportation equipment.

It was under the authority of Section 5(b)(1) that the Adminstrator published the report on May 28, 1975 (40 FR 23105) that identified truck-mounted solid waste compactors as a major source of noise, and under the requirements of Section 6(a)(1) that the Administrator published the Notice of Proposed Rulemaking (42 FR 43226) to control the noise emissions of newly manufactured compactors. It is also under this authority and requirement that the final regulation is published.

Preemption

Section 6(e)(1) of the Noise Control Act states that after the effective date of a Federal regulation "no State or political subdivision thereof may adopt or enforce... any law or regulation which sets a limit on noise emissions from such new product and which is not identical to such regulation of the Administrator." Section 6(e)(2), however, states that "nothing in this section precludes or denies the right of any State or political subdivision thereof to establish and enforce controls on environmental noise (or one or more sources thereof) through the licensing, regulation, or restriction of use, operation or movement of any product or combination of products." The central point to be developed here is the distinction between noise emission standards on products, which may be preempted by Federal regulations, and standards on the use, operation or movement of products, which are reserved to the states and localities by Section 6(e)(2).

Section 6(e)(2) forbids state and local municipalities from controlling noise from products through laws or regulations that prohibit the sale (or offering for sale) of new products for which different Federal noise emission standards already have been promulgated. States and localities may augment the enforcement duties of the EPA by enacting a regulation identical to the Federal regulation, since such action on the state or local level would assist in accomplishing the purpose of the Act. Further, state and local municipalities may regulate noise emissions for all new products that were manufactured before the effective date of the Federal regulation(s).

Section 6(e)(2) explicitly reserves to the states and their political subdivisions a much broader authority: the right to "establish and enforce controls on environmental noise (or one or more sources thereof) through the licensing, regulation or restriction of the use, operation, or movement of any product or combination of products." Environmental noise is defined as the "intensity, duration, and character of sounds from all sources" (Section 3 (11)). Limits may be proposed on the total character and intensity of sounds that may be emitted from all noise sources, "products and combinations of products."

State and local governments may regulate community noise levels more effectively and equitably than the Federal government due to their perspective on and knowledge of state and local situations. The Federal government assumes the duties involved in regulating products distributed nationwide because it is required and equipped to do so. Congress divided the noise emission regulation authorities in this manner to allow each level of government to fulfill that function for which it is best suited. Through the coordination of these divided authorities, a comprehensive regulatory program can be effectively designed and enforced.

One example of the type of regulation left open to the localities is the property line regulation. This type of regulation limits the level of environmental noise reaching the boundary of a particular piece of property. The occupant of the property is free, insofar as state regulations are concerned, to use any products whatsoever, as long as the products are used or operated in such a fashion so as not to emit noise in excess of the "property line" limits specified by the state or municipality. This type of regulation may be applied to many different types of properties, ranging from residential lots to construction sites.

In such a case, state and local regulation of trash compactor trucks may take the form of, but would not be limited to, the following examples:

- o Quantitative limits on environmental noise received in specific land use zones, as in a quantitative noise ordinance.
- o Nuisance laws amounting to operation or use restrictions (including, for example, curfews).
- o Other similar regulations within the powers reserved to the states and localities by Section 6(e)(2).

In this manner, states and local areas may balance the issues involved to arrive at satisfactory environmental noise regulations that protect the public health and welfare as much as possible.

Labeling

The enforcement strategies outlined in Section 8 of this document are accompanied by the requirement for labeling products distributed in commerce. The label provides notice to a buyer that a product is sold in conformity with applicable regulations. The label also makes the buyer and user aware that the trash compactor truck possesses noise attenuation devices and that tampering with such items is prohibited.

RATIONALE FOR REGULATION OF THE TRASH COMPACTOR TRUCK

In determining whether a product (or class of products) is a major noise source for regulation under Section 6 of the Act, the Administrator considers primarily the following factors:

1. The intensity, character and/or duration of the noise emitted by the product (or class of products) and the number of people impacted by the noise;

2. Whether the product, alone or in combination with other products, causes noise exposure in defined areas under various conditions, which exceed the levels requisite to protect the public health and welfare with an adequate margin of safety;

3. Whether the spectral content or temporal characteristics, or both, of the noise make it irritating or intrusive, even though the noise level may not otherwise be excessive;

4. Whether the noise emitted by the product causes intermittent single event exposure leading to annoyance or activity interference.

The Agency has given first priority to those products that contribute most to overall community noise exposure. Community noise exposure is defined as that noise exposure, experienced by the community as a whole, which is the result of the operation of a product or group of products; not that exposure experienced by the user(s) of the product(s).

In terms of assessment, community noise exposure was evaluated in terms of the day/night average sound level (L_{dn}) (Ref. 1-1). Since L_{dn} was developed especially as a measure of community noise exposure and an equivalent energy measure, it can be used to describe the noise in areas in which noise sources operate continuously or intermittently, in a 24-hour period.

Studies have been made of the number of people exposed to various levels of community noise (Ref. 1-1). Table 1-1 summarizes the estimated number of people in residential areas subjected to noise from urban traffic, freeway traffic, and aircraft operations at or above outdoor L_{dn} values ranging from 60 to 80 dB.

EPA has identified an outdoor L_{dn} of 55 dB as the day/night average sound level requisite* to protect the public from long-term adverse health and welfare effects in residential areas (Ref. 1-1).

Table 1-1 shows that many millions of United States residents are subjected to day/night average sound levels in excess of 60 dB; the bulk of the noise exposure is due to traffic noise. In order to reduce this noise exposure significantly, it will be necessary to apply noise control measures to many of the major sources of noise in the environment.

Medium and heavy trucks are responsible for most of the traffic noise, and are regulated by EPA under Part 205 of Title 40 of the Code of Federal Regulations. A number of trucks operate with special equipment mounted, some of which contributes significant noise to the environment in addition to that due to movement of the truck in traffic. One such class of special equipment is the truck-mounted solid waste compactor, which is known to be a source of annoyance and sleep disturbance. Although the noise impact from this class of equipment is lower in magnitude than that due to all truck traffic, it is nevertheless high enough to be classified as a major source of noise itself (see Section 5 for a detailed discussion of the noise impact). In addition, the EPA believes that control of this source of noise is required to avoid reducing the effectiveness of the noise regulation for medium and heavy trucks.

*With an adequate margin of safety and without consideration of the cost and technology involved to achieve an L_{dn} of 55 dB.

TABLE 1-1

ESTIMATED CUMULATIVE NUMBER OF PEOPLE IN MILLIONS IN THE UNITED STATES RESIDING IN URBAN AREAS WHICH ARE EXPOSED TO VARIOUS LEVELS OF OUTDOOR DAY/NIGHT AVERAGE SOUND LEVEL

Outdoor L_{dn} Exceeds	Urban Traffic	Freeway Traffic	Aircraft Operations	Total
60	59.0	3.1	16.0	78.1
65	24.3	2.5	7.5	34.3
70	6.9	1.9	3.4	12.2
75	1.3	0.9	1.5	3.7
80	0.1	0.3	0.2	0.6

Source: Reference 1-1.

NEED FOR CONTINUED COMPLIANCE WITH THE NOISE STANDARD

The attainment of the estimated health and welfare benefits is dependent upon the regulated product continuing to comply with the Federal not-to-exceed noise emission standard for a set period of time or use.

The Agency has given considerable attention to the question of product noise degradation (increase in noise level with time). It is the Agency's belief that if a product is not built such that it is even minimally capable of meeting the standard while in use over a specified initial period, when properly used and maintained, the standard itself will be ineffective and the anticipated health and welfare benefits will not be achieved.

Consequently, the Agency has developed the concept of an "Acoustical Assurance Period" (AAP). The AAP is defined as that specified initial period of time or use during which a product must continue to be in compliance with the Federal standard, provided it is properly used and maintained according to the manufacturer's recommendations.

The Acoustical Assurance Period is independent of the product's operational (useful) life, which is the period of time between sale of the product to the first purchaser and last owner's disposal of the product. The Acoustical Assurance Period is product-specific and thus may be different for different products or classes of products. The AAP is based, in part, upon (1) the Agency's anticipated health and welfare benefits over time resulting from noise control of the specific product, (2) the product's known or estimated periods of use prior to its first major overhaul, (3) the average first owner turnover (resale) period (where appropriate), and (4) known or best engineering estimates of product-specific noise level degradation (increase in noise level) over time.

The AAP requires the product manufacturer to assure that the product is designed and built in a manner that will enable it to comply with the Federal noise emission regulation which exists at the time the product is introduced into commerce, and that it will continue to conform with the applicable regulation for a period of time or use not less than that specified by the AAP.

While the Agency believes that products which are properly designed and durably built to meet a product specific noise emission standard should continue to meet the standards for an extended period of time, it recognizes that some manufacturers may wish to stipulate, based on test results or best engineering judgment, the degree of anticipated noise emission degradation their product(s) may experience during a specified Acoustical Assurance Period. A procedure has been developed by the Agency that permits manufacturers to account for sound level degradation in its compliance testing and verification program. This procedure, if used, would require a manufacturer to subtract a "Noise Level Degradation Factor" (NLDF) from the Agency's not-to-exceed noise emission standard, and thus would result in a manufacturer specific production test level that is lower than that specified by the EPA standard. For example, a manufacturer who estimates that the noise level of a given product model may increase by 3 dB during the prescribed AAP would specify an NLDF of 3 dB. For production verification, the manufacturer would then test to ensure that his product's noise level is 3 dB below that specified in the applicable Federal standard. For those products not expected to degrade during the AAP, the manufacturer would specify an NLDF of zero.

OUTLINE AND SUMMARY OF REGULATORY ANALYSIS

Background information used by EPA in developing regulations limiting the noise emissions from new truck-mounted solid waste compactors is presented in the following sections of this analysis:

Section 2 - The Industry and the Product: contains general information on the manufacturers of truck-mounted solid waste compactors and descriptions of the product.

Section 3 - Baseline Noise Levels for New Truck-Mounted Solid Waste Compactors: presents current noise levels relative to degradation noise levels for existing new solid waste compactors and a discussion of the data used in the development of an Acoustical Assurance Period.

Section 4 - Measurement Methodology: presents the measurement methodology selected by EPA to measure the noise emitted by this product and to determine compliance with the proposed regulation.

Section 5 - Health and Welfare: discusses the adverse impact of and benefits to be derived from regulating noise emissions of solid waste compactors.

Section 6 - Noise Control Technology: provides information on available noise control technology and the criteria for determining the levels to which solid waste compactors can be quieted.

Section 7 - Economic Analysis: examines the economic effects of noise emission standards on the solid waste compactor industry and society.

Section 8 - Enforcement: discusses the various enforcement actions open to EPA to ensure compliance.

Section 9 - Existing Local, State and Foreign Regulations: summarizes current noise emission regulations on truck-mounted solid waste compactors.

Appendix A - The Docket Analysis: summarizes the comments received during the formal docket period and the Agency's response to those comments.

Appendix B - Fractional Impact Procedure: summarizes the procedure used in assessing the health and welfare impact and benefits to be derived from regulating noise emissions.

Appendix C - Organizations and Individuals Contacted: lists the organizations and individuals contacted in order to gather information during the regulatory development process.

Appendix D - Organizations and Individuals to be Contacted: lists the organizatons and individuals to be contacted in the dissemination of information to the public on the benefits and impacts of the regulation.

REFERENCES
Section 1

1-1. Environmental Protection Agency, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, EPA 550/9-74-004, March 1974.

SECTION 2

THE INDUSTRY AND THE PRODUCT

INTRODUCTION

This section provides a description of truck-mounted solid waste compactor bodies and an overview of the compactor body industry. The section is organized as follows:

The Product

Product Applications and Competitive Systems

The Industry

Characteristics of Industry Segments

THE PRODUCT

A truck-mounted solid waste compactor consists of a truck chassis and a compactor body. The body is equipped to receive, compact, transport and unload solid wastes.

The major compactor body types can be operationally classified by the body loading configuration:

1. Front Loaders. These bodies utilize front mounted hydraulic lift arms to lift and dump waste containers into an access door in the top of the body. Packer plates compact the wastes inside the body. Wastes are typically ejected through a tailgate. A typical front loader is illustrated in Figure 2-1, and the six steps for front loading are shown in Figure 2-2. The compaction cycle for a front loader is illustrated in Figure 2-3.

2. Side Loaders. Considerable variation exists in these bodies, but a typical model is illustrated in Figure 2-4. Generally, wastes are manually deposited into a hopper through an access door in the side wall of the body. Packer plates sweep the wastes from the hopper into the body and compress

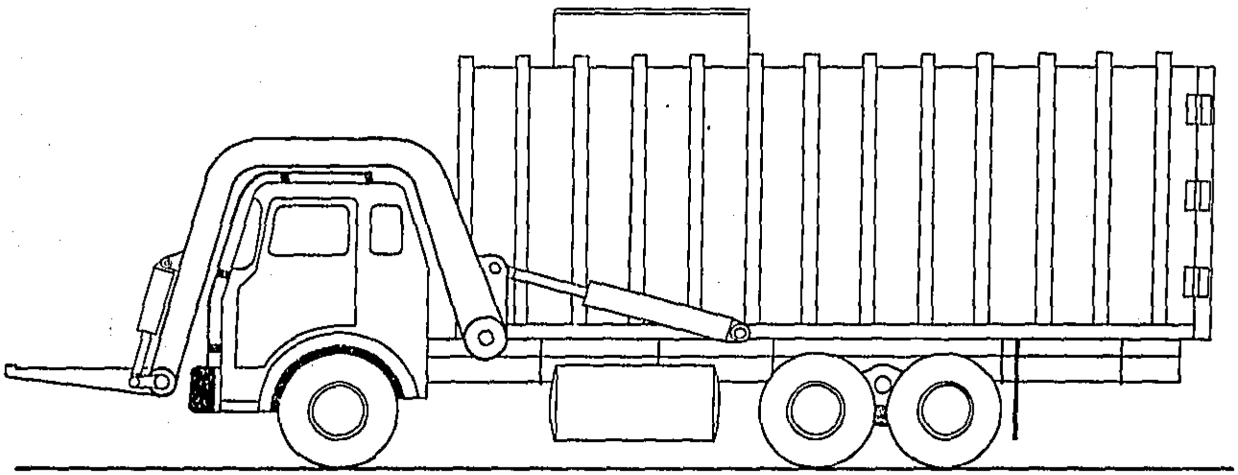


FIGURE 2-1

A FRONT LOADER

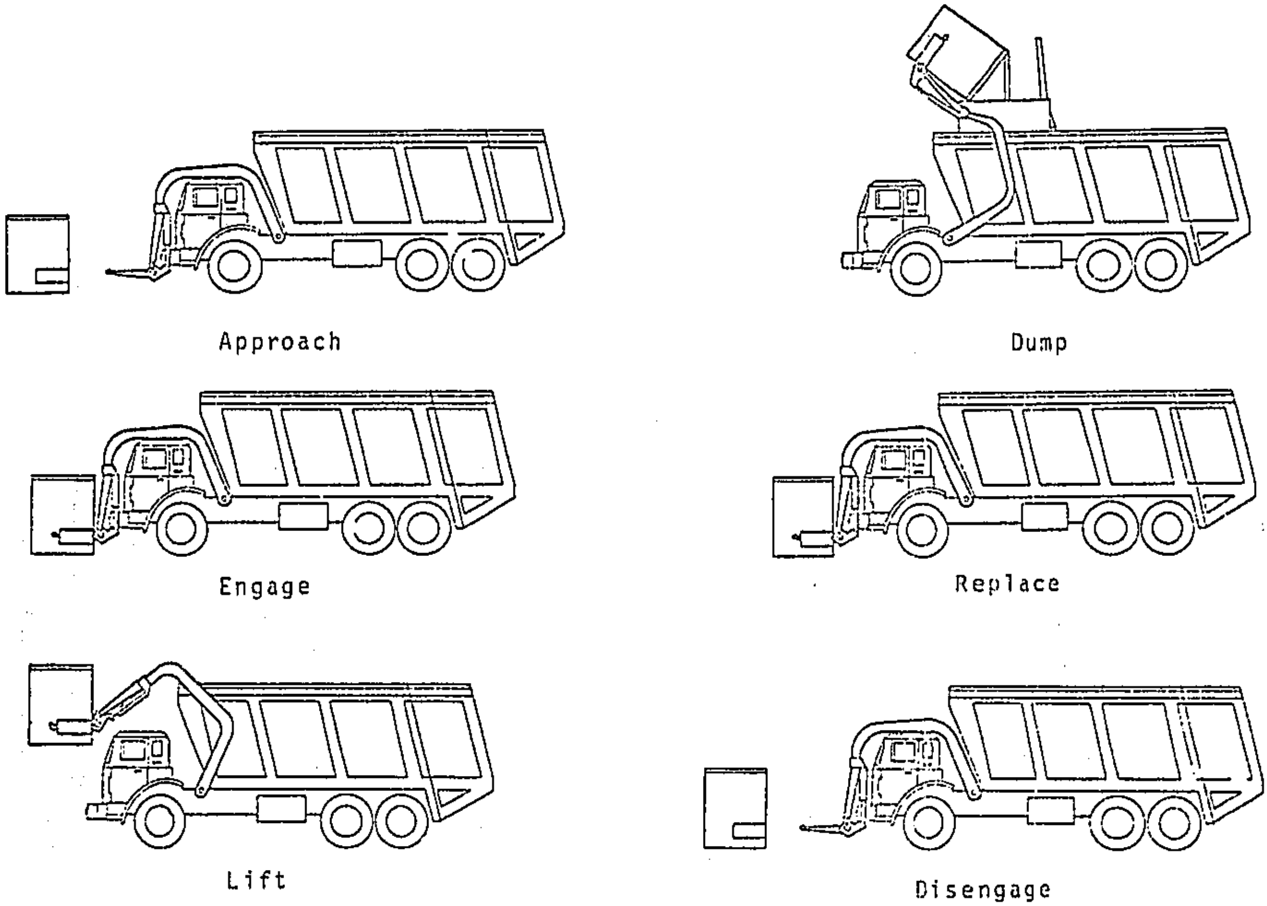
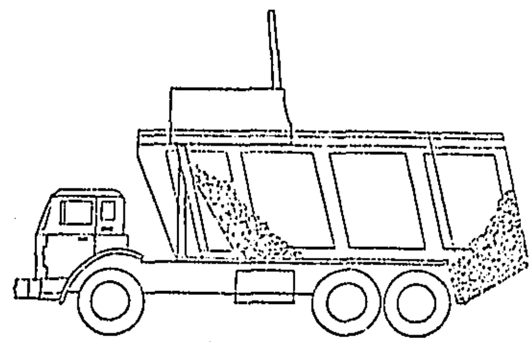


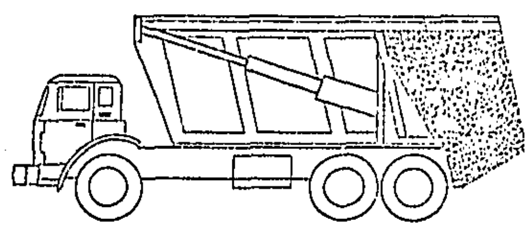
FIGURE 2-2

SIX STEP OPERATIONAL SEQUENCE FOR FRONT LOADING

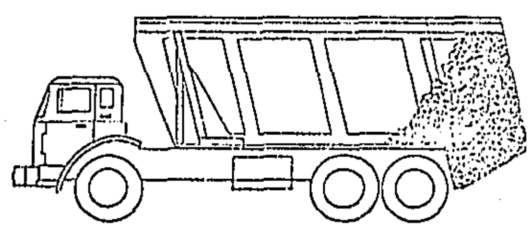
Source: Reference 2-1.



Dump



Compaction



Return

FIGURE 2-3

OPERATION OF A FRONT LOADER (COMPACTION CYCLE)

Source: Reference 2-1.

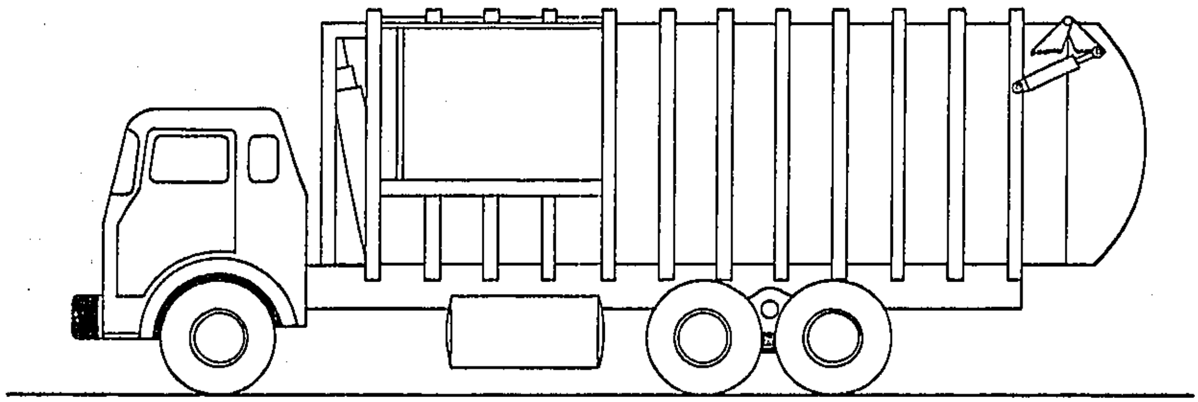


FIGURE 2-4

A SIDE LOADER

the materials against an interior wall, in the same manner as front loaders (Figure 2-3). Some side loaders are also equipped to hydraulically lift and dump waste containers. Ejection of wastes is usually through a tailgate. Many side loader models are not equipped for packer plate ejection, but typically, will hydraulically lift the front end of the body and dump the wastes through a tailgate.

3. Rear Loaders. The hopper on these bodies is located on the rear section of the body (Figure 2-5). Wastes are generally loaded manually into the hopper, but some models have the capability to hydraulically lift and dump containers. The packer plate sweeps the wastes from the hopper into the body and compresses the wastes against an interior wall surface. In most models, the packer plate is also used for tailgate waste ejection.

Two additional categories of solid waste compactors are produced:

1. Satellite Vehicles. These bodies function much like other packers, but are relatively small. They are used in door-to-door waste collection and in conjunction with a larger packer truck. The satellite vehicle body ejects wastes into the hopper of a larger packer truck or serves as a detachable container which is lifted and dumped by a larger truck. These bodies were excluded from consideration because available test information indicated they were not a significant source of noise.

2. Route Trailers. These solid waste compactors are pulled by a truck rather than being mounted on the truck chassis. Operation of the unit is similar to a side loader, except that trailers are powered by a stand-alone auxiliary engine mounted on the trailer. Fewer than 50 units were shipped in 1974 and the estimated number of units in operation is less than 100.

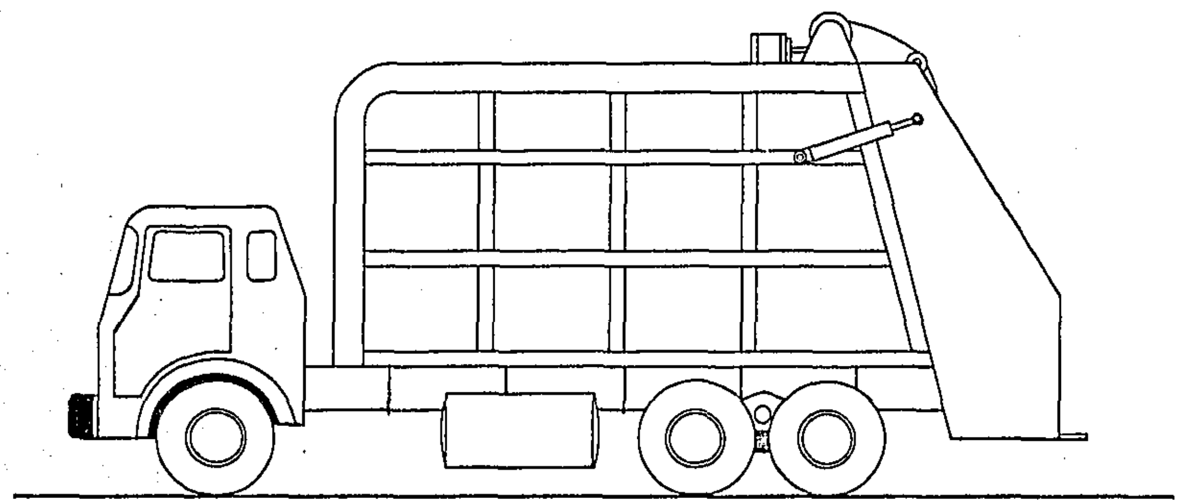


FIGURE 2-5

A REAR LOADER

As indicated in Table 2-1, packer bodies can also be classified by ranges of body capacity measured in cubic yards and the compaction density rating of the body.

Front loaders are essentially all mounted on a heavy duty truck chassis powered by a diesel engine. Side loaders can be mounted on a light, medium, or heavy duty truck chassis. Rear loaders are typically mounted on a medium or heavy duty truck chassis. Approximately 40 percent of the side and rear loader truck chassis are powered by diesel engines, the remainder are powered by gasoline engines. It is estimated that 15 percent of the side loaders and 2 to 3 percent of the rear loaders are powered by a stand-alone auxiliary engine rather than the truck engine.

PRODUCT APPLICATIONS AND COMPETITIVE SYSTEMS

The distribution of packer bodies by loading type and application are shown in Table 2-2 and summarized below:

1. Front loaders are used predominantly in commercial and industrial applications. Commercial collection includes residential complexes with more than two-family units.

2. All other categories of bodies are used principally for residential waste collection. Commercial and industrial application of this equipment is usually limited to light commercial collection utilizing small containers and compactor bodies equipped with hoists.

Substantial potential exists for substitution of equipment for residential collection. Several studies have demonstrated that collection productivity can be dramatically increased by utilizing one-man crews (as compared to multi-man crews). This provides a competitive advantage for side loaders as compared to the more broadly used rear loader.

TABLE 2-1

CLASSIFICATION OF TRUCK-MOUNTED SOLID WASTE COMPACTOR BODIES

Classification	Range of Body Capacity (Cubic Yards)	Estimated Compaction Density (Pounds/Cubic Yard)		Estimated Compactor Body Power Source		
				Truck Engine		Gasoline
		Range	Average	Gasoline	Diesel	Auxiliary
Front Loader	20 - 52	400-750	500	-	100%	-
Side Loader	10 - 38	450-750	500	60%	40	15%
Rear Loader	10 - 31	500-1,000	750	60	40	2-3

Source: Field interviews with product manufacturers, distributors and product literature. The Virginia Town & City "Fuel Conservation in Solid Waste Management", Kenneth A. Shuster, December, 1974, and associated working papers.

TABLE 2-2

TRUCK-MOUNTED SOLID WASTE COMPACTOR BODY APPLICATIONS BY PRODUCT CLASSIFICATION

Equipment Classification	Percent of Total Units Employed by Major Application	
	Residential*	Commercial and Industrial
Front Loader	10-15	85
Side Loader	85	15
Rear Loader	70	30

Source: Field interviews with product manufacturers, distributors and fleet operators.

*Residential includes single-family dwellings and duplexes.

The available competitive waste collection systems identified vary by nature of application. Residential collection could be accomplished by three means:

1. Centrally Located Roll Off Packers. This collection system consists of a truck that periodically removes either a detachable container or the entire compactor itself (both of which are centrally located), and disposes of the collected wastes.

The advantages of this substitute system depend on the methods used to transfer wastes from the household or commercial establishment to the packer, population density, and a number of other variables. Such advantages include higher collection productivity, increased flexibility in usage of sound deadening shields, and increased ability to monitor and control noise levels.

Potential disadvantages include negative public reaction to having to transport wastes to the compactor location, increased exposure of the general public to injury from operation of the compactor, and heavy initial investment in packers and containers.

2. Truck-Mounted Shredder-Compactor Bodies. Truck-mounted shredder-compactors consist of a rear loader cylindrical body which rotates and tumbles wastes. The tumbling action and spiral ribs inside the body shred wastes and drive them toward the front section of the body. In this manner, wastes are compacted to a density similar to that achieved by standard rear loaders.

The only potential advantage identified would be possible reductions in body maintenance expense.

Potential disadvantages relating to models currently available include higher levels of personal injury to the crew and reduction in crew productivity, both attributable to lifting wastes to a higher level for deposit in the body.

No. U. S. manufacturer currently produces this type of body. They are imported from Europe and currently have not significantly penetrated the U.S. market.

No noise measurements were made of this type of collection vehicle. However, domestic conventional packer body manufacturers report that noise levels parallel those of rear loaders.

3. Truck-Mounted Non-Compacting Bodies. Essentially, this system represents a return to pre-packer body collection practices. Noise levels would probably be reduced but crew productivity would be substantially lower.

THE INDUSTRY

Solid Waste Generation

The demand for compactors is based upon the generation of solid wastes, particularly by residences and commercial establishments.

The availability of solid waste generation data is relatively limited and of recent origin. The most broadly accepted estimates are reflected in Table 2-3. It can be seen that total residential and commercial solid waste generation in 1973 is estimated to have been 144 million tons. Resource reclamation provided for the utilization of 9 million tons, resulting in a net disposal of 135 million tons of solid waste.

Projections of total residential and commercial solid wastes for 1980 and 1985 are also shown in Table 2-3. The tonnage of total gross discards is expected to increase to 175 million tons in 1980, an average annual growth rate

TABLE 2-3

BASELINE ESTIMATES AND PROJECTIONS OF POST-CONSUMER* SOLID WASTE GENERATION, RESOURCES RECOVERED AND DISPOSED, 1971-1985

	Estimated				Projected				Average Annual Growth Rate of Total Gross Discards 1973-1985
	1971		1973		1980		1985		
	Total	Daily Per Capita Pounds	Total	Daily Per Capita Pounds	Total	Daily Per Capita Pounds	Total	Daily Per Capita Pounds	
Total Gross Discards	133	3.52	144	3.75	175	4.28	201	4.67	3%
Resources Recovered	8	.21	9	.23	19	.46	35	.81	12
Net Waste Disposed	125	3.31	135	3.52	156	3.81	166	3.86	2

Source: Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, "Third Report to Congress, Resource Recovery and Waste Reduction", (SW-161), 1975, Page 10.

* - Post-consumer solid waste is considered to be residential solid waste.

of four percent between 1973 and 1980. Net wastes disposed are expected to increase to 156 million tons during the same period, an average annual growth rate of two percent. The growth rates are expected to decline between 1980 and 1990.

The composition of residential and commercial solid wastes is shown in Table 2-4. Nearly 70 percent of total wastes are paper, food and yard wastes.

Solid Waste Collection--The Packer Body

The first packer bodies were broadly introduced for solid waste collection in the early 1950s. Market penetration of this equiment was relatively rapid, since it provided a means for dramatic productivity increases in solid waste collection. The major benefit, compared to the traditional open body collection truck, is that compaction allows larger quantities of wastes to be collected between trips to the disposal site. Consequently, more waste collection points can be served between disposal trips, and a substantially higher proportion of total crew time is productive.

Even with the advent of this equipment, waste collection remains an extremely labor-intensive operation. Recent product improvements and new product introductions have focused on further increasing collection crew productivity. The major equipment innovations have been higher density compaction, larger volume bodies, and different loading configurations intended to reduce total crew size.

SIZE AND GROWTH OF THE PACKER BODY INDUSTRY

Units In Operation

The estimated number of packer body trucks in operation in 1974 is shown in Table 2-5. It can be seen that approximately 77,000 units were in operation that year, probably increased to somewhat over 80,000 currently.

TABLE 2-4

POST-CONSUMER** RESIDENTIAL AND COMMERCIAL SOLID WASTE GENERATED AND AMOUNTS RECYCLED, BY TYPE OF MATERIAL, 1973
(AS GENERATED WET WEIGHT IN MILLIONS OF TONS)

Material Category	Gross Discards	Quantity of Materials Recycled	Net Waste Disposed: Quantity	Net Waste Disposed: Percent of Total
Paper	53.0	8.7	44.3*	32.9%*
Glass	13.5	.3	13.2	9.8*
Metals	12.7	.2	12.5	9.3
Plastics	5.0	-	5.0	3.7
Rubber	2.8	.2	2.6	1.9
Leather	1.0	-	1.0	.8*
Textiles	1.9	-	1.9	1.4
Wood	4.9	-	4.9	3.6
Total Non-Food	94.8*	9.4	85.4	63.4
Product Waste				
Food Waste	22.4	-	22.4	16.6
Yard Waste	25.0	-	25.0	18.6*
Misc. Inorganic Wastes	1.9	-	1.9	1.4
Total	144.1*	9.4	134.7*	100.0%

Source: Office of Solid Waste Management Programs, U. S. Environmental Protection Agency, "Third Report to Congress, Resource Recovery and Waste Reduction," (SW-161), 1975, Page 10.

*Arithmetic summations and differences modified to reflect correct total.
**Post-consumer solid waste is considered to be residential solid waste.

TABLE 2-5

ESTIMATED TRUCK-MOUNTED SOLID WASTE
COMPACTOR BODY UNITS IN OPERATION, 1974

Equipment Classification	Truck-Miles (Millions)	Average Annual Miles/Truck (Thousands)	Units	Percent of Total Units	Estimated Average Functional Life Cycle
Front Loader	---	---	11,200	14.6%	8
Side Loader	---	---	11,600	15.1	7
Rear Loader	---	---	53,700	69.7	7
Satellite Vehicles	---	---	500	.6	---
Total	841	12.2	77,000	100.0%	

Source: U.S. Department of Commerce, Bureau of the Census, "Census of Transportation, 1972, Truck Inventory and Use Survey, 1972," Page 2.
Truck Body and Equipment Association, National Solid Waste Management Association and field interviews with equipment manufacturers.

TABLE 2-6

TRUCK-MOUNTED SOLID WASTE COMPACTOR BODY
MANUFACTURER SHIPMENTS, 1964-1974

Equipment Classification	1964 (000s) Units	1964 Millions Dollars	1967 (000s) Units	1967 Millions Dollars	1972 (000s) Units	1972 Millions Dollars	Estimated 1974* (000s) Units	Estimated 1974* % of Total	Estimated 1974* Millions Dollars	Average Annual Growth Rate** 1964-1974 Units	Average Annual Growth Rate** 1964-1974 Dollars	Average Annual Growth** Rate 1967 - 1974 Units	Average Annual Growth** Rate 1967 - 1974 Dollars
Front Loader	-	-	-	-	-	-	1.2	10%	24	-	-	-	-
Side Loader	-	-	-	-	-	-	2.1	17	14	-	-	-	-
Rear Loader	-	-	-	-	-	-	9.0	73	87				
Total	4.9	$22.1	6.5	$31.0	13.5	$86.0	12.3	100%	$125.0	10%	19%	10%	22%

Source: U.S. Department of Commerce, Bureau of the Census, "Census of Manufacturers 1967 & 1972," Motor Vehicles and Equipment, MC 72(2)37A, Page 17; interviews with product manufacturers.

*1974 shipments and mix by loader type estimated from field interviews with product manufacturers.
**Rounded to nearest percentage point.

Rear loaders account for approximately 70 percent of the total. The estimated functional life of front loaders is eight years, and of rear and side loaders is seven years.

Unit and Dollar Manufacturer Shipments

The total units and value of manufacturer shipments in 1964, 1967, and 1972 are shown in Table 2-6. The Table also shows estimates, both total and by loader type, of units and value of manufacturer shipments for 1974. An estimated 12,300 units with a value of $125 million were shipped in 1974. This represents an average annual growth rate between 1964 and 1974 of 10 percent on a unit basis and 19 percent on a dollar basis. Between 1967 and 1974, the unit growth rate remained the same and dollar growth increased to 22 percent. It is estimated that 73 percent of 1974 shipments were rear loaders.

Export Sales

The estimated value of manufacturers' exports in 1974 is shown in Table 2-7. Approximately 20 percent of manufacturers' shipments, worth $22 million, are estimated to be exports. More than 90 percent of the exports are completed bodies.

TABLE 2-7

ESTIMATED VALUE OF TRUCK-MOUNTED
SOLID WASTE COMPACTOR BODY
MANUFACTURERS' EXPORTS, 1974
(MILLION)

Equipment Type	Total Shipment Value	Export Shipments Value	Export Percent of Total Shipments
Complete Bodies	99	20	20%
Components	11	2	20
Total	$110	$22	20%

Source: Dun & Bradstreet, Inc., "Analytical Financial Reports."
Field interviews with equipment manufacturer.

CHARACTERISTICS OF INDUSTRY SEGMENTS

The general structure of the compactor body industry is depicted in the schematic drawing shown in Figure 2-6. Generally, the packer body manufacturer purchases raw materials and components from suppliers, and then builds the body. Bodies are then sold to either truck chassis dealers or truck body distributors, predominantly to the latter. The body is then mounted on a truck chassis and sold to the ultimate end user. The primary end users are municipal governments and private contractors.

A profile for each of the following industry segments is described in this section:

Packer Body Manufacturers
Truck Body Distributors
End Use Market -- Fleet Operators
Truck Chassis Manufacturers and Dealers
Raw Material and Component Suppliers.

Packer Body Manufacturers

1. As of 1974, some 25 companies were identified as manufacturers of packer bodies in the United States (Table 2-8). A few companies have left the field and others have entered it since that year.

2. The total corporate revenues of these companies range from $100,000 to $1.4 billion. Nearly 50 percent of the manufacturers are divisions or operating companies held by corporations which are substantially larger. Nearly all of the specialized independent companies for which data are available have revenues less than $10 million (see Table 2-8).

3. Manufacturer production facilities and products manufactured at each plant are indicated in Table 2-9.

Plants are concentrated in California, Texas, Michigan, Ohio and the Southeastern states. Nearly one-half of the companies have two or more plants. Proximity to markets is an important factor due to the costs for transporting

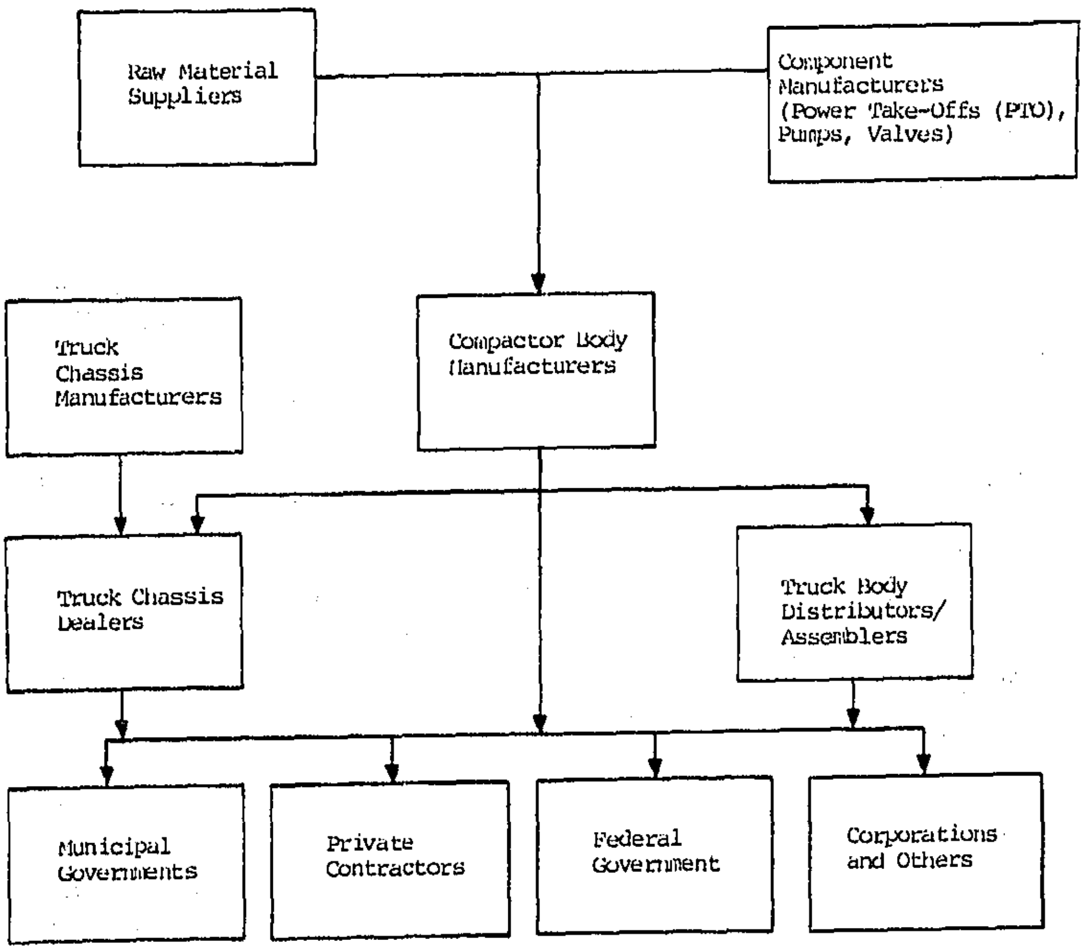


FIGURE 2-6

TRUCK-MOUNTED SOLID WASTE COMPACTOR BODY INDUSTRY STRUCTURE

TABLE 2-8

FINANCIAL PROFILE OF TRUCK-MOUNTED
SOLID WASTE COMPACTOR BODY MANUFACTURERS, 1974
$ (MILLIONS)

COMPANY NAME	DATE FOUNDED	NUMBER OF EMPLOYEES	NET REVENUE	NET PROFIT (LOSS) AFTER TAXES	TOTAL ASSETS	TANGIBLE NET WORTH	NET WORKING CAPITAL
Company S	1946	50	$ 1.9	n/a	$ .3	n/a	n/a
Company T (a)	n/a	27,079	984.6	8.6	794.2	337.1	330.0
Company U (b)	1912	40,765	1,428.0	37.5	982.0	331.0	158.8
Company V	n/a	n/a	25.0	n/a	n/a	n/a	n/a
Company W (b)	1918	26,400	1,315.0	22.7	1,020.8	342.2	139.9
Company X (c)	1938	27	2.4	.1	.1	.1	.2
Company Y	1956	n/a	30.0	n/a	n/a	n/a	5.0
Company Z	1899	14,900	498.1	25.4	318.6	182.0	103.8
Company C (a)	1901	1,633	70.3	2.8	41.7	22.1	23.6
Company AA (d)	1953	140	7.1	.2	3.4	.9	.9
Company D (e)	1957	300	11.4	.4	8.5	1.8	1.8
Company BB	1945	175	7.9	(.3)	n/a	n/a	n/a
Company CC	1960	14	.2	n/a	.1	n/a	n/a
Company B (f)	1952	230	6.8	n/a	4.8	1.9	1.5
Company DD (g)	n/a	n/a	257.9	9.6	205.4	70.0	71.4
Company EE (b)	1906	2,151	109.1	5.2	57.0	37.6	25.6
Company FF (i)	1966	200	13.3	(.7)	8.3	2.0	.5
Company I (g)	n/a	1,622	61.8	1.7	38.8	16.7	16.1
Company GG	1953	150	n/a	n/a	n/a	n/a	n/a
Company HH (fg)	n/a	n/a	123.0	2.8	86.6	22.4	24.8
Company II (h)	n/a	80	2.4	.1	1.4	.4	.3
Company JJ	1976	7	n/a	n/a	n/a	n/a	n/a
Company KK	n/a	36	1.5	n/a	n/a	n/a	n/a
Company LL	1975	3	.2	n/a	n/a	n/a	n/a
Company MM	n/a	35	4.0	n/a	n/a	n/a	n/a

Source: Dun & Bradstreet, Inc., "Analytical Financial Reports," unless otherwise indicated.

n/a = not available

(a) Fiscal year ending October 31, 1974.
(b) Moody's Investors Service, Inc., Industrial Manual, 1975.
(c) Revenue and earnings extrapolated from 6 month data ending March 31, 1975.
(d) Fiscal year ending May 31, 1975.
(e) Fiscal year ending May 31, 1974.
(f) Fiscal year ending June 30, 1974.
(g) Annual Report, 1974.
(h) Fiscal year ending August 31, 1974.
(i) Fiscal year ending March 31, 1975.

TABLE 2-9

FACILITY PROFILE OF TRUCK-MOUNTED SOLID WASTE COMPACTOR BODY MANUFACTURERS, 1974

Company Name	Production Facilities: Facility Size (Thousands of Square Feet)	Owned or Leased	Number of Employees	Products Manufactured
Company B	n/a	n/a	50	- Dump truck beds, hoists, compactor bodies.
Company T [(a)]	n/a	n/a	450	- Containers, transfer stations, refuse compactor bodies, roll-off hoists, compactor trailers.
	n/a	n/a	n/a	- Stationary packers.
	107	n/a	350	- Transport trailers and containers.
Company U	n/a	n/a	n/a	n/a
Company V	n/a	n/a	n/a	n/a
Company W [(b)]	n/a	n/a	n/a	- Transport trailers, compactor trailers, compactor bodies, transfer trailers.
Company X	29	L	27	- Truck dealer and auto repair.
Company Y	n/a	n/a	n/a	- Truck tanks and refuse compactors.
	n/a	n/a	n/a	- Trailers, axles, brake shoes & drums.
Company Z	200	n/a	1,100	- Containers, refuse compactor bodies, stationary compactors, roll-off hoists, transfer trailers.
	n/a	n/a	n/a	- Refuse compactors.
Company C	760	O	n/a	- Truck bodies and hoists, tanks, tanks for trailers; refuse collection and processing equipment, dehydrating machines, material handling equipment, and pulverizing and reclamation equipment.
	n/a	O	n/a	n/a
	80	L	n/a	n/a
Company AA	480	O	n/a	- Front loaders, side loaders, stationary compactors.
Company D	n/a	L	n/a	- Refuse compactor bodies, stationary compactors & hydraulic lift gates.
	194[(e)]	L	n/a	- Mechanized lifts, loading devices & compactors.
	40	L	n/a	- Hydraulic lift & refuse body mfg.

n/a = not available

Source: Dun & Bradstreet, Inc., "Analytical Financial Reports," unless otherwise indicated.

(a) Annual Report, 1974 and interviews with company management.
(b) Moody's Investors Service, Inc. Industrial Manual, 1975.
(e) Total manufacturing facilities in Huntington Park & Los Angeles, California: 194,000 square feet.

TABLE 2-9 (CONTINUED)

Production Facilities

Company Name	Facility Size (Thousands of Square Feet)	Owned or Leased	Number of Employees	Products Manufactured
Company BB	35	O	45	- Refuse compactor bodies, containers, roll-off hoists, portable & stationary compactors, transfer trailers.
	n/a	n/a	130	- Refuse compactor bodies & containers.
Company CC	16.9	O	14	- Refuse packer bodies.
Company B	80	n/a	135	- Stationary refuse compactors, compacting & transfer trailers, containers, & front loader compactors.
	80	n/a	95	- Refuse compactors, refuse trailers, containers & front loader compactors.
Company DD	n/a	n/a	n/a	- Refuse compactor bodies, containers & transfer stations.
Company EE	219	n/a	n/a	- Rail car auto shipping racks, refuse compactor bodies.
Company FF	87	O	120	- Solid waste compactor bodies, containers & roll-off containers & hoists.
Company I(c)	196	L	n/a	- Dump bodies, containers and refuse packer bodies.
Company GG	n/a	n/a	n/a	- Refuse compactor bodies, containers & roll-off hoists.
Company HH(d)	n/a	n/a	n/a	- Refuse compactor bodies.
Company II	34	O	80	- Refuse compactor bodies, truck hoists & miscellaneous truck modifications.
Company JJ	n/a	n/a	n/a	n/a
Company KK	n/a	n/a	n/a	n/a
Company LL	n/a	n/a	n/a	n/a
Company MM	n/a	n/a	n/a	n/a

(c) Annual Report, 1974 and Form 10-K filed with the Securities and Exchange Commission, 1974, Pages 2, 3 and 9.
(d) Annual Report, 1974.

bodies, but favorable investment incentives and labor climates have attracted many plants to the Southeastern states.

In addition to packer bodies, the more common products manufactured are containers, portable and stationary compactors, transfer trailers, transfer station equipment, hydraulic lift gates and hoists.

4. The type and cubic yard capacity of packer bodies produced by each manufacturer as of 1974 is summarized below:

a. Eleven companies produce front loaders. Body cubic capacity of front loaders ranges from 20 to 52 cubic yards. Most models are in the 25 to 35 cubic yard range. Most producers have a broad product range.

b. Ten companies produce side loaders. Body capacity ranges from 10 to 38 cubic yards. The most common size range is from 16 to 24 cubic yards.

c. Ten companies produce rear loaders. Body capacity ranges from 10 to 31 cubic yards. The predominant sizes are 16, 20, and 25 cubic yards.

5. The estimated manufacturer share of shipments by body type in 1974 is shown in Tables 2-10 through 2-12 and summarized below:

a. Three firms dominate the market with approximately 75 percent of all front loaders shipped. The remainder of shipments is distributed among the other eight producers.

b. Three firms shipped about 60 percent of total side loaders.

c. Two firms shipped about 55 percent of all rear loaders. These two firms in combination with two others shipped about 80 percent of rear loaders.

6. The geographic markets served by a plant are limited, usually to a regional area, by the cost to transport a body and the body type usage patterns within a region. This is particularly true for front and side loaders. To a greater extent than the other manufacturers, two of the largest shippers of rear loaders serve a national market.

TABLE 2-10

ESTIMATED MANUFACTURER SHARE OF TRUCK-MOUNTED
FRONT LOADER SOLID WASTE COMPACTOR BODY SHIPMENTS, 1974

No. of Firms	Percent of Total Shipments
Three Firms	75%
Four Firms	20%
Four Firms	5%
Total	100%

Source: Field interviews with equipment manufacturers.

TABLE 2-11

ESTIMATED MANUFACTURER SHARE OF TRUCK-MOUNTED
SIDE LOADER SOLID WASTE COMPACTOR BODY SHIPMENTS, 1974

No. of Firms	Percent of Total Shipments
Three Firms	60%
Three Firms	30%
Three Firms	10%
Total	100%

Source: Field interviews with equipment manufacturers.

TABLE 2-12

ESTIMATED MANUFACTURER SHARE OF TRUCK-MOUNTED
REAR LOADER SOLID WASTE COMPACTOR BODY SHIPMENTS, 1974

No. of Firms	Percent of Total Shipments
Two Firms	55%
Two Firms	25%
Three Firms	15%
Three Firms	5%
Total	100%

Source: Field interviews with equipment manufacturers.

7. Packer body manufacturers mount about 70 percent of the bodies they sell, on truck chassis, for the ultimate purchaser (Figure 2-7). About 90 percent of all front loaders are mounted by the manufacturer. This proportion for all body types will probably increase in the future as larger packer body size increases the need for more specialized and heavy-duty mounting equipment. Increased manufacturer concern regarding product liability will also encourage this practice.

8. The suggested end user list price of packer bodies varies by loader type, nature of body construction and body capacity. The price range of selected manufacturers and packer bodies by sizes (as of 1974) is shown in Table 2-13. Note the following ranges:

Front loaders	$16,000	-	$24,000
Side loaders	6,000	-	11,000
Rear loaders	9,000	-	15,000

Prices have increased somewhat, but not markedly, in the intervening period (Ref. 2-2) (although chassis prices have increased substantially).

9. The estimated pricing structure for packer bodies is shown in Table 2-14. These estimates represent an overall average for all manufacturers, distributors, end users and products. Some variation was noted in pricing practices. Note that average distributors and end user prices are 20 percent and 12 percent off list price, respectively.

10. Manufacturer warranty provisions vary considerably. Typically, only parts are covered, but service adjustment policies may cover labor in some instances. Warranty coverages range from 90 days for selected components or the complete body, to 12 months for the complete unit excluding selected components. Longer warranties (two years or more) have been obtained by large (e.g., municipal) purchasers through negotiation.

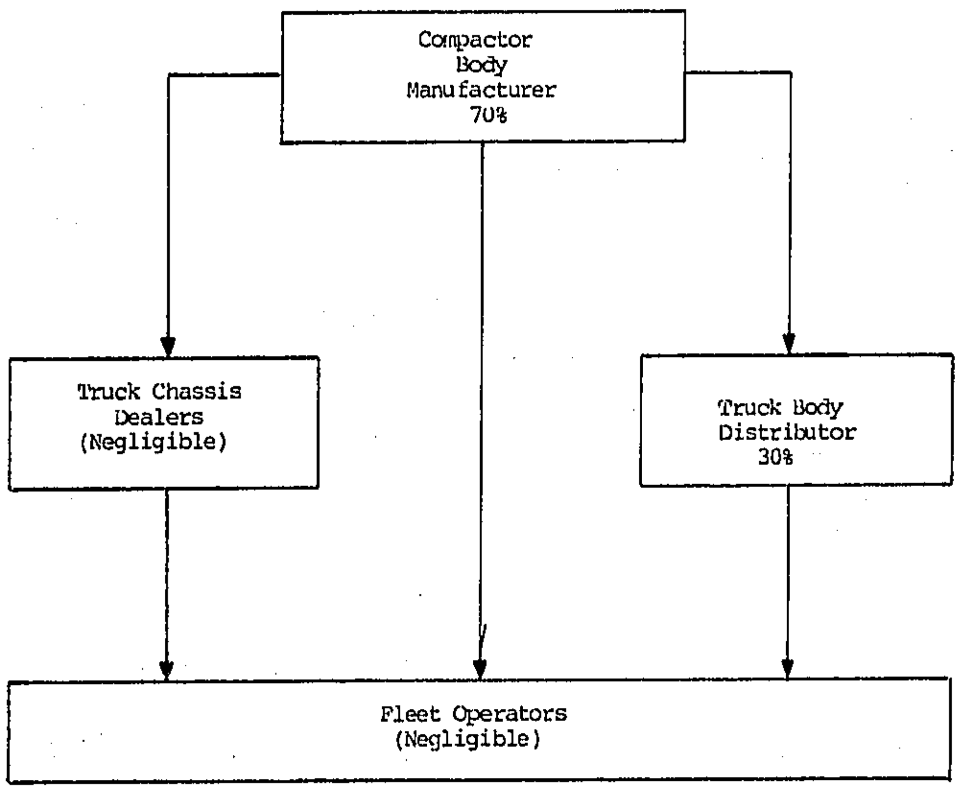


FIGURE 2-7

ESTIMATED BODY MOUNTING PRACTICES FOR TRUCK-MOUNTED SOLID WASTE COMPACTOR BODIES (PERCENT OF TOTAL NEW BODIES MOUNTED)

Source: Truck Body and Equipment Association, and field interviews with equipment manufacturers, distributors and end users.

TABLE 2-13

RANGE OF SUGGESTED LIST PRICES OF SELECTED TRUCK-MOUNTED SOLID WASTE COMPACTOR BODIES*, 1974

Equipment Classification and Body Cubic Yard Capacity	Price Range	Overall Average Price
Front Loaders		$18,780
24-25	$16,000 - 21,000	
30-31	17,000 - 23,000	
40-42	20,000 - 24,000	
Side Loaders**		7,650
12-14	6,000 - 7,000	
16-18	9,000 - 11,000	
Rear Loaders		11,580
16-17	9,000 - 12,000	
20	10,000 - 14,000	
25	13,000 - 15,000	

Source: Manufacturer price lists and interviews with manufacturers.

*Complete factory mounted units with standard equipment, exclusive of freight and Federal Excise Taxes.

**Does not include prices for products built and sold as an integral body and chassis unit.

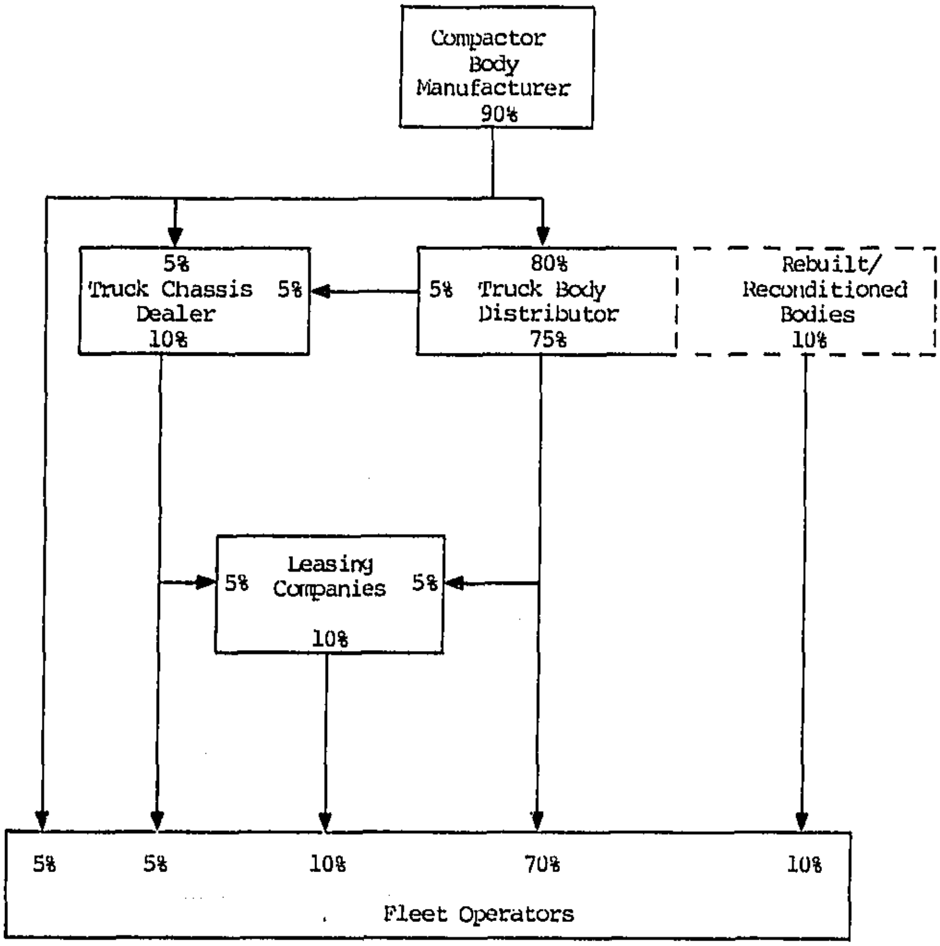


FIGURE 2-8

TRUCK-MOUNTED SOLID WASTE COMPACTOR BODY
CHANNELS OF DISTRIBUTION, BASED ON TOTAL
NEW AND USED UNITS SOLD ANNUALLY

Source: Truck Body and Equipment Distributors Association, and field interviews with product manufacturers, distributors and fleet operators.

TABLE 2-14

ESTIMATED PRICING STRUCTURE FOR TRUCK-MOUNTED SOLID WASTE COMPACTOR BODIES

Purchaser	Average Percent Discount Off Suggested List Price
End User	12%
Distributor	20

Source: Field interviews with equipment manufacturers, distributors and end users.

TABLE 2-15

PROFILE OF TRUCK AND TRACTOR PARTS AND SUPPLIES MERCHANT WHOLESALERS, 1972*

Characteristic	Value/Quantity
Number of Firms	2,420
Sales Revenue $(Millions)	$ 4,430
Average Sales Revenue/Firm $(Millions)	$ 1.8
Number of Paid Employees**	41,481
Average Number of Employees/Firm	17
Payroll, Entire Year $(Millions)	$ 387.5
Average Payroll/Firm	$160,000

Source: U.S. Department of Commerce, Bureau of the Census, "1972 Census of Wholesale Trade", 1972, Page 8.

*Includes distributors of solid waste compactor bodies and insulated-refrigerated truck bodies and trailers.
**For week including March 12.

Truck Body Distributors

The estimated flow of new and used packer bodies is depicted in Figure 2-8. About ten percent of the packer bodies sold annually are rebuilt/reconditioned units, sold by truck body distributors. The predominant pattern is for manufacturers to use distributors to sell and deliver bodies to packer truck fleet operators. Leasing companies finance the purchase of about ten percent of all units sold, mainly new bodies. Rental of packer body trucks is negligible.

A profile of all truck and tractor parts and supplies wholesalers is shown in Table 2-15. This grouping of wholesaler distributors includes a broad spectrum of product areas. Note that the total number of firms is 2,420 and that the average sales revenue per firm is $1.8 million.

A profile of packer body distributors constructed from data provided by the Truck Equipment and Body Distributors Association (Table 2-16) indicates that:

1. There are approximately 500 firms, with average annual revenue of $2.5 million.

2. The distributors' sources of revenue are approximately two-thirds new equipment and one-third parts, used equipment and service labor.

3. The overall average gross profit on net sales is 23 percent, and operating and non-operating expenses are 16 percent. Average net profit after taxes is 3 percent.

4. These firms have average total assets of $700,000.

End Use Market Fleet Operators

As shown in Table 2-17, the two major end use markets for packer trucks are private contractors and municipalities.

TABLE 2-16

PROFILE OF TRUCK MOUNTED SOLID WASTE COMPACTOR BODY DISTRIBUTORS, 1972

Characteristic		Median Value/Quantity
Number of firms		500
Revenue Mix (Percent of Total)		
New Equipment		60-70%
Parts, Used Equipment & Labor		30-40%

Financial Data for Firm Averaged Across All Firms

			Percent of Median Net Revenue
Net Revenue	$2.5 Million		100%
Cost of Goods Sold	1.9		77
Gross Profit	$ .6		23
Operating Expenses	.4		16
Non-Operating Expenses	-		1
Net Profit Before Taxes	$ .2		6
Net Profit After Taxes	$ .1		3%
Total Assets		$700,000	
Current Assets		580,000	
Net Worth		233,000	
Non-Current Assets		120,000	

Source: Truck Equipment and Body Distributors Association, field interviews with product manufacturers and distributors.

TABLE 2-17

PRIMARY END USE MARKETS FOR TRUCK-MOUNTED SOLID WASTE COMPACTOR BODIES

End Use Market	Percent of Total Units in Operation
Private Contractors	60%
Municipalities	35
Federal Government	2
Industrial Corporations	2
Other	1
Total	100%

Source: Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, National Solid Waste Management Association, "The Private Sector in Solid Waste Management. A Profile of Its Resources and Contributions to Collection and Disposal, Volume 2 - Analysis of Data", 1972; U.S. Department of Commerce, Bureau of the Census, "Census of Transportation, 1972, Truck Inventory and Use Survey, 1972"; field interviews with product manufacturers.

1. Private Contractors. These companies are heavily engaged in residential, commercial and industrial refuse collection. Services are contracted on the basis of a direct contract or a municipal contract, franchise or award of a competitive bid.

Even though the operations of a private contractor are local in nature, several conglomerated companies with 100 or more operating locations across the country have evolved in the industry.

A profile of private contractors is shown in Table 2-18. In summary:

a. The number of private contractors in 1970 was greater than 10,000. These companies employ more than 102,000 people.

b. These firms serve 27.3 million customers, operate 61,500 total trucks and collect 685,000 tons of waste daily.

c. Operations of private contractors tend to be concentrated in large metropolitan areas.

The truck equipment operated by private contractors is indicated in Table 2-19. Of the 61,500 trucks operated, 41,602 are packer trucks (primarily rear loaders).

More than 90 percent of private contractor customers are residential, but the total quantity of wastes collected is fairly equally distributed among residential, commercial and industrial customers. Over 40 percent of the contractors collect only commercial and industrial wastes, but together, private contractors collect more than 90 percent of commercial and industrial solid waste. Private haulers serve 50 percent of all residential customers and collect the same proportion of total residential solid waste.

The level of concentration within the industry is relatively low, in terms of number of employees and packer trucks employed by the largest contractors as compared to the industry totals.

TABLE 2-18

PRIVATE CONTRACTORS, EQUIPMENT, EMPLOYEES, CUSTOMERS AND COLLECTION TONNAGE BY METROPOLITAN AREA POPULATION SIZE, 1970

Population	Private Contractors Number	Private Contractors Percent	Total Employees Number (Thousands)	Total Employees Percent	Total Trucks* Number (Thousands)	Total Trucks* Percent	Total Customers Number (Millions)	Total Customers Percent	Total Daily Tonnage** Number (Thousands)	Total Daily Tonnage** Percent
More Than 1 Million	4,456	44.5%	60.5	59.1%	35.9	58.4%	15.8	57.9%	438.7	64.0%
500,000-1 Million	1,311	13.1	15.1	14.8	8.2	13.3	3.8	13.9	111.7	16.3
250,000-499,999	1,498	14.9	11.1	10.9	6.1	9.9	2.6	9.5	53.5	7.8
100,000-249,999	1,017	10.1	7.0	6.8	5.0	8.1	2.5	9.2	35.6	5.2
50,000-99,999	149	1.5	1.1	1.1	.8	1.3	.3	1.1	6.9	1.0
Less Than 49,999	1,596	15.9	7.5	7.3	5.5	9.0	2.3	8.4	39.1	5.7
Total	10,027	100.0%	102.3***	100.0%	61.5***	100.0%	27.3	100.0%	685.5	100.0%
Average per Contractor			10.2		6.2		2.7		68.4	

Source: Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, National Solid Waste Management Association, "The Private Sector in Solid Waste Management - A Profile of Its Resources and Contributions to Collection and Disposal, Volume 2 - Analysis of Data", 1972.

*Includes 41,602 conventional solid waste compactor bodies.
**Includes residential, commercial and industrial waste.
***Adjusted to reflect rounding.

TABLE 2-19

PRIVATE CONTRACTOR TRUCK EQUIPMENT
COMPOSITION, 1970

Equipment Type	Thousands of Units Number	Percent
Front Loaders	7.7	12.5%
Side Loaders	7.7	12.5
Rear Loaders	26.2	42.6
Open Non-Packer	7.2	11.7
Side Loader, Non-Packer	–	–
Roll-Off Chassis	6.5	10.6
Hoist Type Vehicles	2.2	3.6
Other Collection Vehicles	4.0	6.5
Total	61.5*	100.0%

Source: Office of Solid Waste Management Programs, U.S. Environmental Protection Agency, National Solid Waste Management Association, "The Private Sector in Solid Waste Management - A Profile of Its Resources and Contributions to Collection and Disposal, Volume 2 - Analysis of Data", 1972.

*Adjusted to reflect rounding.

2. Municipal Fleets. The scope and nature of municipalities which provide public refuse collection services are difficult to ascertain. There are more than 78,000 local governments, of which 35,500 are municipalities and townships of 2,500 or greater population. Packer body manufacturers report that the latter are the major purchasers of equipment, especially municipalities and townships with populations of 25,000 people or more. Between 800 and 900 governmental units (which account for approximately two-thirds of the population within municipalities and townships) make these purchases. These governmental units account for about 85 percent of governmental general expenditures, and slightly more than 80 percent of the expenditures for sanitation other than sewage.

Approximately 35 percent of the packer trucks in operation are owned and operated by municipalities and used to collect approximately 50 percent of all residential solid wastes. However, this understates the direct and indirect influence of municipalities with regard to total residential collection activity. A large proportion of private hauler residential collection is controlled by municipalities by means of contracts, franchises or competitive bid awards.

Table 2-20 shows that nearly 50 percent of private hauler residential customers are served on the basis of a government franchise.

TABLE 2-20

PERCENT OF RESIDENTIAL CUSTOMERS
SERVED BY PRIVATE HAULERS UNDER
DIRECT CONTRACT AND GOVERNMENT FRANCHISE

	Percent of Customers
Direct Contract	50.3%
Government Franchise	49.7
Total	100.0%

Source: "The Private Sector in Solid Waste Management," U.S. Environmental Protection Agency, 1973, page 6.3.

Truck Chassis Manufacturers and Dealers

Truck chassis manufacturers, through their franchised truck dealer organizations, generally sell truck chassis to the fleet operator to be used in conjunction with a packer body. In a small proportion of total unit sales, the truck dealer will sell an equipped packer body truck to the fleet operator.

The four largest truck chassis manufacturers accounted for more than 80 percent of total sales of medium and heavy duty trucks in 1975.

The National Automobile Dealers Association, in Franchised New Car and Truck Dealer Facts, 1973, indicated that there were 22,270 new truck dealers in 1972.

Raw Material and Component Suppliers

Products purchased from suppliers consist of roll and bar metals, and general components such as power take-off units (PTOs), pumps, cylinders, and valves. All sources of supplies are major manufacturers, and requirements of the packer body industry are considered insignificant when related to the suppliers' total shipments.

REFERENCES
Section 2

2-1. "Noise Control/Technology for Specialty Trucks (Solid Waste Compactors)," Bolt, Beranek and Newman, Inc., BBN Draft Report 3249, February 1976.

2-2. Internal ONAC memoranda, July 11, 1979, summarizing information obtained in telephone calls to distributors.

SECTION 3

TRUCK-MOUNTED SOLID WASTE COMPACTOR SOUND LEVELS

SOUND LEVEL MEASUREMENTS

Sound measurement testing was performed on a total of forty-four truck-mounted solid waste compactors. For most of the tests, noise measurements were made with the microphone located at 7 meters (approximately 23 feet) from each of the four sides of the truck. In a few cases, measurements were made at other distances (mainly 15.2 meters, or 50 feet) and the data were adjusted for the difference in microphone location.

Readings of A-weighted sound levels were taken during compactor operation to characterize both the maximum continuous noise and impact noise. The continuous noise, also denoted as "maximum steady noise level," was read as the average or "central tendency" observed during the noisiest segment of the operational cycle (ignoring impact sounds) using the "fast" response setting of the meter. The noise due to impacts between different components of the compactor mechanism, or between containers (if used) and compactor surfaces, was read as the maximum observed reading of the meter in "fast" response setting.

Data also were analyzed in terms of the maximum reading of the meter in "slow" response setting, regardless of whether or not there were impacts.

All the data obtained are summarized in Table 3-2. The data listed include the calculated logarithmic (energy) average of the four position measurements for the maximum continuous, maximum impact, and maximum "slow" readings, and the associated Sound Exposure Level (SEL) for the maximum continuous and maximum impact readings.

One rear loader (Vehicle No. 18 in Table 3-2) was measured with and without quiet features, and is treated as two separate measurements, one quiet and one conventional. This brings the total number of vehicle measurements to 45. The number of measurements made in each category are tabulated in Table 3-1.

TABLE 3-1

NUMBER OF MEASUREMENTS
MADE IN EACH COMPACTOR CATEGORY

Load Type	Number of Measurements	Number of Conventional	Number of Quieted	Number of Diesel	Number of Gasoline
Rear loader	35	21	14	13	22
Front loader	6	5	1	5	1
Side loader	4	1	3	3	1
TOTAL	45	27	18	21	24

Source: Table 3-2.

Figure 3-1 shows histograms of all measured noise levels of truck-mounted solid waste compactors, including maximum continuous levels and maximum impact levels in "fast" response and the maximum levels in "slow" response. Figures 3-2, 3-3, and 3-4 are histograms for the rear, front and side loaders respectively.

TABLE 3-2

SUMMARY OF TRUCK-MOUNTED SOLID WASTE COMPACTOR SOUND LEVEL MEASUREMENTS
(A-Weighted Noise Levels at 7 meters or converted to 7 meters)

Vehicle Number	Body Mfgr.	Load	Fuel	Quiet/ Conv.	Maximum Continuous (Fast) Energy Avg. (dBA)	Maximum Continuous (Fast) Cycle Time (sec)	Maximum Continuous (Fast) SEL (dBA)	Maximum Impact (Fast) Energy Avg. (dBA)	Maximum Impact (Fast) SEL (dBA)	Maximum (Slow) Energy Avg. (dBA)	Remarks
1	A	RL	G	Q	74	30	87.5	78	75	76	—
2	A	RL	G	C	87	12	94.5	89.5	85	88	2000 rpm
3	B	SL	D	Q	74	10	84	none	—	76	Front PTO
4	C	FL	D	C	79	35	88	86	85	82	Lifting
5	D	RL	G	C	74	20	87	89	78	83	—
6a*	E	SL	G	C	77	8	84	84.5	80	81	Sweep | Aux.
6b	E	SL	G	C	76	75	95	84	79	81	Pack | Engine
7	E	RL	G	C	76	17	88	94	82	79	1 point meas.
8a*	F	FL	D	C	83	40	92	89	80	91.5	Dump | 1 pt.
8b	F	FL	D	C	85	40	100	98	93	—	Compact | meas.
9	F	RL	G	C	79	16	96	88	87	81	50 ft + 6 dB
10	G	RL	D	C	80	25	94	87.5	86	83	50 ft + 6 dB
11	G	FL	D	C	83	—	—	none	—	85	50 ft + 6 dB
12	H	RL	D	C	87	—	—	93	—	88	50 ft + 6 dB
13	H	FL	D	C	87	20	100	97	97	92	50 ft + 6 dB
14	I	RL	D	C	79	40	95	84	—	81	—
15	I	RL	D	C	82	—	—	82	—	86	1 point meas.
16	F	FL	D	C	85	20	—	94	—	—	1 point meas.
17	I	RL	D	C	84	40	—	85	—	84.5	1 point meas.
18a**	J	RL	G	C	82	—	—	—	—	—	1 point meas.
18b**	J	RL	G	Q	67	—	—	—	—	—	1 point meas.
19	J	RL	G	Q	74	8	83	84	79	79	Flywheel PTO
20	F	RL	G	C	80	20	90	82	84	80	Trans. PTO
21	I	RL	G	Q	73	27	85	83	78	74	Flywheel PTO
22	F	RL	G	Q	74	25	87	75	68	74	Flywheel PTO
23	J	RL	G	Q	74	10	82	79	73	—	Front PTO
24	I	RL	G	Q	75	28	87	79	79	—	Front PTO
25	K	RL	G	C	76	Cont.	—	none	—	—	10 m + 3 dB
26a	H	RL	D	C	79	—	—	—	—	—	Packing
26b*	H	RL	D	C	78	—	—	—	—	—	Ejecting
27	I	RL	G	C	79	—	—	—	—	—	3 point meas.
28	I	RL	G	C	78	—	—	—	—	—	3 point meas.
29	J	RL	D	C	79	12	—	86	—	82	
30	J	RL	G	Q	78.5	21	—	85	—	82	Flywheel PTO
31	F	RL	D	C	78	24	—	81	—	79	
32	I	RL	D	C	75	34	—	83	—	79	
33	J	RL	G	Q	79	18	—	90.5	—	85	Flywheel PTO
34	F	RL	D	C	77	22	—	82	—	79	
35	F	RL	D	C	75	23	—	82	—	77	
36a*	C	FL	G	Q	74.5	36	—	89	—	84	Loading
36b	C	FL	G	Q	73	55	—	75	—	74	Compacting
37	J	RL	D	C	79	11	—	87	—	82	
38	A	RL	G	Q	76	—	—	79	—	79	
39	A	RL	G	Q	70	—	—	79	—	74	Front PTO
40	A	RL	G	Q	75	—	—	80	—	77	
41	A	RL	G	Q	68	—	—	80	—	75	Front PTO
42	I	RL	D	Q	76	40	—	81	—	—	Trans. PTO
43a	B	SL	D	Q	71	36	—	none	—	—	w/o override
43b*	B	SL	D	Q	83	8	—	none	—	—	override
44	B	SL	D	Q	77	8	—	78	—	—	aux. engine

*These measurements were not used in the statistical analysis because they do not represent noise emissions of the compaction cycle.
**Vehicle 18 was measured with and without quiet features and is treated as two vehicles.
RL = Rear Loader
SL = Side Loader
FL = Front Loader

Source: Reference 3-1, EPA/ONAC measurements in New York City, EPA/NEF measurements in San Francisco.

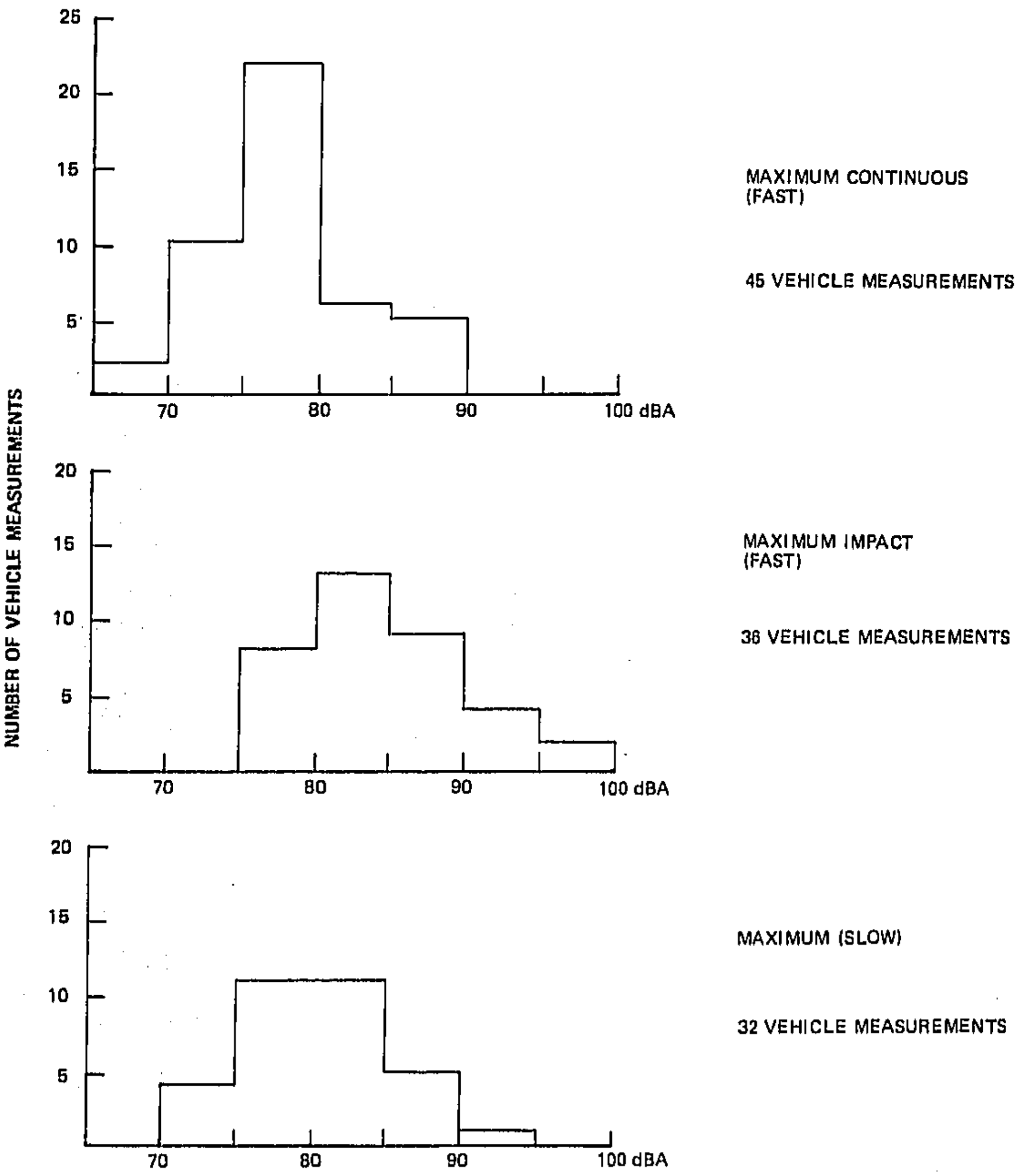


FIGURE 3-1

HISTOGRAMS OF ALL MEASURED TRUCK-MOUNTED SOLID WASTE COMPACTORS

Source: Table 3-2.

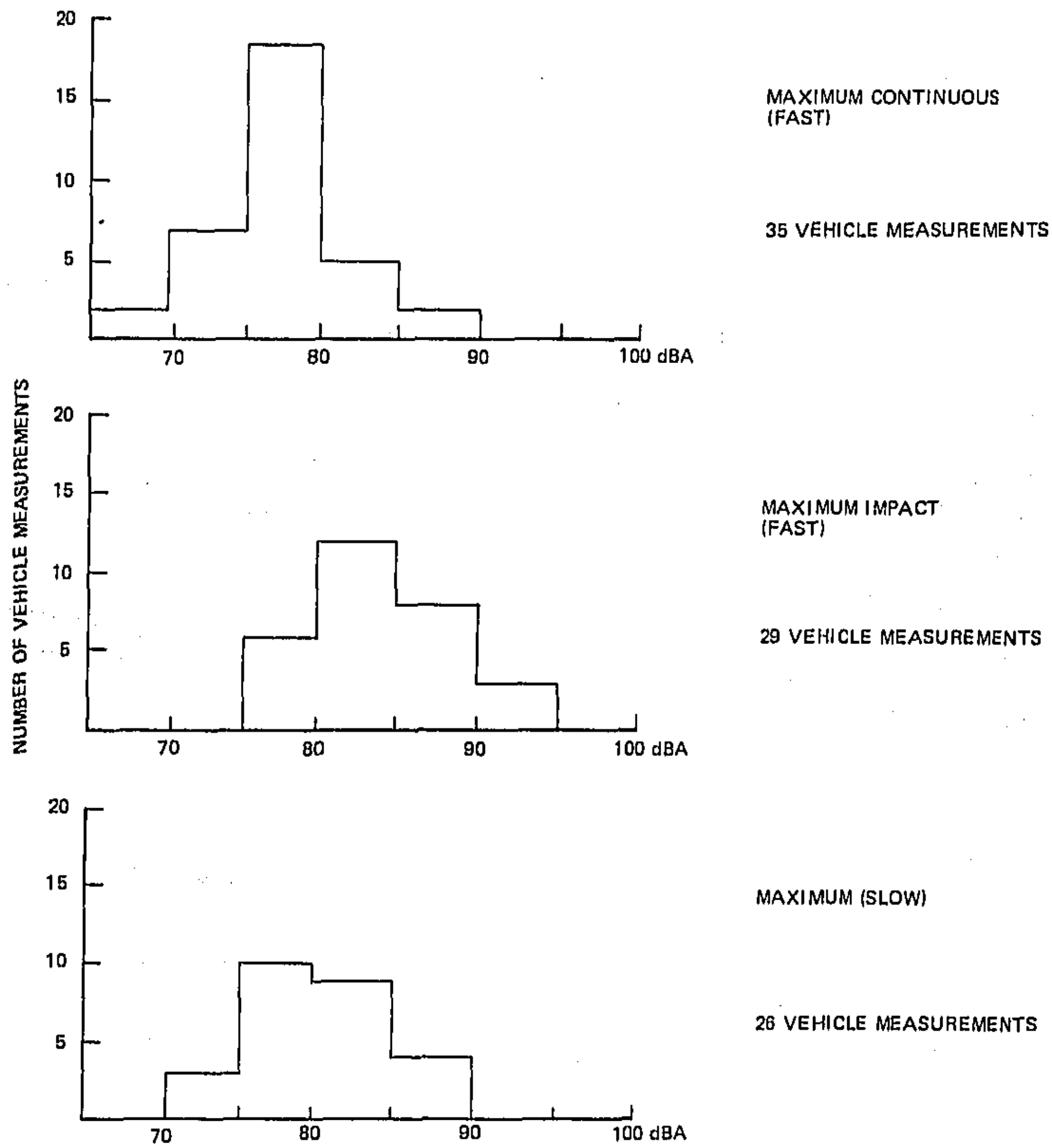


FIGURE 3-2

HISTOGRAMS OF REAR LOADERS

Source: Table 3-2.

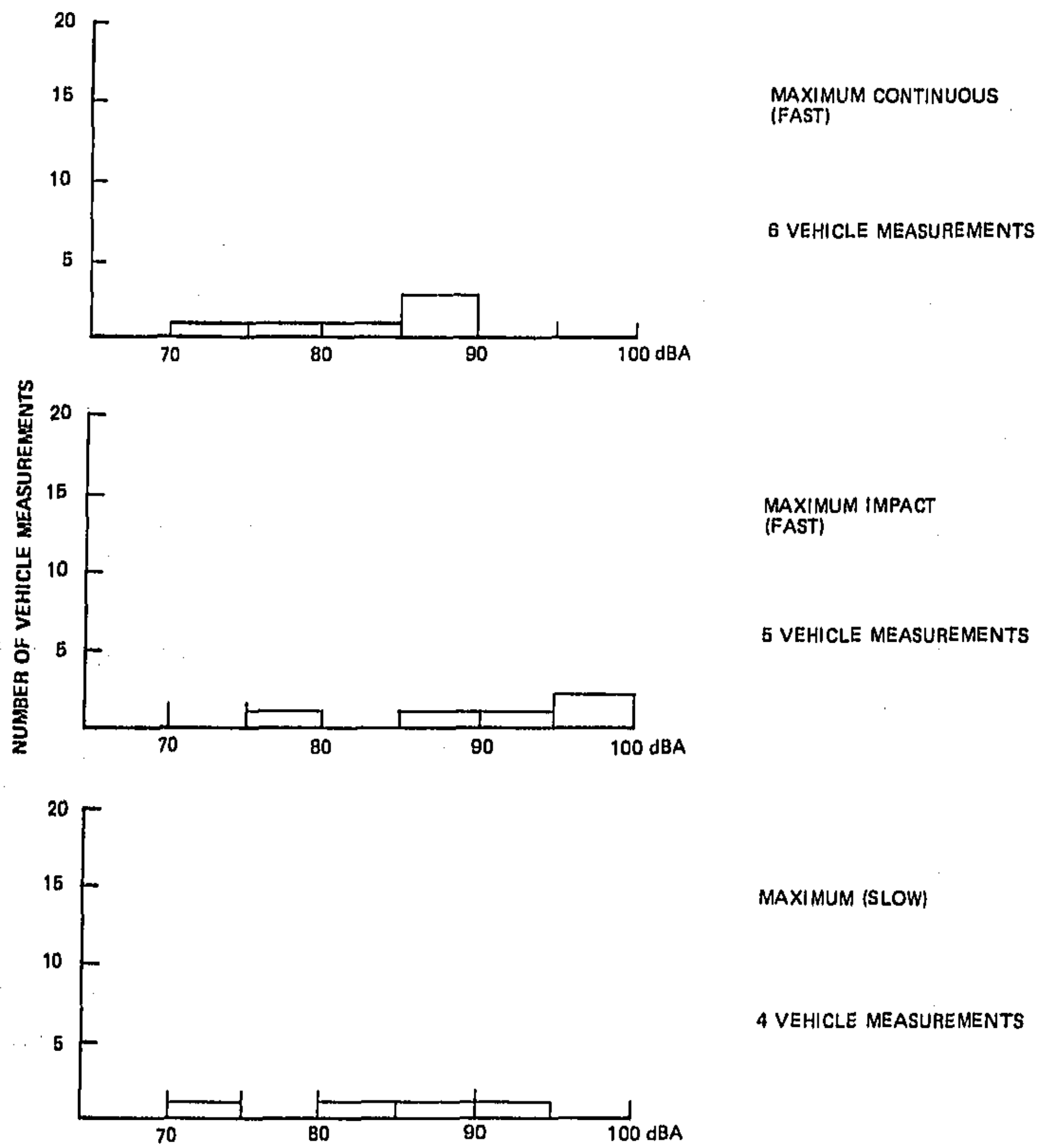


FIGURE 3-3

HISTOGRAMS OF FRONT LOADERS

Source: Table 3-2.

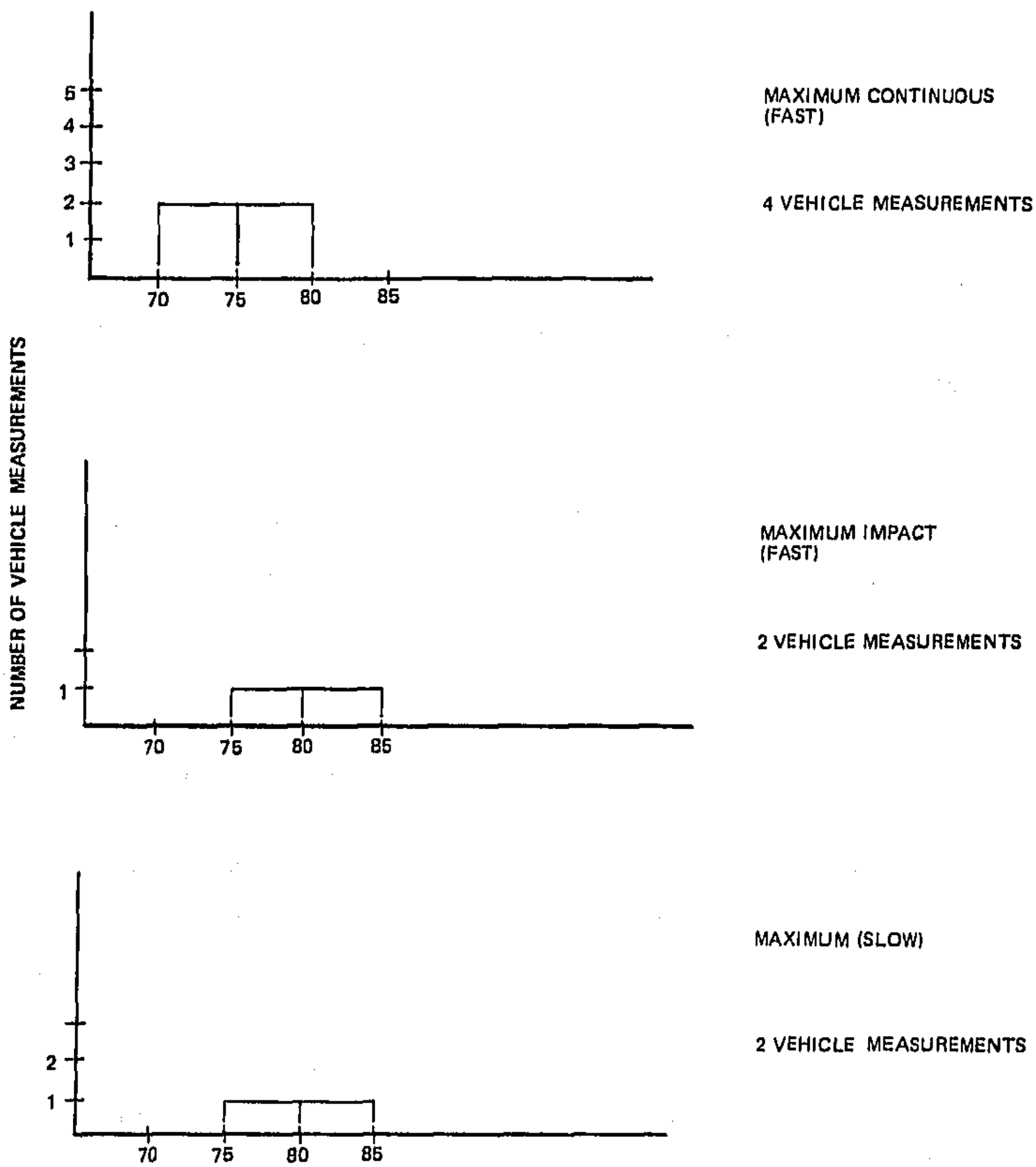


FIGURE 3-4

HISTOGRAMS OF SIDE LOADERS

Source: Table 3-2.

Table 3-3 summarizes the noise measurements of front, rear and side loaders in terms of the mean level and standard deviation. From these data, it can be seen that the noise levels of front loaders are higher than those of rear loaders. The additional noise of front loaders can be attributed to lack of speed control of the engine and the banging of the container on the arms of the loader. Although the three side loaders that were tested were quieter than the rear loaders, the sample was too small to allow any conclusions to be drawn.

Table 3-4 subdivides the noise level data for rear, side, and front loaders into conventional and quieted vehicles. Table 3-5 subdivides the noise level data for gasoline-powered and diesel-powered engines into conventional and quieted vehicles. Both the maximum continuous noise level in fast response and the maximum noise level in slow response are given in Tables 3-4 and 3-5. These data indicate that diesel-powered compactor vehicles tend to be slightly noisier than gasoline-powered units.

TIME HISTORIES

Figure 3-5 shows the time history of a quieted rear loader. The time history of a rear loader typically has three phases corresponding to different functions during the collection cycle. There is usually an impact at the end of each phase due to the bottoming of the hydraulic cylinders.

The time history of a front loader (Figure 3-6) shows the noise level during the loading cycle due to variation in engine speeds. There are numerous impulses due to the banging of the container and closing of the cover during the dump cycle. Fewer peaks occur during the compaction phase (additional time histories are shown in Exhibit 3-2 at the end of this Section).

TABLE 3-3

SUMMARY OF NOISE LEVEL DATA
(dBA at 7 meters)

Maximum Continuous Noise Level (Fast)

Load Type	Number of Measurements	Mean	Standard Deviation
All Vehicles	45	77.5	4.29
Rear Loaders	35	77.0	4.39
Front Loaders	6	82.0	5.18
Side Loaders	4	74.5	2.65

Maximum Impact Noise Level (Fast)*

Load Type	Number of Measurements	Mean	Standard Deviation
All Vehicles	36	84.4	5.23
Rear Loaders	29	83.6	4.51
Front Loaders	5	90.0	9.62
Side Loaders	2	81.0	4.24

Maximum Noise Level (Slow)

Load Type	Number of Measurements	Mean	Standard Deviation
All Vehicles	32	80.5	4.51
Rear Loaders	26	80.3	4.06
Front Loaders	4	83.3	7.45
Side Loaders	2	78.5	3.54

*"No impact" vehicle measurements were excluded from determination of the mean and standard deviation.

Source: Table 3-2.

TABLE 3-4

SUMMARY OF NOISE LEVEL DATA BY LOAD TYPE
(dBA at 7 meters)

Load Type	Conventional or Quieted	Number of Measurements	Mean	Standard Deviation
	Maximum Continuous Noise Level (Fast)			
Rear Loader	Conventional	21	79.2	3.55
Rear Loader	Quieted	14	73.8	3.47
Front Loader	Conventional	5	83.8	3.03
Front Loader	Quieted	1	73.0	—
Side Loader	Conventional	1	76.0	—
Side Loader	Quieted	3	74.0	3.00

Load Type	Conventional or Quieted	Number of Measurements	Mean	Standard Deviation
	Maximum Noise Level (Slow)			
Rear Loader	Conventional	16	82.0	3.30
Rear Loader	Quieted	10	77.5	3.75
Front Loader	Conventional	3	86.3	5.13
Front Loader	Quieted	1	74.0	—

Source: Table 3-2.

TABLE 3-5

SUMMARY OF NOISE LEVEL DATA BY ENGINE TYPE
(dBA at 7 meters)

Engine Type	Conventional or Quieted	Number of Measurements	Mean	Standard Deviation
	Maximum Continuous Noise Level (Fast)			
Gasoline-Powered	Conventional	10	78.7	3.63
Gasoline-Powered	Quieted	14	73.6	3.42
Diesel-Powered	Conventional	17	80.7	3.90
Diesel-Powered	Quieted	4	74.5	3.11

Engine Type	Conventional or Quieted	Number of Measurements	Mean	Standard Deviation
	Maximum Noise Level (Slow)			
Gasoline-Powered	Conventional	6	82.0	3.22
Gasoline-Powered	Quieted	11	77.2	3.71
Diesel-Powered	Conventional	14	82.8	4.04
Diesel-Powered	Quieted	1	76.0	—

Source: Table 3-2.

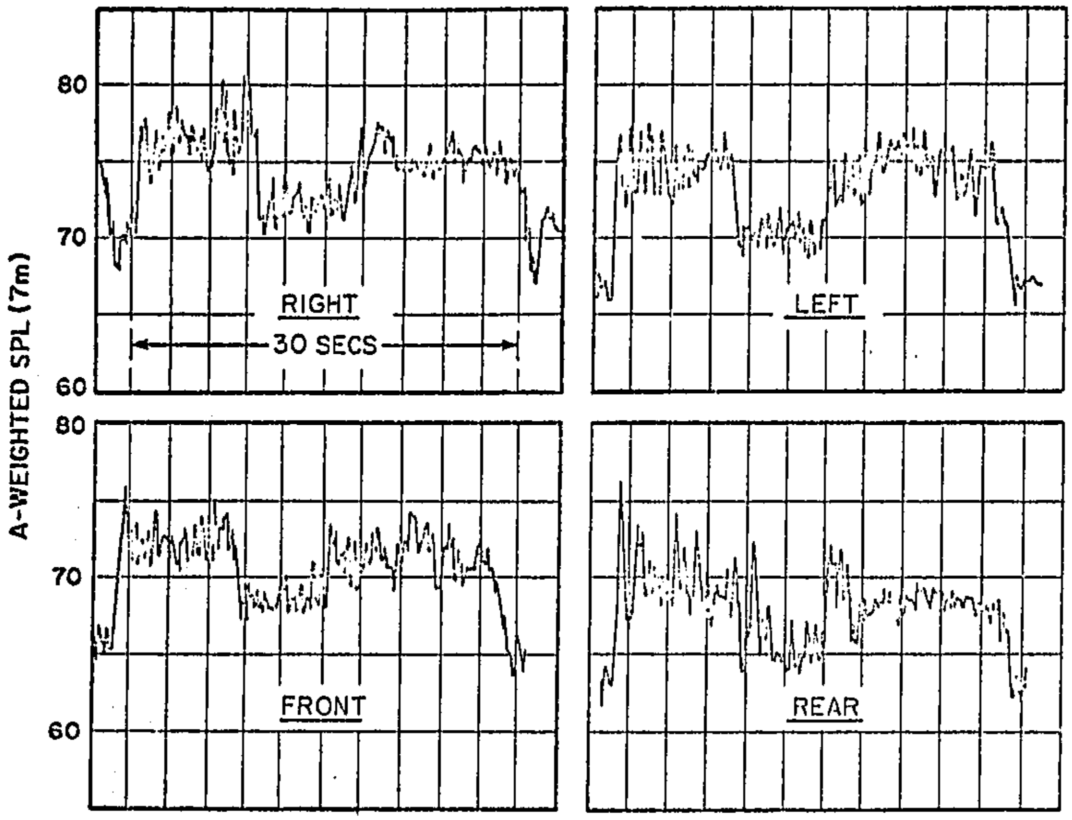


FIGURE 3-5

TIME HISTORIES OF QUIETED REAR LOADER

Source: Reference 3-1.

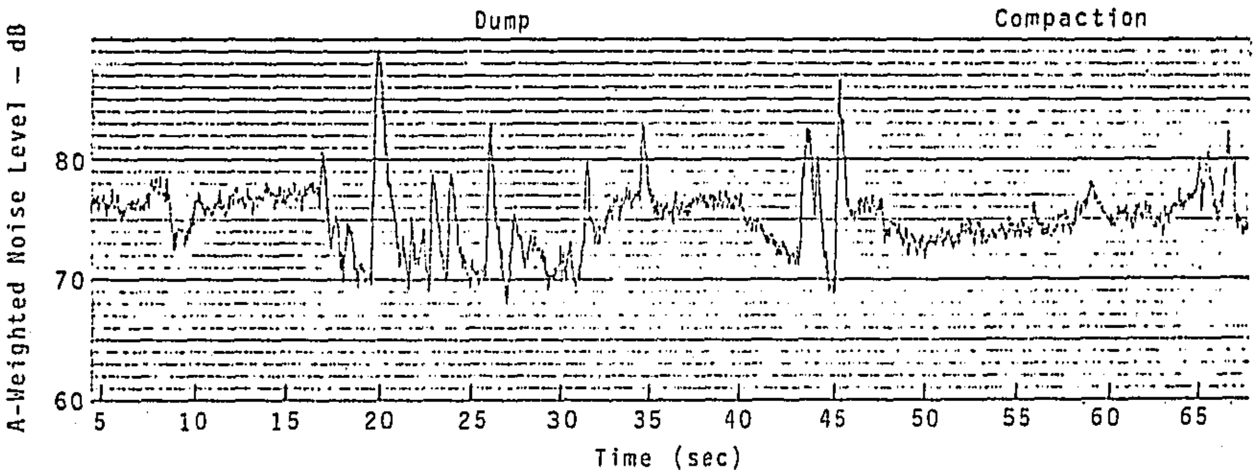


FIGURE 3-6

TIME HISTORY OF THE A-WEIGHTED NOISE LEVEL GENERATED BY A FRONT LOADER DURING A DUMP AND A PARTIAL COMPACTION CYCLE. NOISE LEVELS WERE MEASURED 50 FT TO THE LEFT OF THE VEHICLE CENTER.

Source: Reference 3-1.

Figure 3-7 shows the time history of an operational passby of a quieted side loader with the engine governed at 900 rpm. The truck was equipped with a front power take-off and powered by a 6-cylinder diesel engine. Various noise events can be distinguished from the graph: the noise of the truck as it arrives (80 dBA); squeal of the brakes (82-85 dBA); noise of the engine during loading (75 dBA); banging of cans and containers during loading (80 dBA metal and 77 dBA plastic); noise of the compaction cycle (75 dBA) combined with several impulses due to impacts between trash and compactor walls; noise of the release of the air brakes (87-90 dBA); and the noise of the truck departure (80 dBA).

The major concern of this study was the noise associated with operation of the compactor in loading and compaction of waste, as this noise is most characteristic of the basic function of the truck-mounted solid waste compactor, identified as a major noise source. The other chassis-related noises generally are covered by the Medium & Heavy Truck regulations. State and local authorities have the option of further regulating the other noises associated with trash collection, such as container noise.

NOISE SOURCES

Component Sound Levels

EPA considered in detail the diagnosis of noise sources of a rear-loading solid waste compactor truck. The noise sources identified were:

(1) Truck chassis
(2) Transmission power take-off (PTO)
(3) Hydraulic pump
(4) Compactor body (when isolated from the chassis).

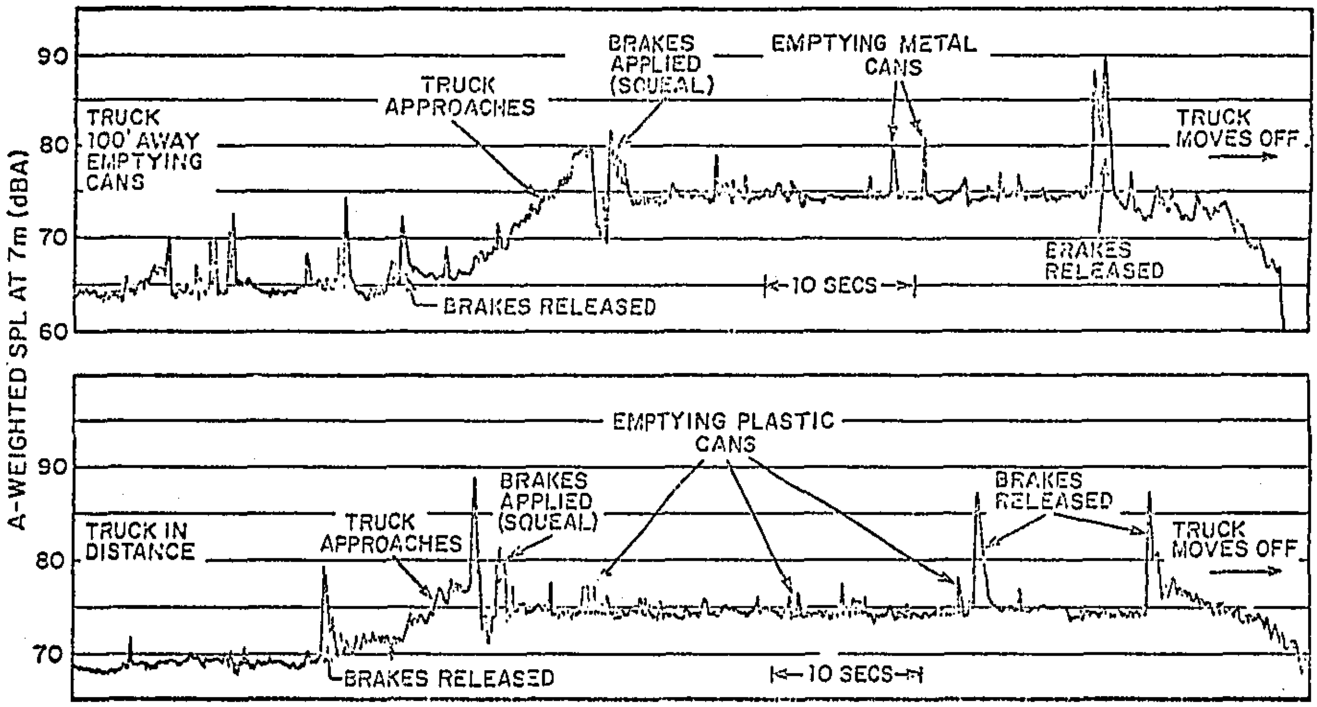


FIGURE 3-7

OPERATIONAL PASSBY OF A QUIETED SIDELOADER

Source: Reference 3-1.

Table 3-6 gives the measured noise levels of each of these components on a typical vehicle. This particular truck was a quieted vehicle, i.e., it already had some noise control features. The chassis had a better than average muffler installed. The truck cycled at an engine speed of 1050 rpm and electric switches reversed the hydraulic cylinders, rather than allowing them to bottom. Very little noise came from the compactor body itself. No significant noise came from the hydraulic lines, valves, or moving parts on the body. Most of the noise came from the chassis and power take-off, and some was from the hydraulic pump.

The chassis and power take-off noise were found to be highly speed-dependent. Figure 3-8 shows the variation of noise with variations in the engine speed of the chassis and with and without the power take-off engaged. Many trucks cycle at engine speeds up to 1800 rpm. It is apparent that substantial noise reduction can be achieved by reducing the truck engine speed during cycling.

Figure 3-9 shows the spectral contributions from the various major noise sources. Low frequency noise comes from the engine, while the hydraulic pump generates two pure tones at 125 and 250 Hz. High frequency noise is due entirely to the transmission power take-off, which radiates sound both directly and through vibrations in the chassis frame.

Truck Chassis Noise

It is clear from the previous section that the noise from the chassis contributes to the overall noise of the truck-mounted solid waste compactor. EPA has set a not-to-exceed noise level of 83 dBA (at 15.2 meters, or 50 feet, in a passby test) for the chassis in the regulation for medium and heavy

TABLE 3-6

NOISE CONTRIBUTIONS
SPL (dBA at 7m)

	Right	Left	Front	Rear	Energy Average
Chassis	64	64.5	63	63	64
Power Take-off (PTO)	73.5	72.5	72	68	72
Pump	64	62	58	61	62
Body*	<65	<60	<65	<65	---
Total	76	75	72.5	70	74

*Noise levels dominated by PTO over 100 ft away.

Source: Reference 3-1.

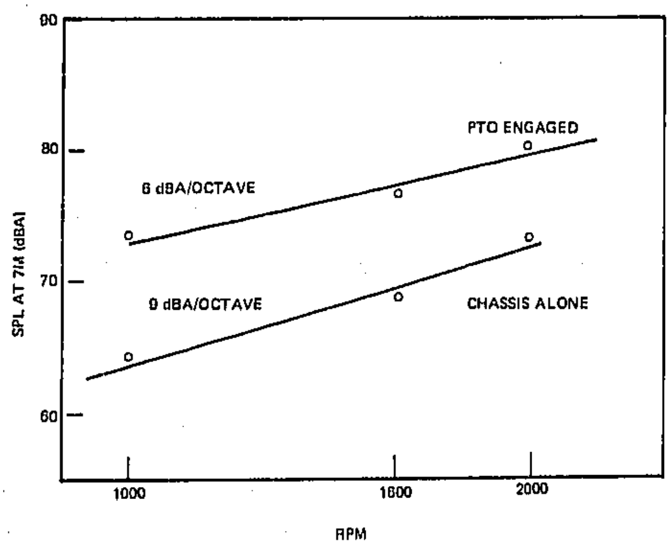


FIGURE 3-8

TRUCK CHASSIS AND PTO NOISE

Source: Reference 3-1.

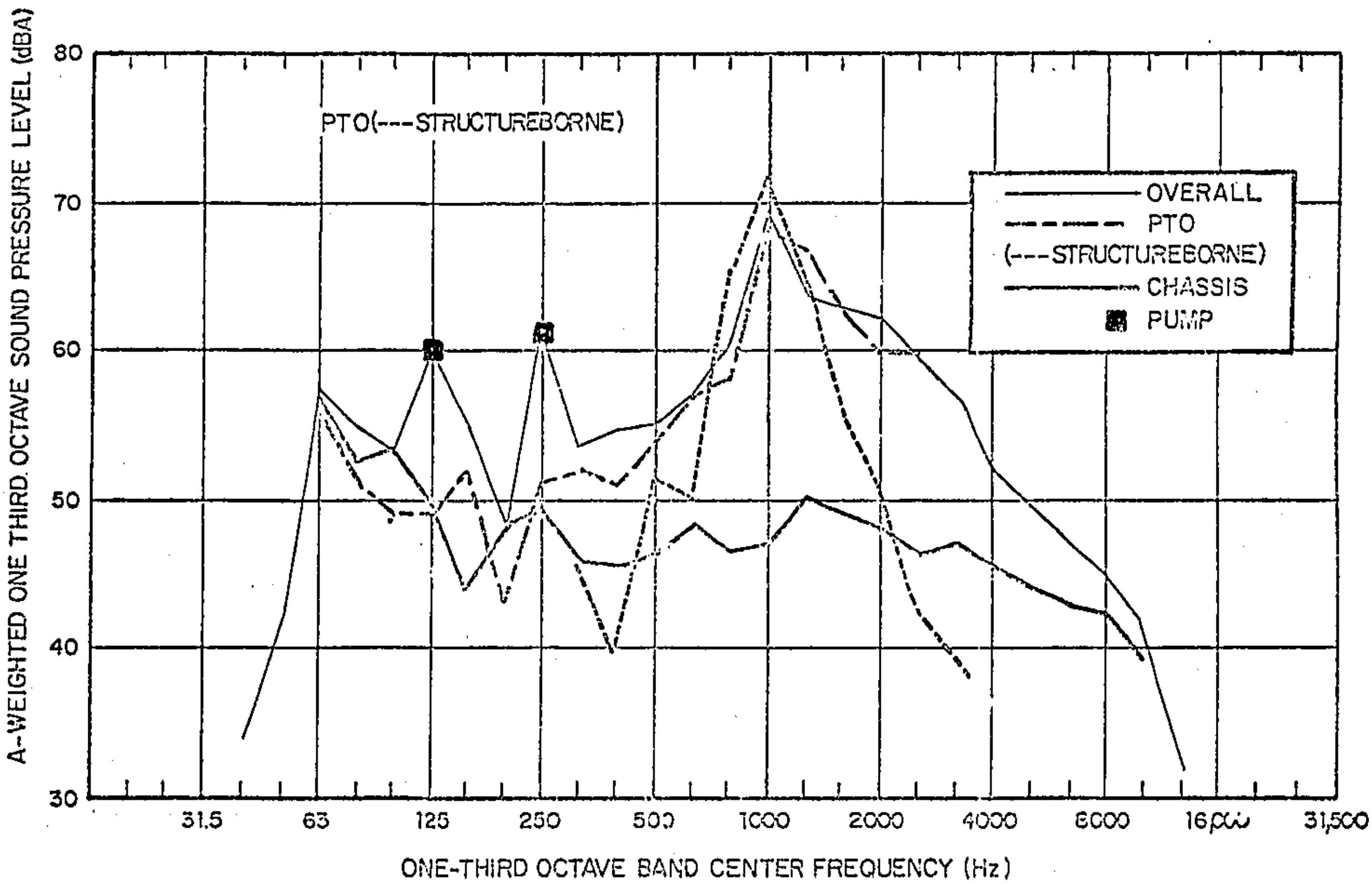


FIGURE 3-9

NOISE SPECTRA (Right Side at 7m)

Source: Reference 3-1.

trucks, and it is anticipated that entry into the market of new truck chassis conforming to this standard will result in less noisy compactor vehicles.

The measurement procedure stipulated in the regulation for medium and heavy trucks requires the engine to be run at full power with maximum rpm. During the compaction cycle, the engine is required to develop only a fraction of maximum horsepower. Because chassis noise is dependent on engine speed, the noise emission of the chassis operating at normal speeds (1800-2000 rpm) during compaction will be considerably less than the 83 dBA standard for vehicles meeting the truck noise regulations. Additional reductions in chassis noise can be achieved by further lowering the engine speed during the compaction cycle.

EPA analysts have reviewed empirical data available on the noise of engines as a function of speed, and have developed a mathematical model describing the effect of engine speed on the various noise sources in an engine. Based on this model, several curves have been plotted portraying predicted engine noise as a function of speed (Ref. 3-1). These curves demonstrate the potential reductions in noise that can be achieved by reducing engine speed.

Three chassis manufacturers supplied chassis noise levels as a function of engine speed for 14 chassis meeting the regulatory level of 83 dBA. These data, along with the levels predicted by the mathematical model for trucks regulated at 83 dBA, are graphed in Figure 3-10. Although several diesel engines exceed the noise level predicted by the model, all of the gasoline engine noise levels are considerably less than the

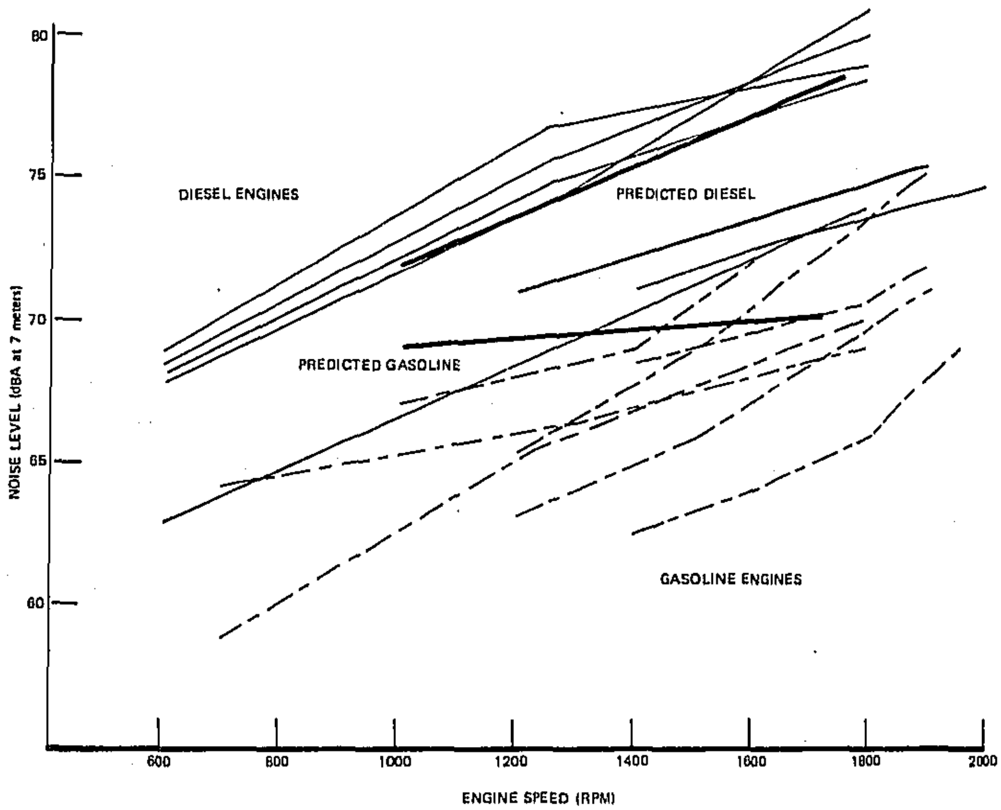


FIGURE 3-10

CHASSIS NOISE LEVELS AS A FUNCTION OF ENGINE SPEED
(Trucks regulated to meet regulatory 83 dBA level)

Source: Chassis noise data from three chassis manufacturers.

predicted levels for gasoline-powered engines. The slopes of the curves representing the manufacturers' data are greater than the slopes of the predicted curves, which indicates there is a greater dependence of noise level on engine speed than predicted by the model.

SAN FRANCISCO NOISE DATA

Noise measurements have been reported on truck-mounted solid waste compactors operating in the city of San Francisco. The San Francisco noise data were not gathered under the controlled conditions or methodology used in EPA measurements, and therefore are not comparable to the other data in this report.

One hundred and fifty-two noise measurements (Exhibit 3-1) were made on compactor vehicles operating in the streets of the city. The measurements were made at a distance of 50 feet from the rear of the truck. (Elsewhere in this report, the data were based on measurements made at 7 meters or 23 feet.) The San Francisco data were corrected by 6 dB to account for the greater distance between the microphone and the vehicle. Table 3-7 summarizes data for two scavenger fleets. Even after this correction, the San Francisco measurements were significantly higher than those reported by EPA in Table 3-1.

Table 3-8 compares the noise levels of sixteen trucks measured both by EPA investigators and by San Francisco. Again, it is obvious that the noise levels measured by the city of San Francisco for the maximum continuous level are generally as high or higher than the EPA level, even though the San Francisco measurements were made twice as far from the truck. The major reason for the increased noise readings in San Francisco probably is

TABLE 3-7

SUMMARY OF SAN FRANCISCO NOISE MEASUREMENTS
(dBA at 50 feet from rear of compactor)

Fleet	Number of Vehicles	Maximum Continuous Noise Level		Average of 3 Highest Peaks	
		Mean	Standard Deviation	Mean	Standard Deviation
A	57	75.35	0.51	78.32	0.32
B	95	78.57	0.36	81.08	0.32

Source: Reference 3-1.

TABLE 3-8

NOISE LEVELS OF SAN FRANCISCO COMPACTOR TRUCKS
(dBA at 23 feet and 50 feet)

Operator	Vehicle Number	Maximum Continuous Noise Level			Maximum Impact Noise Level		
		San Francisco (50 ft)	San Francisco (adjusted)	EPA (23 ft)	San Francisco (50 ft)	San Francisco (adjusted)	EPA (23 ft)
Sunset	X43A	77	83	73	81	87	88
Sunset	29A	78	84	76.5	81	87	85
Sunset	21A	74	80	74	79	85	86
Sunset	51A	80	86	75.5	83	89	78.5
Golden Gate	29	73	79	76	78	84	82
Golden Gate	1	—	—	72	—	—	80
Sunset	G1A	79	85	77	83	89	88
Golden Gate	26	72	78	75.5	80	86	89
Sunset	74A	81	87	79	86	92	83
Sunset	23A	82	88	75	87	93	88
Golden Gate	33/34	—	—	78	—	—	95
Sunset	75A	79	85	74.5	82	88	85
Sunset	59A	78	84	73	78	84	85
Sunset	43A	77	83	76	81	87	89
Sunset	D7	—	—	74.5	—	—	83
Sunset	D7	—	—	73	—	—	74.5

Source: References 3-1, EPA/NEF Measurements in San Francisco.

reverberation. San Francisco has many narrow streets with row housing, which cause a reverberant build-up of noise. The higher correlation between San Francisco and EPA data for the maximum impact levels supports this theory of reverberation. Impact noises are of short duration and do not experience significant reverberant build-up. Therefore, the narrow streets and row housing in San Francisco cause an increase in the maximum continuous level readings but do not affect the maximum impact level readings.

SOUND LEVEL DEGRADATION

There are two general causes of degradation: (1) increase in the noise emission of individual components; and (2) decrease in the efficacy of a noise control treatment.

The sources of noise on a truck-mounted solid waste compactor which are subject to degradation are the truck chassis (engine casing, exhaust, and fan), power take-off (PTO), and hydraulic pump (Table 3-9).

The noise degradation of the chassis is directly related to the average life of the engine. Warranties for truck diesel engines usually cover 50,000 miles or 24 months on parts and labor, or 100,000 miles or 24 months on parts only (Ref. 3-3). The warranty for gasoline engines is half that of diesel engines. Waste compactor truck diesel engines are overhauled approximately every 150,000 miles and gasoline engines every 80,000 to 100,000 miles.

TABLE 3-9

AVAILABLE DATA ON NOISE DEGRADATION FOR TRUCK-MOUNTED SOLID WASTE COMPACTORS REGULATED AT 78 dBA (7 meters)

Noise Source	Unregulated Noise level (dBA)	Regulated Noise level (dBA)	Reduction of Noise (dBA)	Noise Source Degradation	Available Data on Source Degradation	Sources of Data on Degradation	Treatment to Comply	Treatment Degradation
Chassis -Engine -Exhaust -Fan	80 (diesel at 1750 rpm)	75 (diesel at 1750 rpm)	5	for trucks at 83 dBA: -engine-source and treatment -exhaust muffler	-DOT quiet truck field tests -engine useful life -engine warranty -muffler useful life	-DOT quiet truck reports -engine mfgrs. -muffler mfgrs. -compactor users	reduce engine speed	none
PTO	79	(noise from flywheel or front PTO not significant)	-	degradation does not affect over-all level unless PTO fails	-PTO useful life -PTO warranty	-compactor users	replace trans. PTO with front or flywheel PTO	none
Pump	68 (estimated from 64 dBA at 1250 rpm using 30 log of pump speed)	64	4	degradation of pump	-pump useful life -pump warranty	-compactor users	none	--

Department of Commerce data indicate an average annual mileage of 12,200 miles for all compactor vehicles. Front loaders used in commercial trash pickup are driven 15,000 to 25,000 miles per year, while rear and side loaders used in residential operations are driven less than 10,000 miles per year. The average vehicle, therefore, may be driven 5 or 6 years before the first overhaul.

Chassis noise from waste compactors equipped with gasoline or diesel engines is not expected to degrade significantly over the first 50,000 to 75,000 miles of use. Although the gasoline engine has a greater degradation, the chassis noise level of the gasoline powered truck is less than that of the diesel engine truck. If the engine speed is reduced, engine wear may be reduced also, resulting in less noise degradation of the chassis.

The degradation of other noise sources is insignificant. Exhaust mufflers have an average life comparable with that of the engine (Ref. 3-5) and can easily be replaced if necessary. Replacing the transmission PTO with a flywheel or front PTO reduces the noise level of the PTO to an insignificant level, so that degradation can be ignored. Also, since alignment of gears will probably be better for front or flywheel PTOs than for transmission PTOs, gear wear should be less and, therefore, PTO noise degradation less.

The noise treatments of reducing engine speed and replacing the transmission PTO with a front or flywheel PTO are not expected to decrease in efficacy. Therefore, the chassis noise degradation will probably dominate waste compactor noise degradation.

Noise Degradation of Quieted Trucks

The noise emissions from two International Harvester DOT Quiet Trucks with initial noise levels of 80 dBA (low enough to comply with the 83 dBA regulatory level) increased by 1 dBA during the first 150,000 miles of normal use (Ref. 3-2). Two DOT Quiet Trucks with noise levels of 78 dBA (low enough to comply with the 80 dBA regulatory level) demonstrated reductions in their initial noise levels after 90,000 miles.

When chassis noise is reduced to a level below 80 dBA, the noise from the hydraulic pump becomes a significant factor in compactor noise degradation. Pumps are warranted for six months and generally last one to two years during normal use (Ref. 3-6).

REFERENCES
Section 3

3-1. "Noise Control/Technology for Specialty Trucks (Solid Waste Compactors)", Bolt, Beranek and Newman, Inc., BBN Draft Report 3249, February 1976.

3-2. J.T. Shroder, "Field Test Results on a Heavy Duty Diesel Truck Having Reduced Noise Emissions," Truck Noise IV-G Report No. DOT-TST-76-42, December 1975.

3-3. Telephone conversation on 24 May 1977 between C. Burroughs of BBN and Chris Kouts of EPA/ONAC.

3-4. Telephone conversation between Fred Mintz of EPA/ONAC and Allen Berger of Browning-Ferris Industries.

3-5. Gene E. Fax and Michael C. Kaye, "The Economics of Quieting the Freightliner Cab-Over-Engine Diesel Truck," Truck Noise III-D, Report No. DOT-TST-75-22, October 1974.

3-6. Telephone conversation on 22 June 1977 between C. Burroughs of BBN and John Waite of Heil Company.

EXHIBIT 3-1

NOISE EMISSION TESTS MADE ON SAN FRANCISCO CITY TRASH TRUCKS*

Source: Reference 3-1.

Vehicle No.	Compacting (dBA)	Crushing Spikes (dBA)**		
39	80.0	85.0	84.0	84.0
5-3	73.0	75.0	76.0	75.0
5-8	69.0	70.0	70.0	70.0
5	86.0	87.0	88.0	88.0
35	71.0	72.0	74.0	75.0
36	73.0	73.0	74.0	75.0
40	74.0	79.0	80.0	81.0
41	76.0	79.0	80.0	80.0
42	70.0	72.0	72.0	76.0
43	75.0	75.0	77.0	77.0
44	74.0	74.0	75.0	81.0
46	71.0	72.0	74.0	77.0
48	75.0	83.0	84.0	85.0
23	75.0	81.0	82.0	83.0
23	75.0	75.0	76.0	81.0
24	76.0	78.0	77.0	83.0
25	78.0	80.0	82.0	85.0
27	78.0	79.0	80.0	80.0
26	72.0	73.0	78.0	80.0
27	78.0	79.0	79.0	80.0
28	76.0	76.0	76.0	77.0
29	73.0	74.0	76.0	78.0
3147	75.0	75.0	78.0	81.0
32	78.0	79.0	82.0	84.0
33	82.0	86.0	86.0	89.0
10	75.0	77.0	78.0	78.0
12	77.0	82.0	82.0	83.0
11	71.0	75.0	75.0	78.0
14	73.0	73.0	73.0	75.0
15	73.0	73.0	73.0	74.0
169	74.0	75.0	76.0	77.0
169	75.0	78.0	79.0	79.0
1720	73.0	73.0	75.0	81.0
1720	73.0	76.0	76.0	77.0
1720	71.0	71.0	74.0	75.0
1830	75.0	75.0	75.0	79.0
19	75.0	77.0	81.0	84.0
20	70.0	73.0	74.0	73.0
21	72.0	76.0	76.0	78.0
21	74.0	76.0	76.0	81.0
22	73.0	74.0	80.0	85.0
F2	86.0	87.0	87.0	88.0
F5	77.0	78.0	79.0	80.0
2	79.0	79.0	80.0	80.0

*Measurements made at 50 feet on city streets
**Maximum noise spikes associated with the normal operation of the vehicle.

EXHIBIT 3-1 (Continued)

NOISE EMISSION TESTS MADE ON SAN FRANCISCO CITY TRASH TRUCKS

Vehicle No.	Compacting (dBA)	Crushing Spikes (dBA)		
411	77.0	78.0	78.0	80.0
X4	74.0	75.0	76.0	77.0
P4	77.0	78.0	80.0	80.0
411	83.0	83.0	84.0	86.0
411	76.0	76.0	76.0	77.0
X5	75.0	75.0	77.0	77.0
6	73.0	78.0	79.0	82.0
7	79.0	80.0	81.0	83.0
X7	83.0	83.0	84.0	85.0
X8	67.0	68.0	70.0	71.0
8	79.0	80.0	82.0	84.0
9	77.0	77.0	78.0	79.0
10	77.0	79.0	79.0	80.0
68	78.0	78.0	79.0	81.0
70A	76.0	75.0	77.0	78.0
72A	75.0	79.0	82.0	83.0
74A	81.0	81.0	82.0	84.0
74A	81.0	85.0	85.0	86.0
75A	78.0	80.0	81.0	81.0
75A	79.0	79.0	80.0	82.0
76A	80.0	80.0	80.0	83.0
49A	79.0	79.0	80.0	80.0
78A	79.0	81.0	81.0	81.0
79A	78.0	79.0	79.0	79.0
79A	77.0	78.0	77.0	77.0
71A	86.0	87.0	87.0	89.0
73A	78.0	79.0	80.0	87.0
78A	82.0	82.0	82.0	83.0
F4	85.0	85.0	85.0	86.0
63A	80.0	81.0	82.0	82.0
63A	80.0	80.0	82.0	83.0
67A	73.0	76.0	77.0	79.0
68A	78.0	79.0	84.0	85.0
68A	80.0	83.0	84.0	85.0
57A	77.0	78.0	79.0	80.0
58A	82.0	82.0	84.0	85.0
59A	78.0	78.0	78.0	78.0
60	75.0	76.0	76.0	77.0
61A	79.0	80.0	81.0	83.0
62A	77.0	80.0	82.0	88.0
62A	73.0	73.0	75.0	75.0
64A	76.0	80.0	81.0	81.0
64A	78.0	79.0	79.0	80.0

EXHIBIT 3-1 (Continued)

NOISE EMISSION TESTS MADE ON SAN FRANCISCO CITY TRASH TRUCKS

Vehicle No.	Compacting (dBA)	Crushing Spikes (dBA)		
65A	84.0	84.0	85.0	86.0
66A	83.0	86.0	86.0	87.0
68A	75.0	78.0	79.0	79.0
39A	80.0	83.0	85.0	85.0
40A	87.0	90.0	90.0	90.0
41A	80.0	83.0	84.0	86.0
42A	78.0	78.0	82.0	83.0
43A	77.0	80.0	81.0	81.0
44A	80.0	80.0	82.0	84.0
45A	75.0	77.0	78.0	80.0
46A	88.0	94.0	96.0	97.0
47A	79.0	83.0	85.0	87.0
48A	75.0	75.0	75.0	75.0
49A	77.0	81.0	81.0	81.0
51A	82.0	84.0	85.0	86.0
52A	82.0	83.0	84.0	85.0
54A	80.0	80.0	82.0	82.0
55A	79.0	82.0	82.0	85.0
56A	80.0	83.0	87.0	86.0
53A	82.0	82.0	83.0	83.0
51A	80.0	80.0	83.0	83.0
34A	81.0	84.0	86.0	88.0
WD	75.0	81.0	83.0	83.0
2A	74.0	74.0	78.0	79.0
X2	79.0	79.0	79.0	80.0
3A	78.0	78.0	79.0	79.0
4A	75.0	77.0	77.0	77.0
4A	75.0	77.0	78.0	79.0
5A	78.0	79.0	82.0	81.0
X6A	78.0	78.0	79.0	79.0
15A	75.0	75.0	75.0	76.0
16A	80.0	82.0	84.0	84.0
17A	80.0	80.0	82.0	88.0
18A	82.0	84.0	84.0	85.0
19A	79.0	83.0	84.0	84.0
19A	81.0	81.0	82.0	82.0
20A	86.0	87.0	87.0	87.0
21A	74.0	78.0	78.0	79.0
22A	80.0	81.0	81.0	81.0
23A	82.0	82.0	84.0	87.0
24A	84.0	85.0	86.0	86.0
28A	75.0	78.0	79.0	80.0

EXHIBIT 3-1 (Continued)

NOISE EMISSION TESTS MADE ON SAN FRANCISCO CITY TRASH TRUCKS

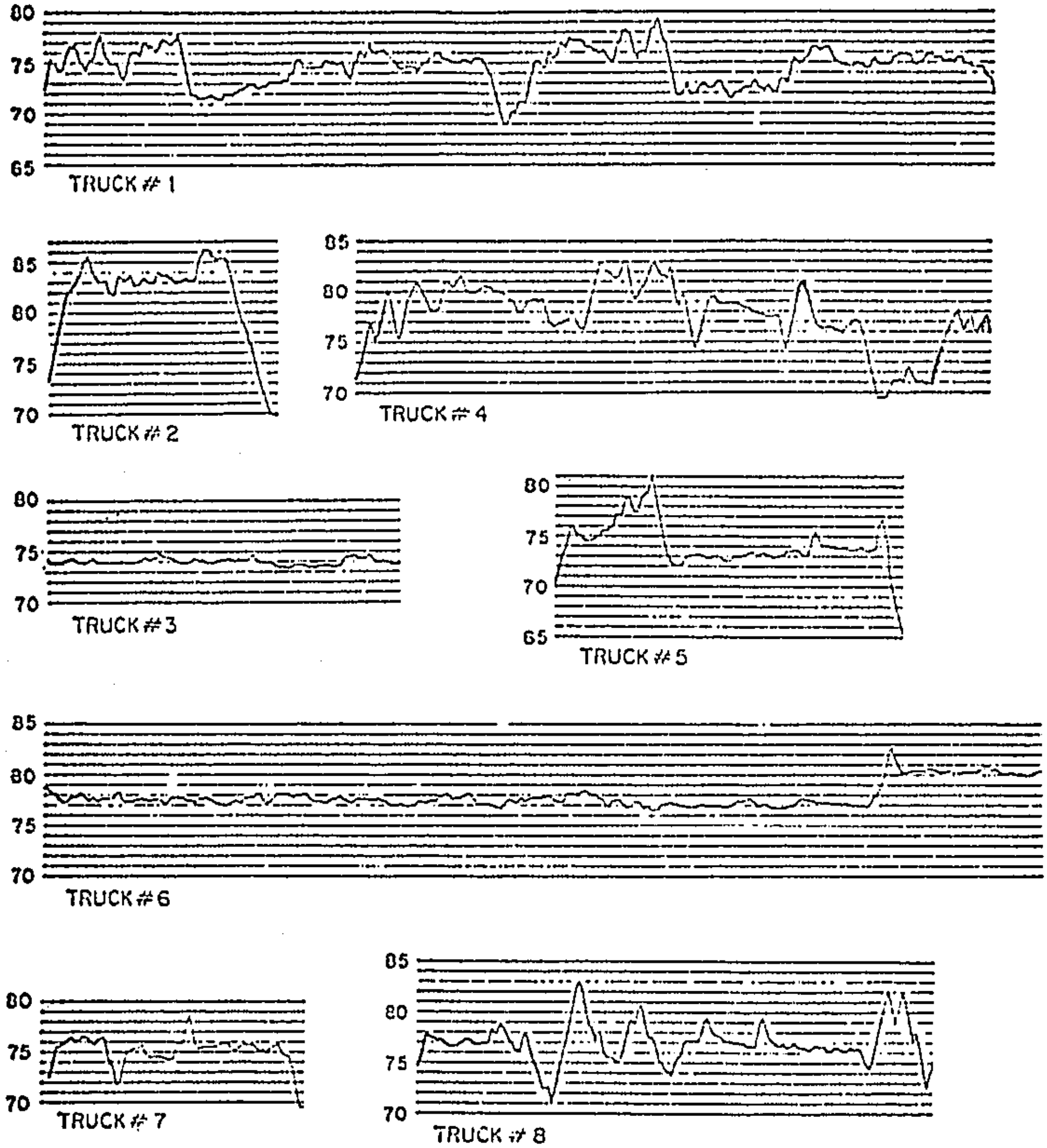
Vehicle No.	Compacting (dBA)	Crushing Spikes (dBA)		
27A	76.0	77.0	79.0	80.0
27A	79.0	80.0	81.0	82.0
29A	78.0	79.0	79.0	81.0
30A	78.0	78.0	79.0	80.0
32A	78.0	78.0	79.0	80.0
34A	77.0	79.0	79.0	79.0
36A	78.0	78.0	79.0	79.0
9A	80.0	80.0	80.0	81.0
38A	82.0	82.0	83.0	83.0
37A	80.0	82.0	83.0	88.0
37A	81.0	83.0	83.0	83.0
38A	77.0	77.0	77.0	80.0
14A	75.0	78.0	80.0	82.0
13A	77.0	77.0	77.0	77.0
12A	71.0	72.0	72.0	74.0
11A	67.0	72.0	73.0	74.0
10A	77.0	79.0	80.0	82.0
8A	68.0	70.0	71.0	71.0
X7A	79.0	79.0	79.0	82.0
X7A	78.0	80.0	82.0	82.0
X7A	80.0	83.0	84.0	89.0
7A	75.0	78.0	78.0	78.0
X6A	81.0	80.0	81.0	83.0

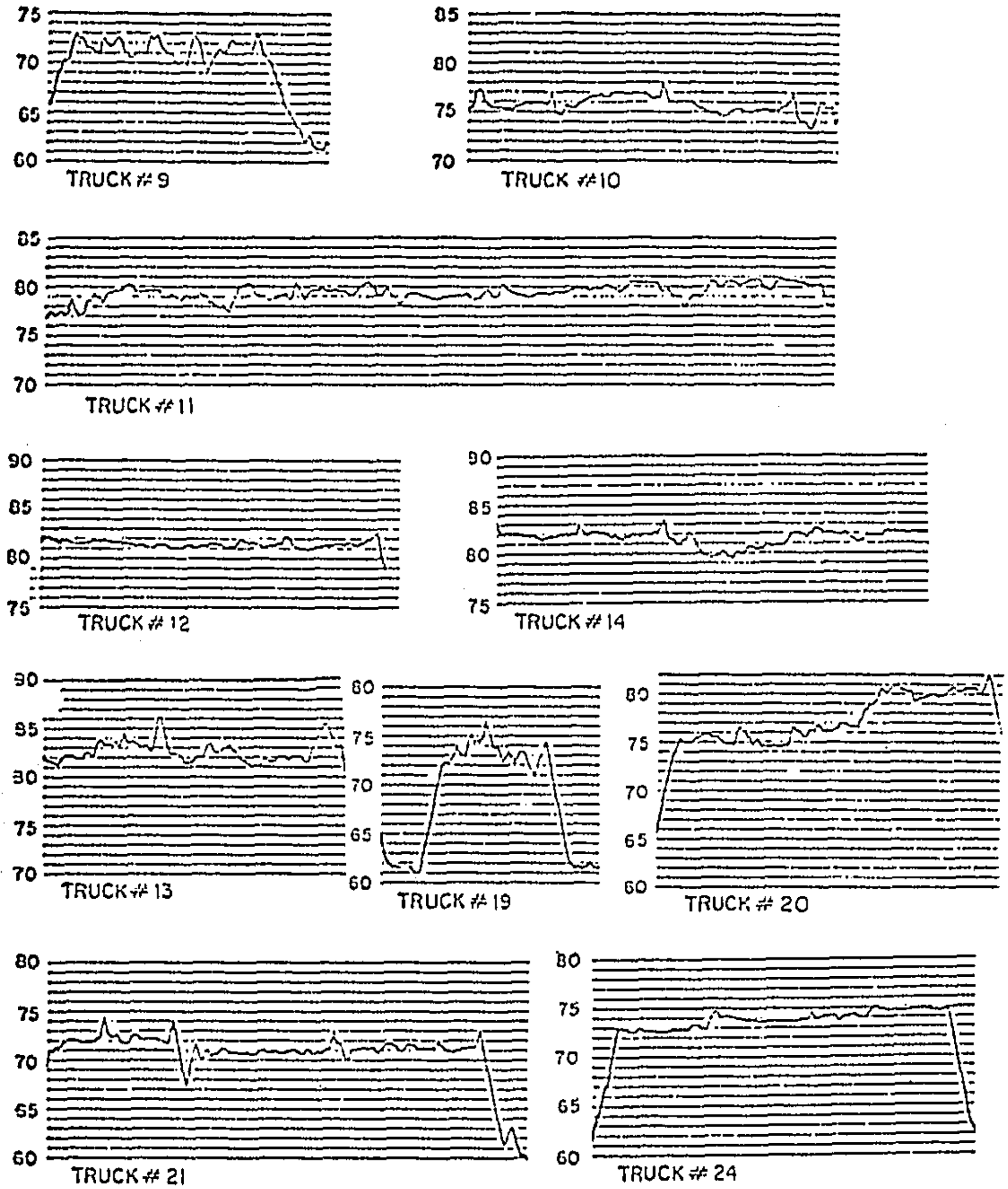
EXHIBIT 3-2

VEHICLE TIME HISTORIES: "SLOW" METER RESPONSE

The following figures show the time histories of the compaction or loading cycles for eighteen (18) of the vehicles listed in Table 3-1. These histories were recorded on a Graphic Level Recorder (GLR) with a writing speed of 16 mm/sec and a chart speed of 3 mm/sec. This roughly corresponds to an averaging time of 0.5 sec or a "slow" meter response. The equivalency is only exact, however, for a 4 dBA sound level spike. A larger spike will cause the GLR to read lower than the sound level meter and a smaller spike will cause it to read higher.

These time histories give an indication of how the sound levels (in "slow" meter response) of the vehicle noise emissions vary throughout the compaction cycle. They indicate the maximum level at one microphone position for the identified vehicle; the four-position energy average for each of these vehicles is listed in Table 3-1.


80
75
70
65
TRUCK # 1
85
80
75
70
TRUCK # 2
85
80
75
70
TRUCK # 4
80
75
70
TRUCK # 3
80
75
70
65
TRUCK # 5
85
80
75
70
TRUCK # 6
80
75
70
TRUCK # 7
85
80
75
70
TRUCK # 8


75
70
65
60
TRUCK # 9
85
80
75
70
TRUCK #10
85
80
75
70
TRUCK # 11
90
85
80
75
TRUCK # 12
90
85
80
75
TRUCK # 14
90
85
80
75
70
TRUCK # 13
80
75
70
65
60
TRUCK # 19
80
75
70
65
60
TRUCK # 20
80
75
70
65
60
TRUCK # 21
80
75
70
65
60
TRUCK # 24

SECTION 4

MEASUREMENT METHODOLOGY

GENERAL REQUIREMENTS

A noise measurement methodology is essentially an easily-conducted, repeatable procedure for acquiring data that correlate well with noise generated under service conditions. In this section each of these factors is discussed as a basis for developing a measurement methodology.

Perhaps the most important feature of a measurement methodology is its correlation with environmental impact. It is not necessary that levels acquired in a standardized way be identical to those observed under ordinary operating conditions. What is important is that standardized data enable one to correctly predict environmental levels. The consequences of inadequate correlation are less than expected environmental protection or inefficient allocation of noise-abatement resources. The relationship between desired environmental control and test standards can be illustrated graphically. As Figure 4-1 shows, the lines corresponding to the desired level of environmental control and the not-to-exceed regulated level divide the noise sources into four categories. In Category I the sources have passed the standard test and therefore would not be controlled further, but are still environmentally objectionable. Those in Category II fail the test and are environmentally objectionable. However, one may presume that some of these will be quieted to the point where they pass the test but are still environmentally objectionable; others will be quieted at some needless expense beyond the point where they are of concern. Similarly, all sources in Category III will be quieted needlessly, i.e, they fail the test but are environmentally acceptable. Category IV sources will not be quieted, since they passed the test and are environmentally acceptable.

In practice, the shortcomings of standard test procedures are inevitable, but may be minimized. Figures 4-1 shows contrasting test procedures that correlate poorly (a) and well (b) with environmental levels. The problems associated with procedures that correlate poorly are inevitably worse than those that correlate well. A major objective in developing the test procedure was to develop a standard measurement procedure that correlates well with environmental levels and is consistent with other test requirements.

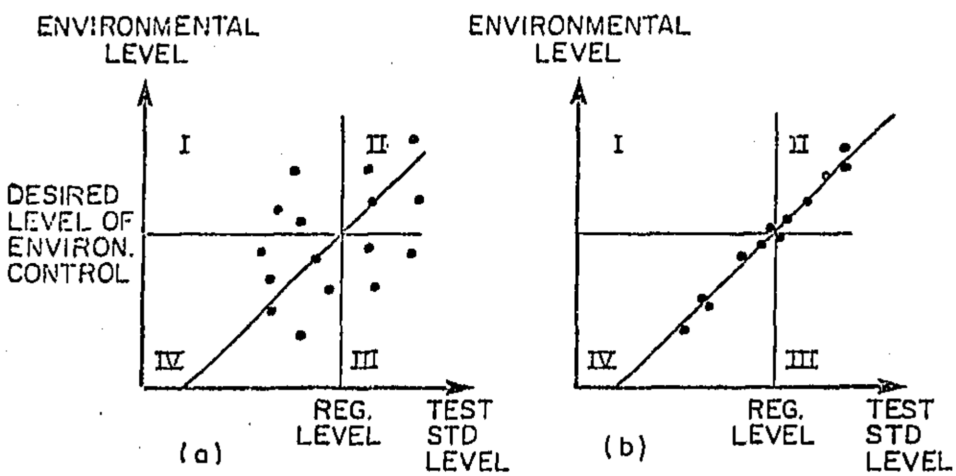


FIGURE 4-1

ILLUSTRATION OF TEST STANDARDS THAT CORRELATE (a) POORLY AND (b) WELL WITH ENVIRONMENTAL LEVELS

Source: Reference 4-3.

Ease of performance is a second factor that must be carefully evaluated in developing a measurement methodology. The methodology should be readily performed by manufacturers to facilitate the many tests required during usual developmental phases. In addition, manufacturers will undoubtedly wish to test at least a sample of products prior to introducing them into commerce. Also, the methodology should be easily performed by enforcement personnel who may test at a manufacturer's facility and/or at a special test site.

Finally, repeatability is obviously desirable. A test which is nonrepeatable, that is, one which does not produce the same results when run more than once under the same conditions, is invariably corrupted by random or unknown factors. To be meaningful, such tests must be conducted many times in order to obtain a statistical characterization. Such a procedure can increase the cost and effort of testing by an order of magnitude and must therefore be avoided.

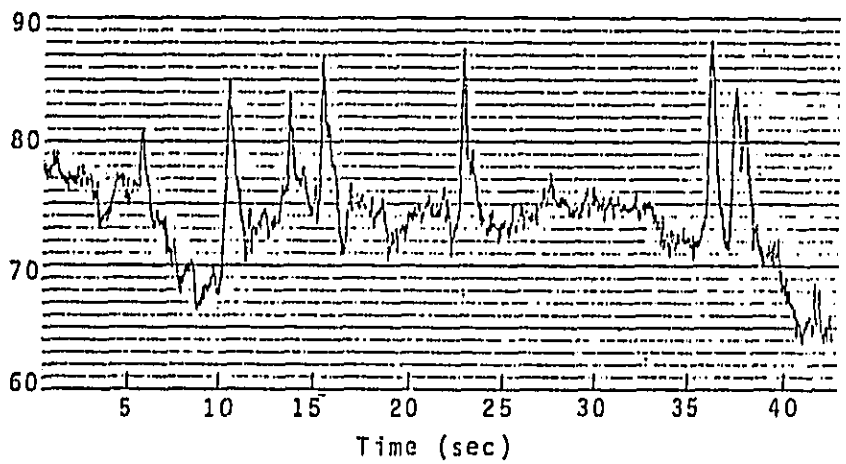


FIGURE 4-2

TIME HISTORY OF THE A-WEIGHTED SOUND LEVEL MEASURED 50 FEET TO THE LEFT SIDE OF A FRONT LOADER

Source: Reference 4-3.

NOISE CHARACTERISTICS

Before proceeding to specific requirements, it is useful to consider the noise profile of a solid waste compactor. Figure 4-2 shows a time history of the A-weighted sound level measured 50 ft. to the left side of a front loader. The first part of the trace is measured during the dump cycle, the second during a sweep cycle. There are two noteworthy features of the data in Figure 4-2. First, there are a number of very noticeable impacts, which, for this unit correspond primarily to container impacts. For other units, especially rear loaders, hydraulic actuators generate similar impacts. Secondly, the quasi-steady level between impacts varies with time. This level is dominated by engine noise, which depends on the speed that is controlled by the driver. Thus, we see that a reasonable method for characterizing impacts must be established, as well as a technique for specifying engine operating conditions or cycle time.

Alternative Measurement Methodologies

Measurement methodologies are comprised of three parts: (1) specification of operating conditions, (2) establishment of measurement criteria (e.g., whether to use A-weighting, B-weighting, etc.,) and (3) specification of test site and instrumentation.

1. Operating Conditions

Two primary factors of concern are the specification of compactor load and of engine speed for engines which are not equipped with mechanical speed control devices.

2. Compactor Load

A decision must be made as to what load will be placed in the hopper of the compactor truck when its noise is being measured. Suggestions have been made that a standard load should be used. This load could consist of paper, garbage or bottles. However, any such load will inevitably vary from one sample to another and not be reproducible. The sample could not even be used twice in the same truck since it would change on being compacted the first time. Accordingly, the only reproducible load that could be devised would be no load. Although an empty hopper does not precisely simulate actual loads, it does provide a constant baseline against which all trucks can be compared.

3. Engine Speed Control

It is desirable to make some provision for specification of engine speed for trucks, such as front loaders, which are not normally equipped with engine speed control devices. At least three possible approaches for doing this are:

- specifying an engine rpm in the regulation
- requiring that the dump or compaction cycle be performed within the time limits published in the manufacturer's advertisements
- specifying the operation of the engine at maximum allowable engine or pump rpm, whichever is lower.

It does not seem appropriate to specify a fixed engine rpm. Such a specification would be a counter-productive constraint on manufacturers who wish to achieve noise control without compromising performance by minimizing engine speeds and using high capacity pumps.

The second approach, requiring that operational cycle times conform to advertised values, has some merit. However, the obvious problems are that, on one hand, cycle times are not advertised for all vehicles and therefore would not be regulated; on the other hand, manufacturers might cease such advertisement if their publication led to excessive noise control problems.

The third technique, specifying operation at the maximum speed allowed by the manufacturer, also has positive and negative attributes. It could be argued that engines or pumps are rarely operated at maximum allowed speeds. However, compactor operators are motivated to operate dump and compaction cycles as quickly as possible to minimize the route-collection time. In fact, there have been cases of operators changing engine speed control settings for this purpose. Furthermore, testing at maximum allowable speed is consistent with many industry practices. SAE test procedures typically specify maximum acceleration/maximum speed conditions. Therefore, the Agency concluded that compactors without mechanical speed controls should be tested at the maximum engine or pump rpm allowed by the manufacturer.

Measurement Criteria

The key measurement problems relate to proper instrumentation, determination of the appropriate noise level reading, the number and location of the microphone positions, and the method of combining the level readings at the various locations to obtain a suitable average level.

1. Weighting Scale

The first question concerns which weighting scale, if any, to use in taking the reading. Several scales have been proposed, and the A, B and C weighting scales are available on most sound level meters. The A-weighting scale has broad general acceptance as representing, in a single number, the subjective perception of intensity, or loudness, of noise. As explained in the EPA "Levels Document" (Ref. 4-4) the A-weighting scale has been selected by EPA as the appropriate metric to use in evaluation of noise impact and for assessing all sources of noise. Consequently, the A-weighted sound level (also referred to as "noise level"), is the quantity to be observed and reported in making noise measurements of truck-mounted solid waste compactors.

2. Meter Response Setting

Originally, the measurement technique used by EPA in obtaining the noise levels of compactors entailed two separate readings: one of "maximum steady" level, intended to represent the essentially continuous noise emissions of the compaction machinery; and the other of "impulse" noise, intended to characterize the occasional abrupt sounds associated with impacts between individual components of the compaction mechanism and the compactor body that occur at the end of the piston stroke or similar episodes during the compaction cycle. Both of these readings were taken with the meter in "fast" response setting, for reasons explained in the draft background document (Ref. 4-5).

Partly as a result of comments received during the public comment period, the Agency recognized that the reading of "maximum steady level" using fast meter setting was subject to considerable variation among different observers. The variations were apparently based on subjective differences in interpreting the concept of "maximum steady level." In most cases, the noise emitted by the refuse collection vehicle during compaction continuously fluctuates in level by several decibels. Thus, the reading taken by any observer was dependent both on his concept of "maximum steady" and his subjective estimate of which position of the meter needle (or a graphic record) suitably characterized the noise. Difficulties also were encountered in obtaining maximum impulse readings on the meter, as the eye does not always follow accurately a rapidly moving meter needle.

A review of the original tape recorded data obtained by the Agency, plus additional noise data, showed that the variability in readings could be reduced by two changes in procedure: use of the "slow" meter setting instead of the "fast" setting; and taking a single reading of the maximum level shown on the meter, rather than a "maximum steady" reading (which implied some type of average reading) and a "maximum impulse" reading. With respect to impulse noises, all of the tested vehicles that had impulse peaks in "fast" response of less than 83 dBA showed maximum values under 79 dBA in "slow" response. This is to be expected, since the impulse response of the sound level meter in "slow" setting is generally about 4 decibels lower than it is in "fast" setting.

Consequently, EPA reached the conclusion that the test procedure could be simplified and the meter reading process made more reliable by setting a single noise level limit based on a reading of the maximum noise level observed with the meter in the "slow" response setting. This replaces the proposed procedure, which required two separate readings, one of "maximum steady" and one of "maximum impact", using the "fast" meter setting. The increase of one decibel in the not-to-exceed limit accounts for the damped response of the meter to a mild impulse (such as was allowed in the proposed impulse overshoot of 5 decibels in "fast" mode, in the proposed regulation) while not degrading significantly the control of continuous noise implied in the earlier "maximum steady" limit.

Consideration also was given to other methods of reducing the uncertainty of the meter reading, such as use of an integrating/averaging sound level meter, also known as "L_{eq} meter." Although this approach has potential merit, it has not been specified in the test standard because of the lack of a national or international standard for such meters. The Agency believes that, to ensure consistency and accuracy of the primary measurement which establishes conformity to a regulatory limit, the instrument used should conform to a widely recognized and accepted consensus standard.

3. Microphone Locations

Compacting-vehicle machinery is often distributed around the vehicle, requiring noise measurements at various locations. Drive train equipment such as the engine and fan are located at the front. PTOs and pumps are on the side, as are auxiliary power plants. Noise-producing hydraulic rams are at the rear of rear loaders. To account adequately for these distributed sources, we have selected measurement at four locations, 7 meters from the vehicle surface, at 90 degree intervals around the vehicle.

4. Combining Noise Levels

Since compactor noise levels are measured on all four sides, a single number is needed that best characterizes the noise emissions of the vehicle.

The total noise emission of the compactor vehicle is obtained by taking an energy average of the four noise level measurements. Mathematically speaking, this energy average is calculated by averaging the antilogarithms of the levels measured on the four sides of the compactor and then taking the logarithm of the result.

EPA MEASUREMENT METHOD

Based on the foregoing considerations, the following measurement methodology has been adopted.

Instrumentation

The following instrumentation shall be used, where applicable, for the measurement required.

1. A precision sound level meter which meets the Type 1 requirement of the American National Standards Specification for Sound Level Meters, S1.4-1971.
2. As an alternative to making direct measurements using a sound level meter, a microphone or sound level meter may be used with a magnetic tape recorder and/or a graphic level recorder or indicating meter, providing the system meets the requirements of the Society of Automotive Engineers (SAE) Recommended Practive J184, Qualifying a Sound Data Acquisition System.
3. A sound level calibrator with an accuracy of $\pm$0.5 dB.
4. A microphone windscreen may be used provided that its effect on the "A" weighted sound level is negligible under zero wind velocity conditions for the type of noise source being measured.
5. A stopwatch having an accuracy of better than one percent.

Test Site

The following test site requirements shall be considered the minimum necessary to conduct effective measurements.

An approved test site shall consist of a level open space free of large reflecting surfaces, such as parked vehicles, signboards, buildings, or hillsides, within approximately 15 meters (50 feet) of either the vehicle or the microphone.

The microphone shall be located 1.2 meters (4 ft) above the ground plane and 7 meters (23 ft) from the mid-point of the surface of the truck on the side on which the measurements are being made. Measurements will be made at four microphone positions to the front, rear and each side of the vehicle.

The measurement area shall, as a minimum, extend from the microphone to the farthest extremity of the truck or trailer. The area shall be surfaced with concrete, asphalt, or similar hard material, and shall be free of powdery snow, grass, loose soil or ashes, or other sound-absorbing materials.

Test Procedure

1. The compactor must be operated with the vehicle stationary.
2. The compactor engine must be started and allowed to reach its recommended operating temperature and conditions. If the ambient temperature is below 16°C (about 60°F), the container handling and compaction equipment shall be operated through enough cycles to ensure that hydraulic oil and components have reached a stable temperature and operating condition.

3. The compactor must be operated empty.

4. The compaction equipment and container handling mechanism (where appropriate) must be operated in accordance with their normal operating procedures except that no container shall be used. The compactor engine must be operated at a speed in rpm corresponding to the maximum allowable speed of the hydraulic pump which powers the compactor mechanism. If the compactor includes an engine speed control or governor which is operational during the container handling and compaction cycle, the test must be run at governed speed, provided that the governor cannot be overridden by an operator during normal in-use operation.

5. The sound level meter must be set for "slow" response and on the "A" weighting network.

6. The container handling and compaction equipment must be operated through two complete cycles for each noise measurement taken. If the test results (4-position energy-average) differ by more than 2 dB, further tests must be run until the two results agree within 2 dB and the average of the two will be reported.

7. Noise level measurements must be taken at each of the four microphone positions around the compactor, and the following data will be reported:

   a. Maximum noise level during a complete cycle of container handling and compaction at each microphone position;

b. The four-position energy average noise level, computed according to the equation:

$$\overline{L} = 10 \log \sum_{i=1}^{4} \left[\text{ant}(L_i/10) \right] - 6 \text{ dB} \qquad (4\text{-}1)$$

where: $\overline{L}$ = energy average noise level, in decibels; L_i is the A-weighted noise level corresponding to the i'th microphone location; and ant(x) means antilogarithm(x), which equals 10^x;

c. The time from the beginning to the end of each operational cycle.

8. The entire acoustical instrumentation system including the microphone and cable must be field-checked before and after each test series.

General Comments

It is strongly recommended that persons technically trained and experienced in the current techniques of sound measurement select the equipment and conduct the tests.

Proper use of all test instrumentation 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. Specific items to be considered are:

1. The effects of ambient weather conditions on the performance of all instruments (for example, temperature, humidity, and barometric pressure).

2. Proper signal levels, terminating impedances, and cable lenghts on multi-instrument measurement systems.
3. Proper acoustical calibration procedure, to include the influence of extension cables, etc. Field calibration shall be made immediately before and after each test sequence. Internal calibration means are acceptable for field use, provided that external calibration is accomplished immediately before or after field use.
4. Proper orientation of the microphone relative to the source of sound as specified by the manufacturer.
5. Measurement shall be made only when wind speed is below 12 mph (19 Km/hr).
6. The ambient sound level (including wind effects) from sources other than the vehicle being measured shall be at least 10 dBA lower than the level of the tested vehicle.
7. Because bystanders have an appreciable influence on meter response when they are in the vicinity of the vehicle or microphone, not more than one person, other than the observer reading the meter, shall be within 15 meters (50 ft) of the vehicle or instrument, and that person shall be directly behind the observer reading the meter, or on a line through the microphone and the observer.

SUGGESTED REFERENCES

Suggested reference material is as follows:

ANS S1.1-1960 Acoustical Terminology.

ANS S1.2-1967 Physical Measurement of Sound.

ANS S1.4-1971 Specifications for Sound Level Meters.

SAE Recommended Practice J-184 - Qualifying a Sound Data Acquisition System.

Applications for copies of these documents should be addressed to the American National Standards Institute, Inc., 1430 Broadway, New York, New York, 10018; or, The Society of Automotive Engineers, Incorporated, Two Pennsylvania Plaza, New York, New York, 10001.

DISCUSSION OF METHODOLOGY

There are a number of points in the methodology presented above which need further explanation. Decisions have been made concerning certain parameters in the methodology, and the reasons for these decisions need to be enumerated.

Measurement Distance

Two measurement distances are commonly employed in the measurement of noise from vehicles: the SAE generally adopts a 50 ft distance, while the International Standards Organization (ISO) adopts a 7 m (23 ft) distance. In this methodology, we have selected the latter distance (7 m) for two reasons. First, the shorter distance allows use of a smaller measurement site. Buildings and reflecting surfaces need only be 50 ft away from the truck and microphone, whereas they need to be 100 ft away if a 50 ft measurement distance is employed. Smaller sites are more readily available. Second, since the noise levels to be measured are not very high, there will be less interference from ambient noise at a 7 m distance than at a 50 ft distance. Accordingly, all noise measurements in this study are quoted for a distance of 7 m (23 ft).

Operation of the Compactor Truck Empty

As indicated earlier, the only practical, reproducible load that could be devised was no load. An empty hopper may not be a good simulation of actual loads, but it does provide a constant baseline against which all trucks can be compared. Also, one series of measurements made on compactors indicated an average increase in noise of only 0.5 dB between empty and full load conditions (Ref. 4-2).

Energy Average

The truck noise levels are measured on four sides. The SAE generally takes the highest of the four levels measured and quotes that level. This is appropriate if one is concerned with determining if there is an excessive noise level in any direction. However, in this study, EPA is concerned with the total impact of the noise on the community. This is best evaluated by taking an energy average around all sides of the vehicle. The energy average is obtained by averaging the antilogarithms of the levels on the four sides of the truck and then taking the logarithm of the result. That is, if the four measurements are L_1, L_2, L_3 and L_4, the energy averaged level, $\overline{L}$, is

$$\overline{L} = \log_{10} \left[1/4 \; (10^{L_1/10} + 10^{L_2/10} + 10^{L_3/10} + 10^{L_4/10}) \right]$$

(which is another way of writing equation 4-1). The resultant value is influenced strongly by the highest level(s) measured at individual microphone position(s), and may be considered analogous to a sound power measurement.

REFERENCES
Section 4

4-1. Blomquist, Donald S. (National Bureau of Standards) letter to Fred Mintz, EPA, dated March 23, 1977.

4-2. Mansbach, Peter A. (National Bureau of Standards) letter to Fred Mintz, EPA dated August 31, 1976.

4-3. "Noise Control/Technology for Specialty Trucks (Solid Waste Compactors)," Bolt, Beranek and Newman, Inc., BBN Draft Report 3249, February 1976.

4-4. Environmental Protection Agency, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, EPA 550/9-74-004, March 1974.

4-5. Environmental Protection Agency, Information in Support of the Proposed Regulation for Truck-Mounted Solid Waste Compactors, Part 2, Draft Background Document, EPA 550/9-77-204, August 1977.

SECTION 5

EVALUATION OF EFFECTS OF TRUCK-MOUNTED SOLID WASTE COMPACTOR NOISE ON PUBLIC HEALTH AND WELFARE

INTRODUCTION

The purpose of this section of the regulatory analysis is to explore in quantitative terms the health and welfare impact of the noise of truck-mounted solid waste compactors, and the benefits, in terms of reduction of this impact, to be expected from a regulation limiting the noise emissions of newly-manufactured compactors. Various regulatory options are considered.

Predictions of both the costs and benefits involved are necessary inputs to define the trade-offs among the various options for the regulatory levels to be included in the final regulations. Presented in this analysis are predictions of the potential health and welfare benefits of selected noise control options that cover a range of possible regulatory programs of new truck-mounted solid waste compactors.

Because of inherent differences in individual responses to noise, the wide range of situations and environments which relate to compactor noise generation, and the complexity of the associated noise fields, it is not possible to examine all situations precisely. Hence, in this predictive analysis, certain stated assumptions have been made in order to approximate typical, or average, situations. The approach taken to determine the benefits associated with the noise regulation is a statistical effort to determine the order of magnitude of the population that may be affected for each regulatory option. Some uncertainties with respect to individual cases or situations may remain.

Effects of Noise on People

The phrase "health and welfare", used in this analysis and in the context of the Noise Control Act, is a broad term. It includes personal comfort and well-being, and the absence of mental anguish, disturbances and annoyance, as well as the absence of clinical symptoms such as hearing loss or demonstrable physiological injury (Ref. 5-20). In other words, the term applies to the entire range of adverse effects that noise can have on people, apart from economic impact.

Noise affects people in many ways, although not all noise effects will occur at all levels. Noise associated with trash collection activity may or may not produce the effects mentioned below, depending on exposures and specific situations. The discussion here refers to noise in general.

The best-known noise effect is probably noise-induced hearing loss. It is characteristic of noise-induced hearing loss that it first occurs in a high-frequency area of the auditory range which is important for the understanding of speech. As a noise-induced hearing loss develops, the sounds of speech which lend meaning become less and less discriminable. Eventually, while utterances are still heard, they become merely a series of low rumbles, and the intelligibility is lost. Noise-induced hearing loss is a permanent loss for which hearing aids and medical procedures cannot compensate.

Moreover, noise is a stressor. The body has a basic, primitive response mechanism which automatically responds to noise as if to a warning or danger signal. A complex of bodily reactions (sometimes called the "flight-or-fight" response) takes place which is beyond conscious control. When noise intrudes, these reactions include elevation of blood pressure, changes in heart rate, secretions of certain hormones into the bloodstream, changes in digestive processes, increased perspiration on the skin and many others.

This stress response occurs with individual noise events, but it is not known yet whether the reactions seen in the short term become, or contribute to, long-term stress diseases such as chronic high blood pressure. Therefore, the stress response to noise cannot yet be quantified.

On the other hand, some of this stress response may be reflected in what people express as "annoyance", "irritation", or "aggravation". The analysis in this section does quantify the generalized adverse reaction of groups of people to environmental noise. To the extent that stress and verbalized annoyance are related, the "general adverse response" quantity may be seen to partially represent or indicate the magnitude of stress response.

The general adverse response relationship to noise levels may also be seen as partially representing another area of noise effects: activity interference. Noise interferes with many important daily activities such as sleep and communication. These effects (sleep disturbance and communication interference) can be quantified. Thus, computations of benefits based on the potential of interference with human activities are included as part of the analysis in this section. In expressing the causes of annoyance due to noise, people often report that noise interferes with sleeping, relaxing, concentration, TV and radio listening, and face-to-face and telephone discussions. Thus, the general adverse response quantity may be seen also to be indicative of the severity of interference with activities.

Measures of Benefits to Public Health and Welfare

People are exposed to noise generated from trash compacting operations most notably when inside their homes during late night or early morning hours. Reducing noise related to trash compaction activity may produce the following benefits:

1. Reduction in average urban noise levels and associated cumulative long-term impact upon the exposed population.
2. Fewer activities, i.e., sleep and speech communication, disrupted by intense individual noise events.

Improvements in public health and welfare are regarded as benefits of noise control. Public health and welfare benefits may be quantified both in terms of reductions in noise exposures and, more meaningfully, in terms of reductions in adverse effects. This analysis first quantifies noise exposure from noise associated with trash collection activity (i.e., numbers of people exposed at different noise levels), then translates this exposure into an estimate of community impact.

Predictions of noise levels under various regulatory schedules are presented in terms of the noise levels associated with typical trash collection operations. The trash produced within a unit area of land will be generated at a rate dependent upon population density and land use. The collection and compaction of this trash is expressed on an amount-per-person-per-day basis for the unit area. The number of noise-producing compaction cycles is a function of this daily collection. The basic unit of area used is the hectare (ha). This unit is about the size of a city block (175 x 600 feet for an oblong block or 330 x 330 feet for a square block).

Reductions in the average urban noise levels from current conditions (i.e., with no compactor noise emission regulations, but taking into account the noise regulation for medium and heavy trucks) are presented for comparison with reductions expected for a number of regulatory options on newly manufactured truck-mounted trash compactors. Projections of the population impacted by compactor noise during the regulatory period are determined from estimating reductions in the average noise levels in various types of residential land use areas.

However, measuring nationwide impact in terms of average urban noise levels does not adequately account for extremely annoying situations arising from a single trash compaction operation, since annoyance or other responses to noise frequently depend on the activity and location of the individual. In addition, measures of average urban noise levels tend not to account for the disruptive and annoying peak noise intrusions produced by individual trash compaction cycles. Significant benefits may be obtained by reducing current noise levels generated during a single compaction activity. These benefits are evaluated in terms of interference with people's activities at current noise emission levels and at the reduced levels associated with the reduction of noise attributable to an individual trash compaction cycle. Sleep disturbance and speech interference are used as indicators of activity interference and the associated adverse impact of noise.

Regulatory Schedules

Predictions of the population impacted by noise related to trash collection activity are presented for the regulatory options shown in Table 5-1.

The base option assumes no specific noise regulation for compactors, and hence the total reduction in noise impact is the result of the noise regulations on medium and heavy duty trucks. Options 1, 3, 5, and 7 were selected from a large list of options which was reduced to these final four, for further study. In all cases, each compactor type is being regulated to the same level. The Silent option (an idealized case) is included for comparison purposes to indicate the lower limit of noise reductions, and the impact of eliminating compactor noise.

TABLE 5-1

REGULATORY OPTIONS: NOT-TO-EXCEED
A-WEIGHTED SOUND LEVELS AT 7m

Options*	Compactor (all types) 1980	1982
Base	U**	U**
Option 1	81	76
Option 3	U**	80
Option 5	U**	76
Option 7	79	76
Silent	0	0

*In all cases, A-weighted sound levels for truck regulations are 83 dB in 1978 and 80 dB in 1982 at 15 meters.

**U = unregulated.

Outline of the Health and Welfare Section

A description of the existing trash (refuse) compactor noise environment is presented in the following section. The next section presents the predicted reduction in impact for the population within various land uses due to the reduction of average community noise levels by regulating truck-mounted solid waste compactors. Following that, predictions of relative potential changes in human activity disturbance due to individual trash collection cycles are estimated for each land use for the regulations under consideration.

REFUSE COLLECTION NOISE LEVELS

A single collection cycle is defined as a refuse collection vehicle arriving at a location, loading trash into the hopper, compacting the trash, and finally, pulling away. This collection event may be considered a stationary noise source which produces a noise field that decreases in intensity with distance. A collection activity without compaction is not considered a collection cycle in this analysis. Collection activity without the accompanying compaction of trash occurs primarily in the less densely populated areas and most of the reduction of noise from collection activities without compaction will result primarily from reducing the truck noise.

Four elements must be evaluated in order to define the population exposure produced by the noise environment of a single trash collection cycle:

- The noise level of the truck which carries the compactor
- The noise produced by the compaction cycle of the compactor type being evaluated

- Propagation of the noise from the source to the receiver through situations which range from narrow streets to open areas
- Attenuation of the sound by buildings or walls.

These elements may be combined and translated into average levels by considering the number of collections occurring per unit area and the mix of collection trucks.

Truck Noise Per Collection Cycle

Much of the total collection cycle noise is generated by the truck which carries the compactor. Time histories of the noise emitted during typical residential trash collection cycles are summarized in Figure 5-1. Truck engine noise occurs while the truck pulls up, while it is idling and is being loaded, while the engine is accelerating during the compaction cycle, again while it is idling, and while it is driven off.

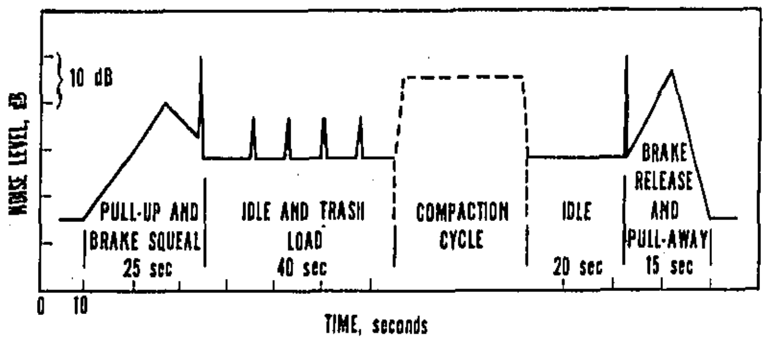


FIGURE 5-1

TYPICAL COLLECTION CYCLE NOISE LEVELS AT 7 M

Source: Reference 5-29.

Medium and heavy gasoline and diesel trucks (the type which carry trash compactors) have been recognized as major contributors to environmental noise (Ref. 5-8). The noise produced by these vehicles has been regulated to a not-to-exceed A-weighted level of 83 dB (based on the J336b test) effective in 1978 and to a level of 80 dB effective in 1980. A more stringent regulation may be promulgated at a later time. As these quieted trucks are introduced into the compactor-truck fleet, the noise associated with the collection cycle will decrease.

Table 5-2 presents an estimate, based on Reference 5-1, of the collection cycle noise levels produced by these quieted trucks. Table 5-2 also presents estimates for levels of truck noise reduction under the medium and heavy truck noise emission regulation (Ref. 5-1). The average values of truck noise used for the analysis in this report are calculated by summing the equivalent energy of each component in the cycle during pull-up, idle and pull-away phases (independent of the increased noise level during the compaction cycle).

Compactor Noise Per Collection Cycle

A summary of measurements of the noise emissions associated with the compaction cycles on 44 trucks (Ref. 5-2) is presented in Table 5-3. The measured sample was not intended to be representative of refuse compactors in general, but rather, measurements were made on available trucks. Since a relatively large number of quieted compactors were in the measured sample, the average sound levels were weighted according to the estimated percentage of quieted and conventional compactors in the total population of vehicles. For purposes of this analysis it is assumed that the measurement results presented in Table 5-3 are representative of average national values,

TABLE 5-2

ESTIMATED A-WEIGHTED SOUND LEVELS
AT 7m OF THE NON-COMPACTION
COMPONENTS OF THE COLLECTION CYCLE

Event	Duration (sec)	Regulated Truck Noise Level @ 15 m. dB U[a]	83	80
Pull-up	25	80	74	71
Brake Squeal	0.5	90	90	90
Idle while Loading	40	67	66	65
Trash Loading Impacts (4) (ea)	0.5	77	77	77
Compaction Cycle	(See Table 5-3)			
Idle	20	67	66	65
Brake Release	0.5	90	90	90
Pull-away	15	86	80	77
Average (not including compaction cycle)	100	77.2	72.8	71.2

Note:
U[a] = existing unquieted trucks

Source: Reference 5-29.

TABLE 5-3

WEIGHTED* AVERAGE NOISE LEVELS AT 7m OF EXISTING REFUSE COMPACTORS

Compactor Type	Continuous Noise: Maximum Sound Level dB		Continuous Noise: Compaction Cycle Time (seconds)		Continuous Noise: L_S**	Impact Noise: Sound Level dB		Impact Noise: L_S**
	Average	Range	Average	Range	Range	Average	Range	Range
Front-loader	82.7	73-87	34	20-55	88-100	91.9	75-98	85-97
Side-loader	75.8	71-77	32	8-75	84-95	83.4	78-84	79-80
Rear-loader	78.8	67-87	23	8-40	82-96	85.4	75-94	68-87

NOTES: * Sound levels are weighted according to number of quieted and conventional compactors in total population; compaction cycle times are not weighted.

** Calculated from $L_S = L_A + 10 \log (\text{duration})$
where L_S = Sound Exposure Level
and L_A is Sound Level

Source: Table 3-2.

although a number of large cities (e.g., New York and San Francisco) require the use of quieted trucks, and thus some densely populated urban areas may be subjected to compactor noise levels lower than those reported in Table 5-3. Independent measurements made by the EPA (Ref. 5-3) are in agreement with the average values listed in this report.

Table 5-3 includes measurement results obtained at 7 meters of the sound level (maximum continuous), the impact sound level, and the time over which these levels were attained during a compaction cycle. The total noise level of the compaction cycle used in this analysis includes both the steady-state and the impact sounds. EPA data indicate that the number of impacts during a cycle varies with the type of compactor. An average of 8 impacts was noted for each front-loader compaction, 2 for each side-loader and 5 for each rear-loader. Each impact noise is assumed to have a duration of 0.5 sec. The average noise level for compaction was calculated using:

$$L_{avg} = 10 \log \left[\left(1 - \frac{t_I}{t_c}\right)\left(10^{L_c/10}\right) + \left(\frac{t_I}{t_c}\right)\left(10^{L_I/10}\right)\right] \text{ dB} \qquad (5\text{-}1)$$

where

t_c = compaction time, in seconds, from Table 5-3,

t_I = impulse time = number of impulses x 0.5 seconds,

L_c = A-weighted sound pressure level, in decibels, of steady-state compaction, from Table 5-3,

L_I = A-weighted sound pressure level, in decibels, of impact noise, from Table 5-3.

Table 5-4 presents the results of these calculations for the three compactor types and defines the noise levels of existing compaction cycles.

TABLE 5-4

AVERAGE (A-WEIGHTED) NOISE LEVEL OF COMPACTION AT 7m PRODUCED BY DIFFERENT COMPACTOR TYPES

Compactor Type	Noise Level dB
Front-loader	85.4
Side-loader	76.4
Rear-loader	80.2

Average Collection Noise Levels Per Unit Area

Each compactor type generates a different noise level, and the mix of compactor types in each land-use category varies as presented in Table 5-5.

TABLE 5-5

AVERAGE PERCENT OF DIFFERENT TYPE COLLECTOR VEHICLES OPERATING PER DAY IN EACH LAND-USE CATEGORY.

	Collector Type		
Land Use	Front-Loader Percent	Side-Loader Percent	Rear-Loader Percent
Surburban Single-Family Detached	7.4	21.5	71.2
Suburban Duplexes	6.8	21.7	71.6
Urban Row Apartments	15.8	18.7	65.5
Dense Urban Apartments	19.4	17.5	63.1
Very Dense Urban Apartments	31.8	13.5	54.8

Source: Reference 5-29.

To simplify the health and welfare calculations, an average noise level per collection for each land-use type was calculated as follows:

(1) The truck noise level (Table 5-2) was energy-averaged with the compaction noise (Table 5-4) as:

$$L_{iL} = 10 \log \frac{1}{t_T + t_c}\left[\left(t_T\right)\left(10^{L_T/10}\right) + \left(t_c\right)\left(10^{L_C/10}\right)\right] \qquad (5\text{-}2)$$

where

L_{iL} = the noise level for each truck-compactor combination, in decibels,

L_T = truck noise level, from Table 5-2, in decibels,

t_T = duration of truck noise for the collection cycle (omitting compaction time) = 100 sec,

L_C = average noise level for each compactor type, from Table 5-4, in decibels,

t_C = compaction time from Table 5-3, in seconds.

(2) The noise level for each compactor type was multiplied by the use factor from Table 5-5, for a mix of truck types in a given area.

$$L_j = 10 \log\left[\left(f_{FL}\right)10^{L_{FL}/10} + \left(f_{SL}\right)10^{L_{SL}/10} + \left(f_{RL}\right)10^{L_{RL}/10}\right] \qquad (5\text{-}3)$$

Where

L_j = collection noise level in a given land use area,

f_{FL} = fraction of front-loaders in a given land-use area, from Table 5-5,

L_{FL} = noise level of front-loaders from Equation 5-2;

and the subscripts SL and RL refer to side-loaders and rear-loaders, respectively.

(3) 0.5 dB was added to the result to account for trash in the compactor.* The result is the average A-weighted sound pressure level produced by a single collection unaffected by reverberant build-up. The data are summarized in Table 5-8.

REFUSE COLLECTION NOISE ENVIRONMENT

Sound Propagation and Amplification

Since sound levels propagate spherically from the source in a free-field environment, the sound pressure level loss due to propagation varies inversely with the square of the distance between the noise source and a receiver. In other words, in the free-field environment the propagation loss is equivalent to 6 dB for each doubling of distance between the source and the receiver, i.e., a -6 dB/dd attenuation rate.

Trash compactor noise, however, does not occur in a free-field environment. Non-uniform attenuation rates have been developed to estimate the sound level attenuation in varying environments (Ref. 5-4). For this analysis, uniform attenuation rates providing an approximation to the non-uniform attenuation rates are used for each land use category. The uniform attenuation rates selected are -6dB/dd for the suburban single-family detached and suburban duplex dwelling categories, -6.5 dB/dd for urban row apartments, -8 dB/dd for dense urban apartments, and -8.5 dB/dd for very dense urban apartments. These attenuation rates apply to distances beyond 50 feet from the source. Up to 50 feet the rate of -6 dB/dd is used for all land use categories.

*The measurements all relate to empty compactors. A recent study (Reference 5-14) indicates that, on the average, there is about a 0.5 dB(A) difference between the load and no-load conditions.

A sound level at a given distance from a source located on an urban street may be considerably higher than the sound level at the same distance from the source in a free-field environment. This phenomenon is referred to as reverberation build-up and occurs because the walls of the buildings on each side of the street cause several multiple-reflection sound propagation paths between source and receiver.

In urban areas where the height of a flanking facade is nearly continuous and is greater than or comparable to the street width, there is a reverberant build-up of sound. Furthermore, there are shielding effects from different types of barriers or buildings on apparent source intensity. For a U-shaped space, which approximates an urban street, amplification factors may be estimated. These factors are dependent on the width of the space. For example, when building fronts are separated by 15 meters (49 feet) the amplification factor is estimated (with linear approximation) to be 2.2 dB. A 7.6 meter (25 feet) separation of building fronts is estimated (with linear approximation) to amplify sound at the source by 8 dB. Therefore, a sound source of 80 dB, referenced at 7 m free-field, would, on a 15 meter wide street, be amplified to 82.2 dB and on a 7.6 meter wide street (alley) to 88 dB (Ref. 5-4).

No data were found for the frequency of alley pickup versus street compactions, or on the relative distribution of alley and street widths between buildings in urban areas. A sample survey, therefore, was conducted in four metropolitan areas* to relate distance between building fronts to collection location for various population density categories. On the basis of this survey it is assumed that one-half of the compactions occur

*Los Angeles, Berkeley, Atlanta, Washington, D.C. Distances between building fronts were paced or estimated.

on streets wider than 24 meters and one-half on streets narrower than 24 meters where amplification may be a problem. In urban row apartment areas, 25 percent of the impact situations will be on steets less than 15 meters (36 feet) and 25 percent on streets less than 7.6 meters (25 feet). In the dense urban and very dense urban apartment areas compactions are assumed to occur 10 percent of the time in 4.5 meters (15 foot) wide alleys, 20 percent on 7.6 meters 25 foot) streets, and 20 percent of the time on 15.2 meters (50 foot) streets. Table 5-6 gives the percentage of collections estimated by the survey for different street widths and the amplification factor associated with that width.

TABLE 5-6

AMPLIFICATION FACTORS DUE TO REVERBERANT BUILDUP IN NARROW STREETS (GROUND REFLECTION IGNORED)

	Width Between Buildings[a] meters	Width Between Buildings[a] feet	Percent of Total Collections	Amplification Factor, dB
Urban Row Apartments	7.6	25	25	8.0
	15.2	50	25	2.2
	>24	>78	50	-1.6
Dense Urban Apartments	4.5	15	10	11.6
	7.6	25	20	8.0
	15.2	50	20	2.2
	>24	>78	50	-1.6
Very Dense Urban Apartments	4.5	15	10	11.6
	7.6	25	20	8.0
	15.2	50	20	2.2
	>24	>78	50	-1.6

[a] Assumes continuous building fronts

Source: Reference 5-29.

Since the apparent build-up in sound level is a function of the width between facing buildings, the technique described in Reference 5-4 was used to calculate the amplification and propagation factors for representative street widths. Adjustment factors of 11.6, 8.0, 2.2, and -1.6 dB added to the noise levels on streets 4.5 meters (15 feet), 7.6 meters (25 feet), 15 meters (49 feet) and 24 or more meters (>78 feet) wide respectively, best represented truck-mounted solid waste trash compactor activity in urban areas. These reverberant build-up factors were added to the noise levels associated with the collections occurring on various street widths in urban areas (see Table 5-6).

No reduction in noise level due to the shielding of a row of buildings between the source and the observer was considered for the suburban single-family detached and suburban duplex land-use categories. The typical collection noise levels in these areas are low enough that they will be insignificant on an adjoining street. For the denser dwelling areas, the barrier effect of a row of buildings is taken into account in the sound propagation (attenuation) rates.

Sound Attenuation Within Buildings

To estimate indoor noise levels from outside noise sources, the attenuation factor of building walls and windows must be calculated. Although dwelling walls attenuate sound, windows generally provide poor insulation from exterior noise. When windows are open the difference between indoor and outdoor noise varies from 8 to 25 dB; while with windows closed, the attenuation varies from 19 to 34 dB, and with double-glazed windows, noise may be reduced as much as 45 dB. Average differences between values for open window and closed window conditions are 15 dB and 25 dB respectively (Ref. 5-19).

The maximum, closed value is seldom achieved in older urban areas, for in these areas the noise reduction is governed by the minute cracks and spaces around the glass panels and the window and door frames. In this analysis an attenuation value of 15 dB will be used for the suburban single-family detached and the suburban duplex areas (assuming window open conditions), and a value of 20 dB will be used for the other dwelling areas to represent the attenuation of outdoor noise by the exterior shell of the house (assuming a mixture of windows open and closed). These attenuation factors represent an average between summer and winter, and new construction and old construction.

Consideration of Ambient Noise Levels

The preceding description of compactor noise ignores the contribution of background ambient noise, i.e., levels of noise due to all other conditions. To better assess the health and welfare impacts some assumptions must be made with respect to the ambient noise levels.

In a study relating population distributions in the U.S. and outdoor noise levels (Ref. 5-7), it was determined that day and night ambient levels can be represented as a function of population density as follows:

$$L_{AD} = 7.90 \times \log PD + 29.1 \qquad (5\text{-}4)$$
$$L_{AN} = 9.73 \times \log PD + 17.4 \qquad (5\text{-}5)$$

where

L_{AD} = ambient daytime equivalent sound level, in decibels
L_{AN} = ambient nighttime equivalent sound level, in decibels
PD = population density (people per square mile)

However, using the above formulae, the resulting ambient noise levels in all residential areas under consideration are significantly above the target ambient levels determined to be requisite to protect the public health and welfare. Therefore, for purposes of this analysis, where ambient levels exceed the minimum community noise level identified by EPA as protective of public health and welfare (L_{dn} = 55 dB) (Ref. 5-5), the ambient levels were set instead to a level of 1 dB under the identified level (L_{dn} = 54dB) under the assumption that ambient levels will, in the future, be lowered by coordinated Federal, state and local efforts to reduce noise, and to better reflect desires of states and municipalities for a quieter environment.

When the ambient noise level at a given location is taken into account, the function that describes the relation between the noise level at that location and the distance R of that location from the source is given by equation 5-6. This relation is used in computing the distances associated with each 1 dB decrease in the noise level. This portion of the analysis consists of defining the annular areas associated with each noise level value (in 1 dB increments) and "counting" the population within that area; the appropriate impact (as described later in this section) is associated with that noise level.

$$R = R_o \left[\frac{10^{L_o/10}}{10^{L_R/10} - 10^{L_{dn}^A/10}} \right]^{(3.01/d)} \qquad (5\text{-}6)$$

where

R = distance from source

R_o = reference noise source distance (7m)

L_o = L at 7m from source

L_R = L_{dn} at distance R from source

L_{dn}^A = ambient noise level

d = attenuation rate (6, 6.5, 8 or 8.5 depending on land use category)

NOISE METRICS

As discussed in the introduction of this section, two methods are used to evaluate the health and welfare benefits of reduced trash compactor noise emissions on the human population. The first method estimates the general adverse response due to trash collection cycle noise as a component of the overall noise in urban areas. The second method estimates the potential human activity interferences (sleep disturbances and speech communication interference) attributable to individual trash collection cycles.

Three primary noise metrics are used in the two methods. The primary measures of noise exposure for general annoyance are the equivalent A-weighted sound level (L_{eq}) and the day-night sound level (L_{dn}). Sleep disturbances are calculated using the Sound Exposure Level (L_S) of the individual event as the primary measure of noise impact. Speech interference is calculated using the L_{eq} of the individual event as the primary measure of noise impact. A brief description of these three noise metrics follows.

Equivalent Sound Level (L_{eq})

This analysis uses a noise measure that condenses the physical acoustic properties characteristic of a given noise environment into a simple indicator of the quality and quantity of noise. Moreover, this measure correlates quite well with the overall long term effects of environmental noise on public health and welfare. EPA has selected the equivalent A-weighted sound level in decibels, L_{eq}, as its general measure for environmental noise (Ref. 5-5 and 5-14).

The basic definition of L_{eq} is:

$$L_{eq} = 10 \log_{10} \left(\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p^2(t)}{p^2{}_0} \bullet dt \right) \qquad (5\text{-}7)$$

where $t_2 - t_1$ is the interval of time over which the levels are evaluated, p(t) is the time-varying magnitude of the sound pressure, and p_0 is a reference pressure standardized at 20 micropascals. When expressed in terms of A-weighted sound level, L_A, the equivalent A-weighted sound level, L_{eq}, is defined as:

$$L_{eq} = 10 \log_{10}\left(\frac{1}{t_2-t_1} \bullet \int_{t_1}^{t_2} \left[10^{L_A(t)/10}\right] \bullet dt\right) \qquad (5\text{-}8)$$

When associated with a specific short time interval, t_2-t_1, or T, the L_{eq} (T) represents the energy-averaged sound level over that interval of time. Commonly used time intervals are 24-hour, 8-hour, 1-hour, day and night, symbolized as L_{eq} (24), L_{eq} (8), L_{eq} (1), L_d and L_n, respectively.

Day-Night Sound Level (L_{dn})

In describing the impact of noise on people, the measure called the day-night sound level (L_{dn}) is used. This is a 24-hour measure with a weighting applied to nighttime noise levels to account for the increased sensitivity of people to intruding noise associated with the decrease in background noise levels at night. The L_{dn} is defined as the equivalent noise level during a 24-hour period, with a 10-dB weighting applied to the equivalent noise level during the nighttime hours of 10 p.m. to 7 a.m. The basic definition of L_{dn} in terms of the A-weighted sound level is:

$$L_{dn} = 10 \log_{10} \frac{1}{24} \left(\int_{0700}^{2200} 10^{L_A(t)/10}\, dt + \int_{2200}^{0700} 10^{(L_A(t)+10)/10}\, dt\right) \qquad (5\text{-}9)$$

This may also be expressed by the following equation:

$$L_{dn} = 10 \log_{10} \frac{1}{24} \left\{15 \left(10^{L_d/10}\right) + 9 \left[10^{(L_n+10)/10}\right]\right\} \qquad (5\text{-}10)$$

where L_d is the "daytime" equivalent level obtained between 7 a.m. (0700)

and 10 p.m. (2200), and L_n is the "nighttime" equivalent level obtained between 10 p.m. and 7 a.m.

The total day-night sound level, L_{dn}, including ambient levels and collection sound levels is calculated as follows:

$$L_{dn} = 10 \log \left[10^{L^C_{dn}/10} + 10^{L^A_{dn}/10} \right] \qquad (5\text{-}11)$$

where

L^C_{dn} = the collection sound level

L^A_{dn} = ambient noise levels.

Sound Exposure Level (L_S)

Most of the criteria which relate noise exposure to human impact deal with pervasive environmental noise rather than discrete noise events. Specification of the noise environment in terms of equivalent A-weighted sound level is adequate for pervasive noises. Single events, like a trash collection cycle, may contribute an insignificant amount to the total environmental noise, yet be of significant impact. Fortunately, some effects of noise on people have been quantified in terms of sound level over a particular duration. A simple metric which measures sound level, taking into account the duration of the event, is the Sound Exposure Level (L_S). The sound exposure level is the integral of the sound power per unit area received at a specified distance during a single occurrence of a noise producing event. The sound exposure level, in decibels, is defined as:

$$L_S = 10 \log \int_0^T \frac{p^2(t)}{p^2_0} \, dt \qquad (5\text{-}12)$$

where p(t) is the A-weighted sound pressure at time t, p_0 is the reference pressure (20 micropascals), and T is the duration of the noise event. For a rectangular pulse time history of approximately constant average sound level, L_A, such as a trash collection cycle, an approximation is:

$$L_S = L_{max} + 10 \log (T) \qquad (5\text{-}13)$$

where T is the time in seconds over which the sound is present and L_{max} is the maximum A-weighted sound level.

REFUSE COLLECTION NOISE LEVELS UNDER REGULATORY OPTIONS

Average Sound Level (L_A) for Collection Activity

The average life of a compactor is about 7 years (Ref. 5-6). Therefore, 1/7 of the compactor fleet is replaced each year.* It was assumed that manufacturers would design to a level 2 dB below the not-to-exceed level, to account for normal production variations. Using this assumption, the regulatory schemes presented in Table 5-1, the regulated truck noise levels of Table 5-2, and the noise metrics outlined in the preceding section, the average sound level, L_A, for each land use area to the year 2000 was calculated. The results of these calculations can be found in Exhibit 5-A at the end of this section.

Sound Exposure Levels for Collection Activity

Sound exposure levels were calculated for each component of truck collection noise shown in Table 5-2 and for compaction and impulse noise shown in Table 5-3. For steady-state noise pulses, Equation 5-13 was used. For triangular pulses, the sound exposure level was approximated by:

$$L_S = L_{max} + 10 \log(t/2) \qquad (5\text{-}14)$$

where L_{max} is the maximum sound level.

*Reference 5-6 reports that a compactor body may be remanufactured and placed on a new truck. This analysis assumes the remanufactured units meet the noise standards of new units.

An average collection cycle time containing a compaction (t_{avg}) for each land-use class was calculated. This average time changed as the mix of collector vehicles, each with different compaction times, changed. The average time of compaction for each compactor type is listed in Table 5-3, the average time of non-compacting truck noise during the collection cycle is given in Table 5-2, and the fraction of collections performed by each type of compactor in each land-use class in Table 5-5. The average collection time in each land use category was thus calculated as:

$$t_{avg} = \sum_i \left[(t_c \times f_c)_i \right] + t_T \qquad (5-15)$$

where

t_c = compaction time for a given compactor type, Table 5-3,

f_c = fraction of collections by a given compactor type in the land-use class being examined, Table 5-5,

t_T = non-compacting truck noise time, Table 5-2,

i = rear loader, side loader or front loader compactor type.

Average times for the complete collection cycle and components of the collection cycle are shown in Table 5-7.

TABLE 5-7

AVERAGE COLLECTION CYCLE
TIMES FOR VARIOUS LAND-USE AREAS

Land Use	Average Compaction Time (seconds)	Average Truck Sound Time (seconds)	Average Collection Cycle Time (seconds)
Suburban Single-Family Detached	25.8	100	125.8
Suburban Duplexes	25.7	100	125.7
Urban Row Apartments	26.4	100	126.4
Dense Urban Apartments	26.7	100	126.7
Very Dense Urban Apartments	27.7	100	127.7

The calculated sound exposure levels were combined in the same manner as the sound levels to produce sound exposure levels for the entire trash collection activity, including compaction. Table 5-8 presents the results of these calculations and describes the existing noise environment for a single compaction when compactors are unregulated. Exhibit 5-F at the end of this section contains sound exposure levels for each year and regulatory option.

TABLE 5-8

EXISTING AVERAGE A-WEIGHTED SOUND LEVELS AT 7 METERS FOR VARIOUS LAND-USE CATEGORIES (ADJUSTED FOR TRUCK MIX, TRASH NOISE AND REVERBERANT AMPLIFICATION)

Land Use Type	L_A (From Equations 5-2 and 5-3)	L_S	Propagation
Suburban Single-Family Detached	78.6	99.2	-6 dB/dd
Suburban Duplexes	78.6	99.2	-6 dB/dd
Urban Row Apartments	82.6	103.4	-6.5 dB/dd
Dense Urban Apartments	84.3	105.2	-8 dB/dd
Very Dense Urban Apartments	84.8	105.8	-8.5 dB/dd

The sound exposure level data are of concern primarily with respect to sleep disturbance effects discussed later in this section. The data listed in Table 5-8 give sound exposure levels for the collecting cycle times shown in Table 5-7. Although the published data upon which the sleep disturbance criteria are based do not extend beyond a 30-second duration, it is EPA's judgment that extrapolation up to the time periods used in this analysis is valid.

Equivalent Noise Level (L_{eq})

Similarly, the L_{eq} for a 24-hour period for each year of each option was calculated in the following manner:

1. The average collection cycle times listed in Table 5-7 were used.

2. The number of seconds per day the noise source operated in each hectare (ha) of land-use class for each year up to year 2000 was calculated. The average collection time was multiplied by the number of compactions per ha per day (Table 5-9) for each land-use class for each year. The number of total daily compactions for each year was taken from Table 5-10 which incorporates the yearly growth factor into daily compactions. The total daily collection times for the different land-use categories for selected years are listed in Table 5-11.

3. L_{eq} (with ambient noise) for each year and dwelling category was calculated as:

$$L_{eq} = 10 \log \left\{ \left[1 - \frac{t_s}{t_r}\right] 10^{L_{AMB}/10} + \left[\frac{t_s}{t_r} \; 10^{L/10}\right] \right\} dB \qquad (5\text{-}16)$$

where

t_s = time of source, from Step 2 above

t_r = reference time, 86,400 sec/day

L = A-weighted sound-pressure level from Table 5-7 and Exhibit 5-A.

The resulting 24-hour L_{eq} for each year of each option is given in Exhibit 5-B at the end of this section.

Day-Night Average Noise Levels (L_{dn})

Similarly, Exhibit 5-C gives the values of L_{dn} for the five dwelling categories to the year 2000. The values for L_d and L_n were calculated using Equation 5-10. The reference times were 54,000 sec for day and 32,400 sec for night and the data for the number of compactions occurring in the day and in the night were used from Table 5-10.

TABLE 5-9

DAY-NIGHT DISTRIBUTION OF AVERAGE COMPACTIONS PER HECTARE FOR 1976

Land Use	Front-Loader		Side-Loader		Rear-Loader		Total		
	Day	Night	Day	Night	Day	Night	Day	Night	Total
Suburban Single-Family Detached	0.0219	0.0003	0.6338	0.0009	0.2115	0.0029	0.2972	0.0041	0.3011
Suburban Duplexes	0.0541	0.0035	0.1734	0.0111	0.5725	0.0365	0.8000	0.0511	0.8510
Urban Row Apartments	0.2733	0.0849	0.3235	0.1005	1.1332	0.3520	1.7301	0.5374	2.2674
Dense Urban Apartments	0.6455	0.5817	0.5822	0.5247	2.0994	1.8919	3.3271	2.9982	6.3253
Very Dense Urban Apartments	2.6084	2.3505	1.1046	0.9954	4.4990	4.0549	8.2120	7.4009	15.6136

Source: Reference 5-29.

TABLE 5-10

PROJECTIONS OF AVERAGE SOLID WASTE TRUCK COMPACTIONS
PER HECTARE TO THE YEAR 2000

YEAR	Surburban Single-Family Detached (SSF)	Suburban Duplexes (SD)	Urban Row Apartments (UR)	Dense Urban Apartments (DU)	Very Dense Urban Apartments (VDU)
1976D	0.2972	0.8000	1.7301	3.3271	8.2128
1976N	0.0041	0.0511	0.5374	2.9982	7.4009
1976T	0.3013	0.8511	2.2675	6.3253	15.6137
1977D	0.3026	0.8145	1.7614	3.3873	8.3615
1977N	0.0042	0.0520	0.5471	3.0525	37.5349
1977T	0.3068	0.8665	2.3085	6.4398	15.8963
1978D	0.3081	0.8292	1.7933	3.4486	8.5128
1978N	0.0042	0.0530	0.5570	3.1077	7.6712
1978T	0.3123	0.8822	2.3503	6.5563	16.1840
1979D	0.3136	0.8442	1.8258	3.5111	8.6669
1979N	0.0043	0.0539	0.5671	3.1640	7.8101
1979T	0.3180	0.8982	2.3929	6.6750	16.4770
1980D	0.3175	0.8546	1.8482	3.5542	8.7735
1980N	0.0044	0.0546	0.5741	3.2029	7.9062
1980T	0.3219	0.9092	2.4223	6.7571	16.6796
1981D	0.3214	0.8651	1.8709	3.5980	8.8814
1981N	0.0044	0.0553	0.5811	3.2423	8.0034
1981T	0.3258	0.9204	2.4521	6.8402	16.8848
1982D	0.3253	0.8758	1.8940	3.6422	8.9906
1982N	0.0045	0.0559	0.5883	3.2822	8.1018
1982T	0.3298	0.9317	2.4823	6.9244	17.0925
1983D	0.3293	0.8865	1.9173	3.6870	9.1012
1983N	0.0045	0.0566	0.5955	3.3225	8.2015
1983T	0.3339	0.9432	2.5128	7.0095	17.3027
1984D	0.3334	0.8974	1.9408	3.7324	9.2132
1984N	0.0046	0.0573	0.6029	3.3634	8.3024
1984T	0.3380	0.9548	2.5437	7.0958	17.5155
1985D	0.3370	0.9071	1.9618	3.7727	9.3127
1985N	0.0046	0.0579	0.6094	3.3997	9.3920
1985T	0.3417	0.9651	2.5712	7.1724	17.7047
1986D	0.3406	0.9169	1.9830	3.8134	9.4132
1986N	0.0047	0.0586	0.6160	3.4364	8.4827
1986T	0.3453	0.9755	2.5989	7.2499	17.8959
1987D	0.3443	0.9268	2.0044	3.8546	9.5149
1987N	0.0048	0.0592	0.6226	3.4736	8.5743
1987T	0.3491	0.9860	2.6270	7.3281	18.0892

Source: Reference 5-29.

TABLE 5-10 (Continued)

YEAR	Surburban Single-Family Detached (SSF)	Suburban Duplexes (SD)	Urban Row Apartments (UR)	Dense Urban Apartments (DU)	Very Dense Urban Apartments (VDU)
1988D	0.3480	0.9368	2.0260	3.8962	9.6177
1988N	0.0048	0.0598	0.6293	3.5111	8.6669
1988T	0.3528	0.9967	2.6554	7.4073	18.2845
1989D	0.3518	0.9470	2.0479	3.9383	9.7215
1989N	0.0049	0.0605	0.6361	3.5490	8.7605
1989T	0.3567	1.0075	2.6841	7.4873	18.4820
1990D	0.3546	0.9546	2.0645	3.9702	9.8003
1990N	0.0049	0.0610	0.6413	3.5777	8.8314
1990T	0.3595	1.0156	2.7058	7.5479	18.6317
1991D	0.3575	0.9624	2.0812	4.0024	9.8797
1991N	0.0049	0.0615	0.6465	3.6067	8.9030
1991T	0.3625	1.0238	2.7277	7.6091	18.7826
1992D	0.3604	0.9702	2.0981	4.0348	9.9597
1992N	0.0050	0.0620	0.6517	3.6359	8.9751
1992T	0.3654	1.0321	2.7498	7.6707	18.9348
1993D	0.3633	0.9780	2.1151	4.0675	10.0404
1993N	0.0050	0.0625	0.6570	3.6654	9.0478
1993T	0.3683	1.0405	2.7721	7.7328	19.0882
1994D	0.3663	0.9859	2.1322	4.1004	10.1217
1994N	0.0051	0.0630	0.6623	3.6951	9.1211
1994T	0.3713	1.0489	2.7945	7.7955	19.2428
1995D	0.3688	0.9927	2.1469	4.1287	10.1915
1995N	0.0051	0.0634	0.6669	3.7206	9.1840
1995T	0.3739	1.0562	2.8138	7.8493	19.3755
1996D	0.3713	0.9996	2.1618	4.1572	10.2619
1996N	0.0051	0.0638	0.6715	3.7462	9.2474
1996T	0.3765	1.0634	2.8332	7.9034	19.5092
1997D	0.3739	1.0065	2.1767	4.1859	10.3327
1997N	0.0052	0.0643	0.6761	3.7721	9.3112
1997T	0.3791	1.0708	2.8528	7.9580	19.6438
1998D	0.3765	1.0134	2.1917	4.2148	10.4040
1998N	0.0052	0.0647	0.6808	3.7981	9.3754
1998T	0.3817	1.0782	2.8725	8.0129	19.7794
1999D	0.3791	1.0204	2.2068	4.2438	10.4757
1999N	0.0052	0.0652	0.6855	3.8243	9.4401
1999T	0.3843	1.0856	2.8923	8.0682	19.9159
2000D	0.3817	1.0275	2.2220	4.2731	10.5480
2000N	0.0053	0.0656	0.6902	3.8507	9.5053
2000T	0.3870	1.0931	2.9122	8.1238	20.0533

TABLE 5-11

PROJECTIONS OF DAILY COLLECTION TIMES (IN SECONDS) PER HECTARE
FOR SELECTED YEARS TO THE YEAR 2000

Year	Suburban Single-Family Detached	Suburban Duplexes	Urban Row Apartments	Dense Urban Apartments	Very Dense Urban Apartments
1976	37.9	107.0	286.6	801.4	1993.9
1980	40.5	114.3	291.8	856.1	2130.0
1985	43.0	121.3	306.2	908.74	2260.9
1990	45.2	127.7	342.0	956.3	2379.3
1995	47.0	132.8	355.7	994.5	2474.3
2000	48.6	138.0	368.1	1029.3	2560.8

Source: Table 5-10 and Table 5-8.

The minimum value of L_{dn} is attained at the time that the entire fleet is composed of trucks quieted by the regulation. After this date, the values of L_{dn} rise, reflecting the growth rate of the refuse collection activity.

The results of L_{dn} calculations when ambient noise is considered are presented in Exhibit 5-D at the end of this section.

IMPACT OF REDUCTION OF REFUSE COLLECTION NOISE - GENERAL ADVERSE RESPONSE

In order to project the potential benefits of reducing the noise of refuse collection vehicles, it is necessary to statistically describe the noise exposed population (on a national basis) both before and after implementation of the regulation. The statistical description characterizes the noise exposure distribution of the population by estimating the number of people exposed to different magnitudes of noise as defined by metrics such as day-night sound level. This is conceptually illustrated in Figure B-1 of Appendix B, which compares the estimated distribution of the noise exposed population before and after implementation of a hypothetical regulation. This type of approach provides a basis for evaluating the change in noise impact due to the regulation.

It is also necessary to distinguish, in a quantitative manner, between the differing magnitudes of impact upon different individuals exposed to different values of L_{dn}. That is, the magnitude of human response to noise generally inceases progressively from an identified "no response" threshold to some extreme maximum projected impact -- the greater the exposure, the more extreme the response. Hence, once the identified level is exceeded, the degreee of human response associated with the noise will increase with increased noise exposure.

EPA has adopted a procedure, based on recommendations of the National Academy of Sciences Committee on Hearing, Bioacoustics and Biomechanics (CHABA), that permits the assessment of environmental noise impact by mathematically taking into account both extent and intensity of impact (Ref. 5-21) (See Appendix B). This procedure, the fractional impact method, computes total noise impact by simply counting the number of people exposed to noise at different levels and statistically weighting each person by the intensity of response to the noise exposure. The result is a single number value which represents the overall magnitude of the impact.

To assess the impact of trash collection activity noise using the fractional impact procedure, a relation between the changes in collection noise and the responses of the people exposed to the noise is required. Human responses may vary depending upon previous exposure, age, socioeconomic status, political cohesiveness, and other social variables. In the aggregate, however, for residential locations, the average response of groups of people is related to cumulative noise exposure as expressed in a measure such as L_{dn}. For example, the different forms of response to noise, such as hearing damage, speech or other activity interference, and annoyance, were related to L_{eq} and L_{dn} in the EPA Levels Document (Ref. 5-5). For the purposes of this part of the analysis, criteria based on L_{dn} presented in the EPA Levels Document are used. Furthermore, it is assumed that if the outdoor level of L_{dn} is less than or equal to 55 dB (which is identified in the EPA Levels Document as requisite to protect public health and welfare), no adverse impact in terms of general annoyance and adverse community response exists.

The community reaction and annoyance data contained in Appendix D of the Levels Document (Ref. 5-5) show that the expected reaction to an identifiable source of intruding noise changes from "none" when the day-night average sound level of the intruding noise is 5 dB below the level existing without the presence of the intruding noise to "vigorous" when the intruding noise is 20 dB above the level before intrusion. For this reason, a level which is 20 dB above L_{dn} = 55 dB is considered to result in a near maximum impact on the people exposed. Such a change in level would increase the percentage of the population that is "highly annoyed" by noise to 35-40 percent of the total exposed population. Further, the data in the Levels Document suggest that for environmental noise levels which are intermediate between 0 and 20 dB above L_{dn} = 55 dB, the impact varies linearly. That is, a 5 dB excess (L_{dn} = 60 dB) constitutes a 25 percent impact, and a 10 dB excess (L_{dn} = 65 dB) constitutes a 50 percent impact.

For convenience of calculation, a function for weighting the magnitude of noise impact with respect to general adverse reaction (annoyance) has been used. This function, normalized to unity at L_{dn} = 75 dB, may be expressed as representing percentages of impact in accordance with the following equation (see Appendix B):

$$W(L_{dn}) = \begin{cases} 0.05\ (L_{dn} - C) & \text{for } L_{dn} \geq C \\ 0 & \text{for } L_{dn} < C \end{cases} \qquad (5\text{-}17)$$

where $W(L_{dn})$ is the weighting function for general adverse response, L_{dn} is the measured or calculated community noise level, and C is the identified threshold below which the public is not at risk (L_{dn} = 55 dB).

A recent compilation of 18 social surveys from 9 countries (Ref. 5-21 and 5-22) shows, in fact, that the response curve relating "percent highly annoyed" to the noise measured around respondents' homes is best represented by a curvilinear function. However, it has also been shown that the single linear function can be used with good accuracy in cases where day-night sound levels range between L_{dn} values of 55 dB to 80 dB.

Using the derived relationship between community noise exposure and general adverse response (Equation 5-17), the Level-Weighted Population (LWP)* associated with a given level of trash collection noise (L^i_{dn}) may be obtained by multiplying the number of people exposed to that level of noise by the relative weighting associated with that level as follows:

$$LWP_i = W(L^i_{dn})\ P_i \qquad (5\text{-}18)$$

where LWP_i is the magnitude of the impact on the population exposed to trash collection noise L^i_{dn} and is numerically equal to the number of people who would all have a fractional impact equal to unity (100 percent). $W(L^i_{dn})$ is the weighting associated with a day-night sound level of L^i_{dn}, and P_i is the population exposed to that level of noise. To illustrate this concept, if there are 1000 people living in an area where the noise level exceeds the identified threshold level by 5 dB (and thus are considered to be 25 percent impacted, $W(L_{dn}) = 0.25$), the environmental noise impact for this group is the same as the impact on 250 people who are 100 percent impacted (1000 x 25% = 250 x 100%). A conceptual example is portrayed in Figure 5-2.

When assessing the total impact associated with trash collection noise, the observed levels of noise decrease as the distance between the source and receiver increase. The magnitude of the total impact may be computed by determining the partial impact at each level and summing over each of the levels. The total impact is given in terms of Level Weighted Population by the following formula:

$$LWP = \sum_i LWP_i = \sum_i W(L^i_{dn})\ P_i \qquad (5\text{-}19)$$

where $W(L^i_{dn})$ is the fractional weighting associated with L^i_{dn} and P_i is the population exposed at each L^i_{dn}.

The change in impact associated with actions leading to reduced noise emissions from trash compactor vehicles may be assessed by comparing the magnitude of the

*Other terms such as Equivalent Population (Peq) and Equivalent Noise Impact (ENI) are used interchangably with LWP.

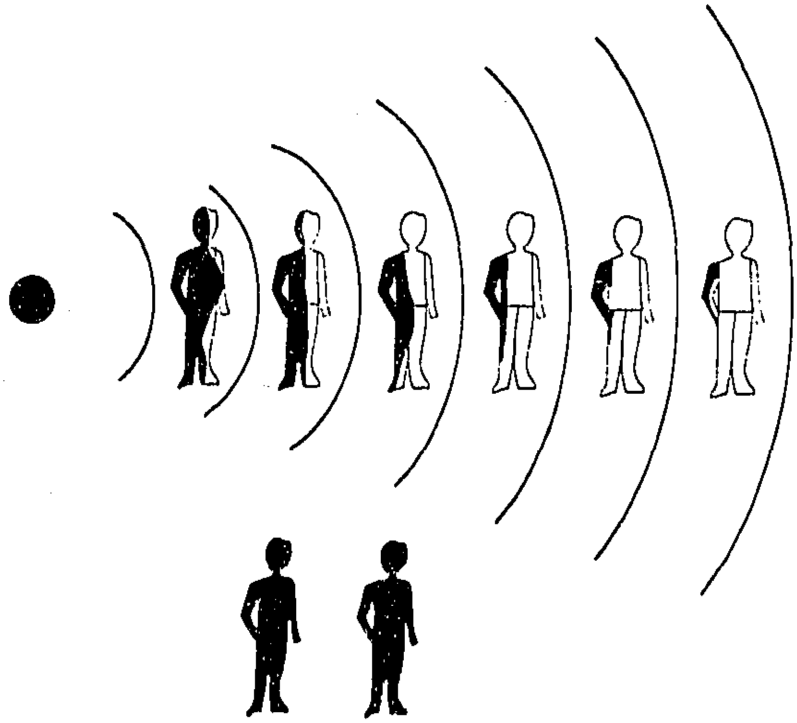


FIGURE 5-2

LEVEL WEIGHTED POPULATION: A METHOD TO ACCOUNT FOR THE EXTENT AND SEVERITY OF NOISE IMPACT

The computation of LWP allows one to combine the number of people jeopardized by noise above an L_{dn} of 55 dB with the degree of impact at different noise levels. The circle is a source which emits noise to a populated area. The various partial amounts of shading represent various degrees of partial impact by the noise. The partial impacts are summed to give the LWP. In this example, 6 people who are adversely affected by the noise (partially shaded) results in a Level Weighted Population (LWP) of 2 (totally shaded).

impacts, both before and after implementation of noise reduction measures, in terms of the Relative Change in Impact (RCI), which is calculated from the following expression:

$$RCI = 100 \frac{[LWP\ (before) - LWP\ (after)]}{LWP\ (before)} \qquad (5\text{-}20)$$

This basic fractional impact procedure may be used to compute noise impact using a variety of additional criteria (e.g., activity interference, hearing damage risk, etc.) other than general adverse response (Ref. 5-30).

RESULTS OF ANALYSIS

While the exact value of present or future LWPs may not be known precisely, the relative reductions of the LWP due to noise regulations - of primary interest here - are known with much greater accuracy than the absolute value of the LWP since the changes in the theoretical components of LWP can be well defined. For instance, it may not be possible to determine whether the present estimated LWP due to noise from trash collection activity, an absolute value, is actually 0.1 million too high. However, it is possible to determine, for example, that the regulation of rear loading truck-mounted trash compactors will not reduce the LWP by more than 0.1 million. Extensive investigation of such small changes may seem unnecessary if it is not kept in mind that, although truck-mounted solid waste compactors represent only a small part of urban activity in the United States, their impacts may be considerable when measured by metrics other than LWP. Thus, the changes found to occur in LWP may help indicate what equivalent changes would occur in impact measures which are not used in this analysis but whose absolute values may reflect more accurately the effects of compactor noise on people.

As discussed above, the concept of fractional impact, expressed in units of LWP and RCI, is most useful for describing relative changes in impact from a specified baseline for the purpose of comparing benefits of alternative regulatory schedules. In order to assess the absolute impact or benefits corresponding to any regulatory schedule, information on the distribution of population as a function of noise environment is required. This information is included in this section in the form of tables showing the number of people exposed to different levels of compactor noise. The anticipated absolute impact of noise upon those individuals exposed to any given noise level may be traced by referring to the various noise effects criteria presented in the Levels Document as well as in this analysis.

The resulting noise impact, in terms of LWP, for each land use area is calculated (taking ambient into account) for each regulation schedule and study year by applying the noise reduction of new trucks in combination with lessened emissions from the compactor unit. A summary of the results of this analysis for general adverse response (annoyance) is displayed in Table 5-12. Also included in Table 5-12 is the year by year percentage benefit in extent and severity of impact relative to the impact in 1976. Tabulated complete results of LWP and RCI are presented in Exhibit 5-E at the end of this section.

Table 5-12 shows that up to a 30% reduction in the extent and severity of noise impact (a reduction in LWP of about 630,000) from refuse collection noise will occur in 1991 because of the truck (chassis) noise regulation, without a compactor regulation. The regulatory schedules under consideration for refuse collection vehicles are anticipated to result in up to a 75 percent benefit (Options 5 and 7) over the 1976 (base year) case (a reduction in LWP of about 1,570,000). Likewise in 1991, Options 5 and 7 show a 64% reduction in noise impact over and above that achieved by reduction of truck chassis noise alone (a reduction in LWP of about 940,000). Benefits

TABLE 5-12

LEVEL WEIGHTED POPULATION IMPACTED (LWP) (in millions)
AND PERCENTAGE BENEFIT (RCI)
(Taking ambient into account, from Exhibit 5-D)

		Options					
		Base	One	Three	Five	Seven	Silent
1976	Total	2.11	2.11	2.11	2.11	2.11	2.11
	RCI	0.0	0.0	0.0	0.0	0.0	0.0
	RCI*	0.0	0.0	0.0	0.0	0.0	0.0
1982	Total	1.71	1.44	1.62	1.60	1.40	1.31
	RCI	19.0	31.7	23.1	24.4	33.5	38.0
	RCI*	0.0	15.8	5.2	6.4	18.1	24.0
1991	Total	1.48	.54	.77	.54	.54	.38
	RCI	30.0	74.5	63.4	74.5	74.5	82.2
	RCI*	0.0	63.5	48.0	63.5	63.5	74.3
2000	Total	1.57	.58	.82	.58	.58	.40
	RCI	25.5	72.7	61.0	72.7	72.7	80.9
	RCI*	0.0	63.0	47.8	63.0	63.0	74.5

RCI: Percentage reduction in impact from base year (1976).

RCI*: Percentage reduction in impact from base option. Base option includes benefits from medium and heavy truck regulation.

appear to lessen (i.e., more impact) relative to the 1976 case beyond the year 1991 due to the projected increase in collection activity and population exposed.

To further illustrate the benefits and relief afforded the population by reducing new trash compactor noise levels, Tables 5-13 and 5-14 are presented. In Table 5-13, the number of people exposed to L_{dn} above 55 dB, in 5-dB increments, for the existing noise level and the 1991 maximum quieted level for each option is shown. Table 5-14 is presented as an example to show that the impact is not uniform over the entire population. Note that the noise impact is confined primarily to dense urban areas.

TABLE 5-13

NUMBER OF PEOPLE EXPOSED TO L_{dn} (in millions)
(Taking ambient into account)

L_{dn}	Baseline 1976	1991 Option					
		Base	One	Three	Five	Seven	Silent
55-60	17.36	12.66	5.50	7.41	5.50	5.50	4.10
61-65	1.77	1.20	0.46	0.59	0.46	0.46	0.33
66-70	0.45	0.32	0.05	0.12	0.05	0.05	0.02
>70	0.09	0.03	-	-	-	-	-
Total	19.67	14.21	6.01	8.12	6.01	6.01	4.45

TABLE 5-14

POPULATION EXPOSED TO TMSWC NOISE (in millions)
(Taking ambient into account)

Type of Area	L_{dn}	1976 Baseline	1991 Baseline	1991 Option 7	1991 Silent
Single Family	-	0.0	0.0	0.0	0.0
Suburban Duplex	-	0.0	0.0	0.0	0.0
Urban Row	55-60	6.82	4.66	1.82	1.24
	61-65	0.46	0.20	-	-
Dense Urban	55-60	8.34	6.23	2.92	2.26
	61-65	1.02	0.76	0.36	0.25
	66-70	0.34	0.24	0.02	-
	>70	0.05	-	-	-
Very Dense Urban	55-60	2.20	1.77	0.76	0.60
	61-65	0.29	0.24	0.10	0.08
	66-70	0.11	0.08	0.03	0.02
	>70	0.04	0.03	-	-
Total All Areas	55	19.67	14.21	6.01	4.45

REDUCTION OF NOISE IMPACT OF INDIVIDUAL TRASH COLLECTION EVENTS

To this point, the analysis of truck-mounted trash compactor noise impact has been concerned with the contribution that compactors make to average day-night urban noise (L_{dn}). The impact contributions, which are calculated in this way, are somewhat generalized and do not necessarily represent specific impact situations. On some occasions, noise associated with trash collection activity will be completely masked out by other noises, making the conclusions reached by using L_{dn} essentially correct. At other times or in other situations, one can expect that other noise sources will not mask trash collection noise, and thus trash compactors will cause a finite impact. The actual impact from trash compactors is certainly due to a combination of various levels of trash collection noise and other environmental noise. Thus, the preceding analysis does not reflect the fact that almost the entire amount of daily acoustical energy contributed by trash compactors in an area may be generated in only a few minutes of noise during trash collection activity. Yet this intrusive, short, intense event may be one of the most annoying noise-related situations faced over the entire day by a large number of residents. Admittedly, such annoyance is a difficult reaction to measure. It may pass rapidly and the actual cause may remain unnoticed. Or it may add to other agents causing stress and lead to physiological problems (Ref. 5-14 and 5-15).

A loud, short-duration noise event may also interrupt people's activities, such as conversation or sleeping. The interruptions may again lead to annoyance, but in themselves they may represent a degradation of health and welfare. For instance, in a recent study of the annoyance caused by different levels of simulated aircraft noise for people seated indoors watching television, annoyance was seen to be mediated, at least in part, by speech interference. Not only is the TV program or other person speaking more difficult to hear during the time in which there is a noisy event, but it has been observed that the distraction which may occur from the conversation in which the person is engaged may contribute in itself to annoyance (Ref. 5-9). The speaker may behaviorally attempt to cope with the noise intrusion either by increasing his or her vocal effort, or in more severe cases, by discontinuing conversation altogether. Such behavioral reactions may be quite indicative of general annoyance and disturbance with the intrusive noise event. Similarly, the reaction to a noise intrusion during sleep may be, in many cases, difficulty in falling asleep, a change in sleep stage (from "deeper" to "lighter" stage) or, if the intrusive noise is intense or long enough, an actual awakening. In either case, repeated disturbance of people's activities may be expected to adversely affect their well-being (Ref. 5-24 and 5-25). Covariance of verbalized annoyance with the interference of activities has been amply demonstrated in many social surveys (Ref. 5-5, 5-12, 5-16, 5-17, 5-18, 5-23, 5-26). In fact, one recent survey (Ref. 5-23) found respondent indications of interference with sleep and speech communication to correlate more highly with feelings of generalized annoyance than with any other factor, including actual sound levels measured outdoors.

For these reasons it seems appropriate for an analysis of noise impact to examine in some detail the importance of individual event exposures upon human activities (Ref. 5-27 and 5-28), in particular, the activities of speech communication and sleep. Such an analysis was undertaken both in order to determine the direct effect trash compactor noise may have on these activities, as well as to aid in an estimation of the total annoyance attributable to the noise. These single event noise intrusions become particularly important in light of other regulations and efforts to reduce the noise from other urban noise sources, i.e., without a reduction in emissions from trash compactors, these units may very well stand out as one of the most intrusive noise sources.

Sleep Disturbance

The sleep periods of humans are typically classified into five stages. In Stages I and II sleep is light and the sleeper can be easily awakened. Stages III and IV are states of deep sleep where a person is not as easily awakened by a given noise, but the sleep may shift to a lighter stage of sleep. An additional stage is termed REM (rapid eye movement) and corresponds to the dream state. When exposed to an intrusive noise, a sleeper may (1) show response by a brief change in brainwave pattern, without shifting sleep stages; (2) shift to a lighter sleep stage; or (3) awaken. The greatest known impact occurs due to awakening, but there are also indications that disruption of the sleep cycle causes impact (irritability, etc.) even though the sleeper may not awaken (Ref. 5-14).

A recent study (Ref. 5-10 and 5-11) has summarized and analyzed sleep disturbance data. This study demonstrated a relationship between frequency of response (disturbance or awakening) and noise level of a stimulus, and further determined as well that the duration of the noise stimulus is a critical parameter in predicting response. The study also showed that the frequency of sleep disruption is predicted by noise exposure better than is arousal or behavioral awakening. It is important to note that sleep disturbance is defined as any physiological change which occurs as a result of a stimulus. The person undergoing such disturbance may be completely unaware of being affected; however, the disturbance may disrupt the total sleep quality and thus lead to, in certain situations, behavioral or physiological consequences (Ref. 5-14).

To determine the magnitude of sleep disturbance caused by trash compactors, some consideration must be made of the hours of trash collection activity. Table 5-15 shows the percentage of day, evening and nighttime collections used for this analysis. Although some fraction of the population sleeps during the day, it is assumed for this analysis that sleep occurs only during nighttime hours. Therefore, only the fraction of total refuse collection activity that occurs during nighttime hours is applicable.

To determine the impact of trash collection noise on sleep and the reduction in sleep disturbance achievable with noise emission regulations for compactor trucks, the following steps were followed:

Step 1. Average sound exposure levels at 7 meters were computed for all collector truck types (rear, front and side loaders). These data are presented in Exhibit 5-F at the end of this section.

Step 2. The distances from the compactor operation at which the noise levels from Step 1 decreased in 1 dB intervals were calculated. Propagation laws employed for each land use area were discussed previously in this Section.

Step 3. The number of people living in each 1 dB band was calculated by multiplying the population density within each land use area in which trash collection activity takes place by the area of the 1 dB bands (calculated in Step 2). This is then multiplied by

TABLE 5-15

PERCENTAGES OF TOTAL REFUSE COLLECTIONS

		Daytime Collection 6:00 am - 6:00 pm		Evening Collection 6:00 pm - 10:00 pm		Nighttime Collection 10:00 pm - 6:00 am	
Land Use Category	1976 Population (millions)	% of Collections	Population Involved (millions)	% of Collections	Population Involved (millions)	% of Collections	Population Involved (millions)
Wilderness	2	NA	NA	NA	NA	NA	NA
Rural	57.0	100	57.0	0	-	-	0
Suburban Single-Family Detached	106.1	98	103.9	0.7	0.7	1.4	1.5
Suburban Duplexes	17.4	91	15.8	3.0	0.5	6.0	1.1
Urban Row Apartments	22.2	64.5	14.3	11.8	2.6	23.7	5.3
Dense Urban Apartments	12.0	28.9	3.5	23.7	2.8	47.4	5.7
Very Dense Urban Apartments	2.0	28.9	0.6	23.7	0.5	47.4	0.9

Source: Reference 5-29.

the number of trash collections within the given land uses. (The number of trash collections by land use area is presented in Table 5-10.)

Step 4. The average sleep impact is calculated for each of the 1 dB bands. The impact, expressed as a fraction, is found from functions that relate sleep disturbances to sound exposure level (Figure 5-3 for disruption and Figure 5-4 for awakening). This procedure is analogous to the fractional impact method used for calculating LWP for general adverse response.

Step 5. The relative total impact is computed in each band by multiplying the number of people living in each band (from Step 3) by the associated fractional impact (from Step 4).

To determine the resulting sound exposure level inside the home, transmission losses were applied to the propagated noise levels, depending on land use as discussed previously in this section.

The function relating the disruption of sleep by noise is given in Figure 5-3 where the frequency of sleep disturbance (as measured by changes in sleep stage, including behavioral awakening) is plotted as a function of the sound exposure level of the intruding noise. It also should be noted that, in the calculations of the impact of trash collection noise, the analysis arbitrarily ignored impact contributions below L_S = 55 dB indoors. This cut-off was selected to account for the continuous presence of low, nighttime ambient noise levels indoors, on the order of 40 - 45 dB.

The frequency of behavioral awakening as a function of sound exposure level is shown in Figure 5-4. The relationships, displayed in Figures 5-3 and 5-4, adapted from Figures 1 and 2 of Reference 5-10, consist of data derived

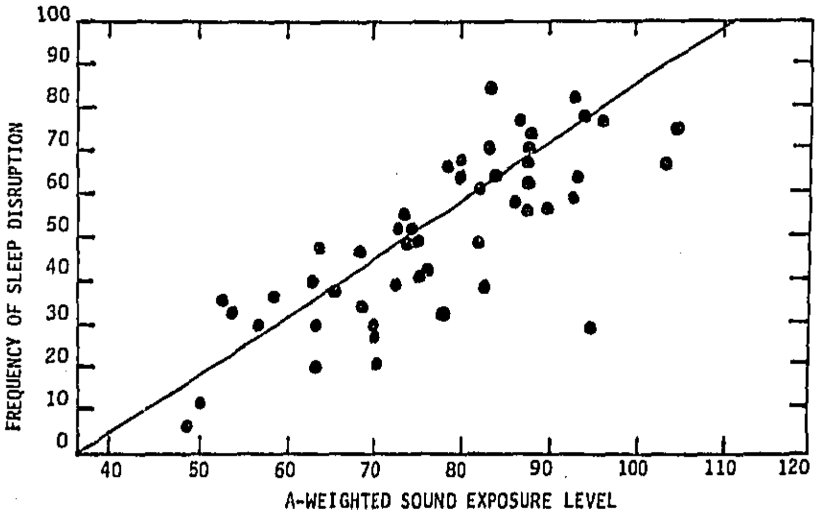


FIGURE 5-3

PROBABILITY OF A NOISE INDUCED SLEEP STAGE CHANGE

Source: Reference 5-10, updated.

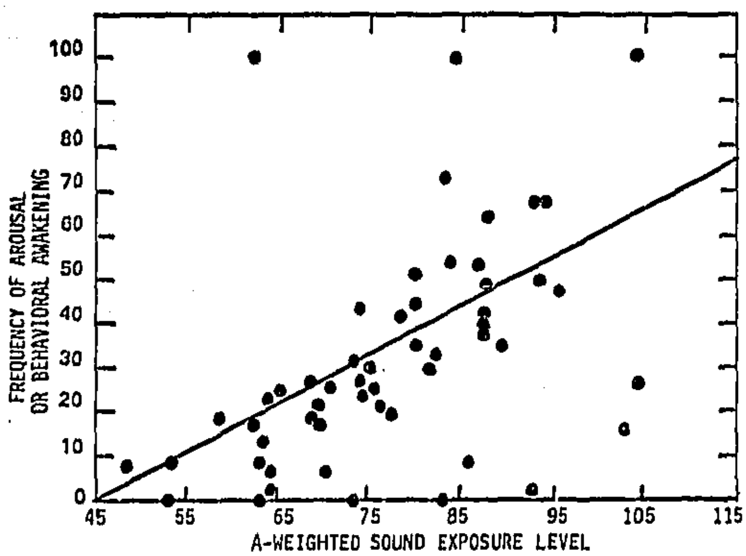


FIGURE 5-4

PROBABILITY OF A NOISE INDUCED AWAKENING

Source: Reference 5-10, updated.

from a review of most of the recent experimental sleep data and noise relationships. The curves of Figures 5-3 and 5-4 have been modified slightly from those contained in References 5-10 and 5-11.* The regression equations used are:

$$Y = 1.35x - 50, \text{ for sleep disturbance, and} \quad (5\text{-}21)$$
$$Y = 1.10x - 49.5, \text{ for sleep awakening.}$$

The functions (y) indicate the approximate degree of impact (percent disruption or awakening) as a function of noise level derived from the indoor Sound Exposure Level (x). Furthermore, the noise data contained within these references were measured in terms of "effective perceived noise level" with a reference duration of 0.5 second $\left(L_{EPNL(0.5\ sec)}\right)$. This measure was converted to L_S by the following approximate relationship:

$$L_S = L_{EPNL(0.5\ sec.)} - 16\ dB \quad (5\text{-}22)$$

The LWP for sleep disturbance and awakening was derived for each of the regulatory schedules and study years under investigation using equation 5-18, substituting L_S for L_{dn}. The weighting functions for sleep disturbance and sleep awakening are based on Figures 5-3 and 5-4, modified as follows:

The probability of disruption was a compound probability which accounted for the number of nightly compactions in each area.** The compound probabilities were calculated as:

$$p_a^i = 1 - [(p_{na}^i)C] \quad (5\text{-}23)$$

*Personal Communication, J. S. Lukas, July, 1976.

**For example, if the probability of awakening is 0.34 for a single event it is 0.56 for two events and 0.71 for three. Compound probability applies here, as each noise event is considered to be independent of the other events in terms of its probability of disrupting sleep, and the number of individual noise events per unit area could be derived.

where

p_a^i = probability of sleep disruption at L_S^i

p_{na}^i = probability of no disruption = $1 - [(L_S^i - 37)\ (.0135)]$

C = compactions per night per hour from Table 5-15

L_S^i = sound exposure level in the i^{th} increment.

The probability factor was multiplied by the population contained in the 1 dB band and the sum of the bands resulted in the number of equivalent people per night with a probability of 1.0 of having sleep physiologically disrupted.

The probability of an awakening was computed in the same manner as the probability of disruption except that the probability of no awakening used the following basic equation:

$$p_{na}^i = 1 - [(L^i - 45)\ (.011)] \qquad (5\text{-}24)$$

Table 5-16 shows the sleep disturbances (LWP) for each option and the percent reduction in impact accomplished by each regulation with reference to the no regulation case for selected years. A complete listing of the results is provided in Exhibit 5-G at the end of this section.

Table 5-17 shows the LWP for sleep awakening and the percent reduction in awakening-related impacts accomplished by each regulation with reference to the no regulation case for selected years. A complete listing is presented in Exhibit 5-H at the end of this section.

In order to explain more fully the contents of Tables 5-16 and 5-17, an example follows. In Table 5-17, by consulting the year 1991 row, it is found that for regulatory options 3 and 7 the potential sleep awakening,

TABLE 5-16

SLEEP DISTURBANCES LWP
(LWP in millions; RCI percentage benefits)

		Options					
		Base	One	Three	Five	Seven	Silent
1976	Total	13.85	13.85	13.85	13.85	13.85	13.85
	RCI	0.0	0.0	0.0	0.0	0.0	0.0
	RCI*	0.0	0.0	0.0	0.0	0.0	0.0
1982	Total	11.41	9.59	10.83	10.66	9.36	8.75
	RCI	17.6	30.8	21.8	23.0	32.4	36.8
	RCI*	0.0	16.0	5.2	6.7	18.0	23.3
1991	Total	9.49	2.84	7.48	2.84	2.84	1.57
	RCI	31.5	79.5	67.6	79.5	79.5	88.7
	RCI*	0.0	70.1	52.8	70.1	70.1	83.5
2000	Total	10.01	2.99	4.73	2.99	2.99	1.66
	RCI	27.7	78.4	65.9	78.4	78.4	88.1
	RCI*	0.0	70.1	52.7	70.1	70.1	83.4

RCI: Percentage reduction in impact from base year (1976).

RCI*: Percentage reduction in impact from base option. Base option includes benefits from medium and heavy truck regulation.

TABLE 5-17

SLEEP AWAKENING LWP
(LWP in millions; RCI percentage benefits)

		Options					
		Base	One	Three	Five	Seven	Silent
1976	Total	11.5	11.5	11.5	11.5	11.5	11.5
	RCI	0.0	0.0	0.0	0.0	0.0	0.0
	RCI*	0.0	0.0	0.0	0.0	0.0	0.0
1982	Total	9.51	7.99	9.02	8.88	7.80	7.29
	RCI	17.3	30.6	21.6	22.8	32.2	36.6
	RCI*	0.0	16.0	5.1	6.6	18.0	23.3
1991	Total	7.94	2.37	3.74	2.37	2.37	1.31
	RCI	31.0	79.4	67.5	79.4	79.4	88.6
	RCI*	0.0	70.1	52.8	70.1	70.1	83.5
2000	Total	8.38	2.50	3.96	2.50	2.50	1.38
	RCI	27.1	78.2	65.6	78.2	78.2	88.0
	RCI*	0.0	70.1	52.7	70.1	70.1	83.5

RCI: Percentage reduction in impact from base year (1976).

RCI*: Percentage reduction in impact from base option. Base option includes benefits from medium and heavy truck regulation.

LWP (measure of the extent and severity of the impact) due to trash collection noise is reduced to 3.74 million per night and 2.37 million per night, respectively. Therefore, the relative difference in LWP between the options is 1.37 million. Examining the percent reduction in extent and severity of impact, we find that the 3.74 LWP value translates to 67.5 percent reduction in impact relative to the 1976 case prior to regulation. Likewise, the 2.37 million LWP value translates to a 79.4 reduction relative to 1976. However, relative to the year 2000 base case (where only truck chassis noise is reduced), the benefits for options 3 and 7 translate to only 52.8 percent and 70.1 percent, respectively.

As was the case for the analysis of general adverse response, Options 5 and 7 show the greatest benefits. Benefits are reduced slightly beyond 1991 due to projected increases in refuse collection activities and population growth.

It should be noted that this analysis examines the effects of reducing trash collection noise alone, and does not take into account the presence of other noise sources in the environment. It is obvious that other environmental noise sources create background noise over which, in many situations, trash collection noise will not intrude. The benefits presented in this analysis represent the benefits accrued during those times when the collection activity noise clearly intrudes over an ambient background. The absolute sleep impact attributable to trash collection noise is, of course, dependent on the background ambient levels characteristic of the environments where trash collection vehicles are operating. However, the relative benefits stated (in terms of percent reduction in impact) are representative of the relative reductions of trash collection noise over any given ambient level.

Speech Communication Interference

As is the case with sleep disruption, speech interference occurs as a result of individual noise events. The potential for speech interference (i.e., the interruption of conversation) due to trash collection activity occurs when externally-propagating collection noise exceeds certain levels. However, unlike sleep disruption, the impact of noise on speech interference is not cumulative. That is, the duration of the noise event causing speech interference does not affect the kind of interference, it only affects the duration of the interference. This is in contrast to sleep disturbance where the cumulative effect of noise can change the impact from one of sleep stage disturbance to actual sleep awakening. Therefore, the appropriate noise metric for measuring speech interference potential is an L_{eq} occurring for the duration of the event, rather than a sound exposure level which considers the effects of the duration of the event.

Also, unlike sleep disruption, interference of speech may occur when people are either indoors or outdoors. The degree of speech interference from noise is dependent on the particular circumstances involved, such as noise level and duration, separation distance of the conversers, and vocal effort. The relationship of these factors is described in Reference 5-5. The methodology for determining outdoor and indoor speech interference will be discussed separately in the following sections. It should be understood that the impacts calculated represent potential interference with speech, not actual occurrences, as it cannot be assumed that people are engaged in conversation continuously. Further, the analysis assumes that people do not converse during the nighttime hours (when they are presumed to be asleep). Thus, only daytime and evening refuse collection is considered.

Outdoor Speech Interference

The population exposed to potential outdoor speech communication interference are those people who are outside of any building but not along a street. This analysis does not take into account pedestrians or people engaged in other forms of transportation during the day. Rather, it is intended to include those time-periods in which people are relaxing outdoors - either outside a home, business, or cultural institution.

Outdoor speech interference potential due to trash collection activity occurs when the noise level of the activity exceeds a typical outdoor background level of 55 dB. Although average outdoor urban ambient noise (L_{dn}) in many areas may tend to be greater than the assumed outdoor background level, a concerted effort to reduce urban noise in the future would make the 55 dB level a more appropriate figure to use for this analysis.

Propagation loss is computed for each land use category in the same manner as discussed in the section, Sound Propagation and Amplification. The distances at which the noise levels fall off in 5 dB steps are computed, and the number of people living within each band is derived using the functional relationship pertaining to outdoor speech communication interference shown in Figure 5-5 (Ref. 5-5). This number is multiplied by the number of collections occurring during the time in which people are estimated to be outdoors each day (0.4 hours, i.e., 2.7 percent of the day) (Ref. 5-29) to give the total LWP due to outdoor speech interference.

The potential LWP for outdoor speech communication for selected years is given in Table 5-18 for the study regulation schedules. The relative change in impact obtained with these regulations also is tabulated. Complete results are presented in Exhibit 5-I at the end of this section.

Indoor Speech Interference

Indoor speech interference is assumed to occur when trash collection activity noise penetrates through walls of residences or buildings and remains above a typical indoor background level of 45 dB. The critera of impact for indoor speech interference are given in Figure 5-6 (Ref. 5-5). The curve is based on the reduction of sentence intelligibility relative to the intelligiblity which would occur at 45 dB. If people are conversing indoors during the time a trash collection operation is occurring, the probability of a disruption in communication is given by Figure 5-6. Before impact is computed, the same reductions in levels due to transmission through walls which were

TABLE 5-18

OUTDOOR SPEECH INTERFERENCE
(LWP in millions; RCI percentage benefits)

		Options					
		Base	One	Three	Five	Seven	Silent
1976	Total	29.63	29.63	29.63	29.63	29.63	29.63
	RCI	0.0	0.0	0.0	0.0	0.0	0.0
	RCI*	0.0	0.0	0.0	0.0	0.0	0.0
1982	Total	22.72	19.54	21.71	21.32	19.01	17.67
	RCI	23.3	34.1	26.7	28.0	35.8	40.4
	RCI*	0.0	14.1	4.4	6.2	16.3	22.0
1991	Total	18.53	7.34	10.46	7.34	7.34	5.32
	RCI	37.5	75.2	64.7	75.2	75.2	82.1
	RCI*	0.0	60.4	43.6	60.4	60.4	71.4
2000	Total	19.24	7.65	10.90	7.65	7.65	5.54
	RCI	35.1	74.2	63.2	74.2	74.2	81.3
	RCI*	0.0	60.2	54.2	60.2	60.2	71.4

RCI: Percentage reduction in impact from base year (1976).

RCI*: Percentage reduction in impact from base option. Base option includes benefits from medium and heavy truck regulation.

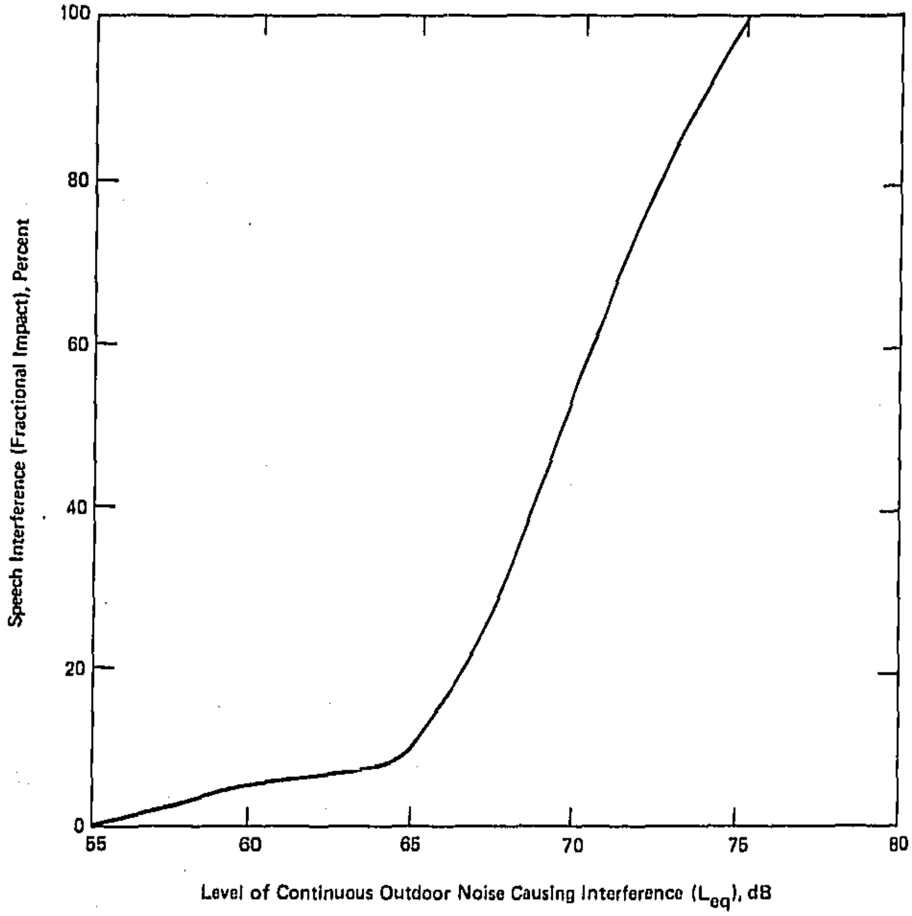


FIGURE 5-5

CRITERIA FOR OUTDOOR SPEECH INTERFERENCE
(NORMAL VOICE AT 2 METERS)

Source: Reference 5-5.

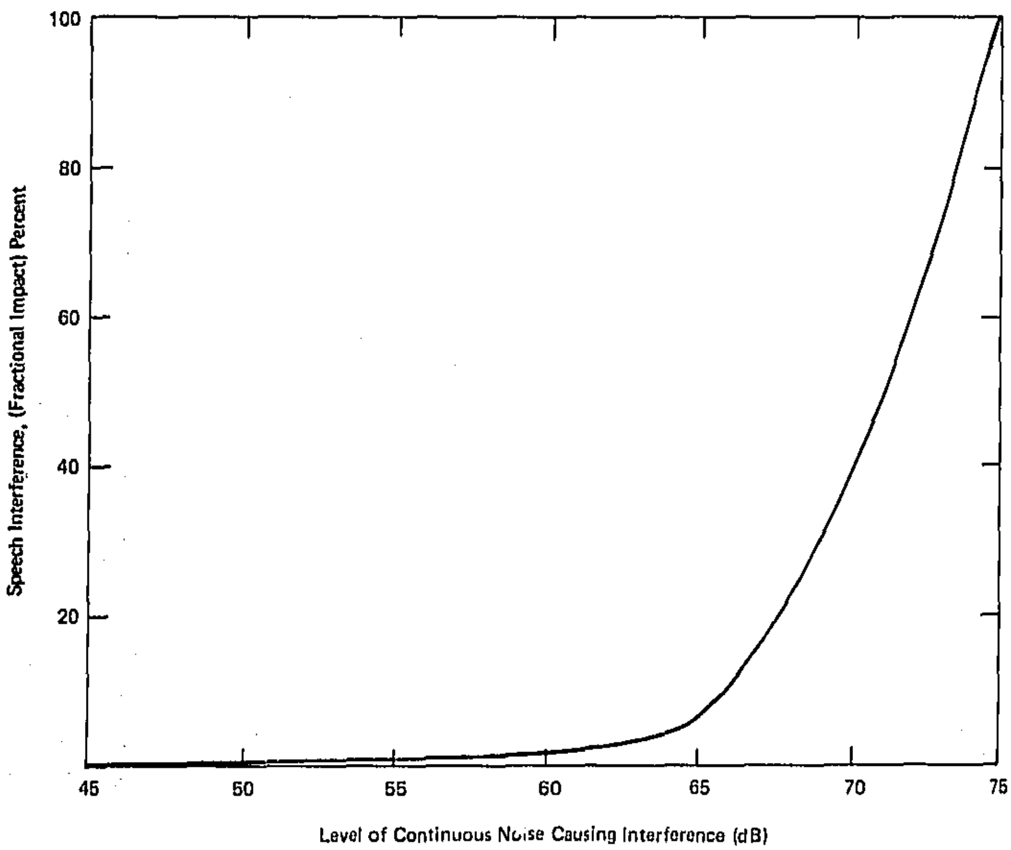


FIGURE 5-6

CRITERIA FOR INDOOR SPEECH INTERFERENCE (RELAXED CONVERSATION AT GREATER THAN 1 METER SEPARATION, 45 dB BACKGROUND IN THE ABSENCE OF INTERFERING NOISE)

Source: Reference 5-5.

used previously must be taken into account. During times when trash collection activity is not occurring, no trash collection speech interference occurs. It is estimated that people spend an average of 13 daytime hours inside each day, i.e., they spend about 86.7 percent of the day inside (Ref. 5-29). Taking the fraction of the daytime hours spent inside and the number of collection cycles occurring during these hours, the indoor speech impact can be computed in the same manner as the outdoor impact. A summary of the estimated LWP for potential indoor speech interference and the percent reduction is given in Table 5-19 for each of the regulatory options. A complete listing of results is presented in Exhibit 5-J at the end of this section.

Adding these impacts to the potential outdoor impact described above gives the total estimated equivalent noise impact due to the potential interference of speech by trash collection operations. The result is the equivalent number of people who are unable to conduct normal conversation during each two minute collection cycle as shown in Table 5-20. The associated percent reduction is also shown in Table 5-20.

Again, it should be noted that the single event noise analysis examines the effects of reducing trash collection noise alone, and hence does not take into account the presence of other noise sources in the environment. It is obvious that other environmental noise sources create background noise at such levels in certain situations that trash collection noise will be masked. This analysis only represents the benefits accrued during those times when trash collection noise clearly intrudes over the ambient or background noise. The overall absolute speech and sleep impact is, of course, dependent on the background level assumed. However, the present reduction of LWP is representative of the relative reduction in impact of trash collection noise over any given ambient level.

TABLE 5-19

INDOOR SPEECH INTERFERENCE
(LWP in millions; RCI percentage benefits)

		Options					
		Base	One	Three	Five	Seven	Silent
1976	Total	.84	.84	.84	.84	.84	.84
	RCI	0.0	0.0	0.0	0.0	0.0	0.0
	RCI*	0.0	0.0	0.0	0.0	0.0	0.0
1982	Total	.65	.56	.62	.61	.55	.51
	RCI	21.8	32.8	25.3	26.6	34.7	39.4
	RCI*	0.0	13.8	4.6	6.1	15.4	21.5
1991	Total	.54	.21	.30	.21	.21	.14
	RCI	35.0	74.9	63.6	74.9	74.9	82.9
	RCI*	0.0	61.1	44.4	61.1	61.1	74.1
2000	Total	.57	.22	.32	.22	.22	.15
	RCI	31.4	73.4	61.5	73.4	73.4	81.9
	RCI*	0.0	61.4	43.9	61.4	61.4	73.7

RCI: Percentage reduction in impact from base year (1976).

RCI*: Percentage reduction in impact from base option. Base option includes benefits from medium and heavy truck regulation.

TABLE 5-20

TOTAL OUTDOOR PLUS INDOOR SPEECH INTERFERENCE
(LWP in millions; RCI percentage benefits)

		Options					
		Base	One	Three	Five	Seven	Silent
1976	Total	30.47	30.47	30.47	30.47	30.47	30.47
	RCI	0.0	0.0	0.0	0.0	0.0	0.0
	RCI*	0.0	0.0	0.0	0.0	0.0	0.0
1982	Total	23.37	20.1	22.33	21.91	19.56	18.18
	RCI	23.3	34.0	26.7	28.1	35.8	40.3
	RCI*	0.0	14.4	4.5	6.2	16.3	22.2
1991	Total	19.07	7.55	10.76	7.55	7.55	5.46
	RCI	37.4	75.2	64.7	75.2	75.2	82.1
	RCI*	0.0	60.4	43.6	60.4	60.4	71.4
2000	Total	19.81	7.87	11.22	7.87	7.87	5.69
	RCI	35.0	74.2	63.2	74.2	74.2	81.3
	RCI*	0.0	60.3	43.4	60.3	60.3	71.3

RCI: Percentage reduction in impact from base year (1976).

RCI*: Percentage reduction in impact from base option. Base option includes benefits from medium and heavy truck regulation.

SUMMARY AND CONCLUSIONS

The calculation of noise impact from trash compactor noise is based primarily on a single equation:

$$LWP = W(L_{dn}) \times P$$

where

LWP = the level weighted population,

$W(L_{dn})$ = the weighting function representing severity of impact,

P = the population impacted.

This basic equation finds many forms as the investigated area of impact changes from urban noise to individual collection events. Table 5-21 summarizes the forms used in the preceding sections. Three areas of impact are distinguished:

a. General adverse response (annoyance) from environmental noise (expressed in terms of day-night sound level);

b. Sleep disturbance from individual events;

c. Speech interference from individual events.

The expected benefits from the major options considered are presented in summary form in Table 5-22. The table summarizes the expected improvements in environmental noise impact for the key options considered for two specific periods: 1984, which represents a "near-term" period, and 1991, which typifies the period when essentially the entire fleet will consist of vehicles that are in compliance with the standard.

The following conclusions may be drawn from the data shown in Tables 5-12 5-10, 5-17, 5-20, and 5-22;

(1) Substantial benefits in terms of reduction in extent and severity of impact may be realized as a result of a compactor regulation in concert with the regulation reducing new truck noise emissions as promulgated (Ref. 5-1).

TABLE 5-21

SUMMARY EQUATION DESCRIBING CALCULATION
OF TRASH COMPACTOR NOISE IMPACTS

Basic Equation: Level Weighted Population = Fractional Impact x Population

a. Impact of total urban noise.

$$LWP_{traffic} = \sum_{i = 55\ dB}^{L_{dn}\ max} (W(L_{dn}^{i}) \times Pop_i)$$

where

$$W(L_{dn})_{annoyance} = \begin{cases} 0 & L_{dn} \leq 55dB \\ .05(L_{dn} - 55) & L_{dn} > 55dB \end{cases}$$

b. Sleep disturbance and sleep awakening from individual events.

$$LWP_{\substack{sleep\\ disturbance\\ (awakening)}} = \left(\sum_{\substack{i = 37dB\\ (50)}}^{L_s max} W(L_{dn}^{i})_{\substack{sleep\\ disturbance\\ (awakening)}} \times \text{Pop. Density} \times \text{Size of Area} \right)$$

where

$$W_{sleep\ disturbance} = 1.35\ L_s - 50.0$$

$$W_{sleep\ awakening} = 1.10\ L_s - 49.5$$

c. Speech interference from individual events.

$$LWP_{\substack{speech\\ disturbance\\ outdoors\\ (indoors)}} = \sum_{\substack{i = 55dB\\ (45)}}^{L_{eq}} \left(W(L_{dn}^{i})_{\substack{speech\\ disturbance\\ outdoors\\ (indoors)}} \times \text{Pop. Density} \times \text{Size of Area} \right)$$

TABLE 5-22

SUMMARY OF EXPECTED BENEFITS
FROM VARIOUS REGULATORY OPTIONS
(LWP in millions; RCI percentage benefits)

General Adverse Response

Regulatory Option	1976 LWP	1984 (Near-term) LWP	RCI	RCI*	1991 (Long-term) LWP	RCI	RCI*
Baseline (Quieted truck chassis only)	2.11	1.47	30.4	—	1.48	30.0	—
1	2.11	0.94	55.5	36.1	0.54	74.5	63.5
3	2.11	1.20	43.4	18.4	0.77	63.4	48.0
5	2.11	1.11	47.5	24.5	0.54	74.5	63.5
7	2.11	0.90	57.5	38.8	0.54	74.5	63.5
Silent	2.11	0.75	64.4	49.0	0.38	82.2	74.5

Sleep Disturbance

Regulatory Option	1976 LWP	1984 (Near-term) LWP	RCI	RCI*	1991 (Long-term) LWP	RCI	RCI*
Baseline (Quieted truck chassis only)	13.85	9.93	28.3	--	9.49	31.5	—
1	13.85	6.29	54.6	36.7	2.84	79.5	70.0
3	13.85	8.05	41.9	18.9	4.51	67.4	52.4
5	13.85	7.49	45.9	24.6	2.84	79.5	70.0
7	13.85	6.03	56.4	39.3	2.84	79.5	70.0
Silent	13.85	5.07	63.4	48.9	1.57	88.7	83.5

RCI: Percentage reduction in impact from base year (1976).

RCI*: Percentage reduction in impact from base option. Base option includes benefits from medium and heavy truck regulation.

TABLE 5-22 (Continued)

Sleep Awakening

Regulatory Option	1976 LWP	1984 (Near-term) LWP	RCI	RCI*	1991 (Long-term) LWP	RCI	RCI*
Baseline (Quieted truck chassis only)	11.50	8.28	28.0	—	7.94	31.0	—
1	11.50	5.25	54.4	36.6	2.37	79.4	70.2
3	11.50	6.71	41.7	19.0	3.74	67.5	52.9
5	11.50	6.25	45.7	24.5	2.37	79.4	70.2
7	11.50	5.03	56.3	39.3	2.37	79.4	70.2
Silent	11.50	4.23	63.3	48.9	1.31	88.6	83.5

Outdoor Speech Interference

Regulatory Option	1976 LWP	1984 (Near-term) LWP	RCI	RCI*	1991 (Long-term) LWP	RCI	RCI*
Baseline (Quieted truck chassis only)	29.63	19.02	35.8	—	18.53	37.5	—
1	29.63	12.65	57.3	33.5	7.34	75.2	60.4
3	29.63	15.80	46.7	16.9	10.46	64.7	43.6
5	29.63	14.60	50.8	23.2	7.34	75.2	60.4
7	29.63	12.08	59.2	36.5	7.34	75.2	60.4
Silent	29.63	10.03	66.2	47.3	5.32	82.1	71.3

Indoor Speech Interference

Regulatory Option	1976 LWP	1984 (Near-term) LWP	RCI	RCI*	1991 (Long-term) LWP	RCI	RCI*
Baseline (Quieted truck chassis only)	0.84	0.55	34.4	—	0.54	35.0	—
1	0.84	0.36	56.6	34.5	0.21	74.9	61.1
3	0.84	0.45	45.6	18.2	0.30	63.6	44.4
5	0.84	0.42	49.9	23.6	0.21	74.9	61.1
7	0.84	0.35	58.6	36.4	0.21	74.9	61.1
Silent	0.84	0.29	65.7	47.3	0.14	82.9	74.1

By 1991, the number of people exposed to environmental noise levels above L_{dn} = 55 dB due to solid waste collection activities is expected to have decreased from the baseline of over 19 million to approximately 6 million. These 6 million people will also benefit from the reduced levels of environmental noise. The severity and extent of general adverse response and annoyance are expected to be reduced by 74%. A reduction of 75-80% in the occurrences of sleep disturbances and speech interference events is also anticipated.

(2) Options 1, 5, and 7 are shown in Table 5-21 to produce identical benefits in the long-term (1991), and all produce greater benefits than Option 3. However, Option 7 produces greater near-term benefits (1984) than either Option 1 or 5.

(3) Relief afforded by limiting noise emissions from newly manufactured truck-mounted trash compactors adds significantly to the benefits consequent to a new truck regulation, i.e., absence of a trash compactor regulation will negate the full potential benefits that may be realized from the truck noise regulation.

(4) As new truck regulations become more stringent, greater relative benefits are realized from noise emission restrictions on trash compactors.

(5) Regulating a truck-mounted compactor more stringently than is done in Option 7 would result in only slightly greater benefits because of the noises other than compaction occurring during the collection cycle.

(6) Benefit is afforded mainly to those people in dense urban areas. These areas are currently the most heavily impacted. The population living in suburban or low density urban areas, being initially impacted to a lesser degree, receive fewer benefits.

REFERENCES
Section 5

5-1 Environmental Protection Agency, Transportation Noise Emission Controls, Proposed Standards for Medium and Heavy Trucks, Federal Register 39: 210 (Part II), 38338, October 30, 1974.

5-2 "Noise Control/Technology for Specialty Trucks (Solid Waste Compactors)", Bolt, Beranek and Newman, Inc., BBN Draft Report 3249, February 1976.

5-3 Letter from R. A. Simmons, Supervisor--Noise Control Program, U. S. Environmental Protection Agency/Region VIII to Fred Mintz, EPA/ONAC, dated August 24, 1976.

5-4 Plotkin, K., "Assessment of Noise at Community Development Sites," Appendix A, Noise Models. Wyle Research Report, WR75-6, October 1975.

5-5 Environmental Protection Agency, Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With An Adequate Margin of Safety, EPA 550/9-74-004, March 1974.

5-6 "Cost and Economic Analysis: Specialty Truck Components", A. T. Kearney, Inc., Preliminary Draft report submitted to EPA Office of Noise Abatement and Control, February 6, 1976.

5-7 Environmental Protection Agency, Population Distribution of the U. S. As A Function of Outdoor Noise Level, EPA-550/9-74-009, June 1974.

5-8 Environmental Protection Agency, Background Document for Medium and Heavy Truck Noise Emission Regulations, EPA-550/9-76-008, March 1976.

5-9 Gunn, W., T. Shighehisa, and W. Shepherd, "Relative Effectiveness of Several Simulated Jet Engine Noise Spectral Treatments in Reducing Annoyance in a TV-Viewing Situation." NASA Langley Research Center, Draft Report, 1976.

5-10 Lukas, J. S., Measures of Noise Level: Their Relative Accuracy in Predicting Objective and Subjective Responses to Noise During Sleep, EPA Report No. 600/1-77-010, February 1977.

5-11 Lukas, J. S., "Noise and Sleep: A Literature Review and a Proposed Criterion for Assessing Effect", Journal of the Acoustical Society of America, Vol. 58(6):1232-1242, December 1975.

5-12 McKennell, A.C., "Aircraft Noise Annoyance Around London (Heathrow) Airport," U.K. Government Social Survey Report, SS.387, 1963.

5-13 Sutherland, L., Braden, M., and Colman, R., "A Program for the Measurement of Environmental Noise in the Community and its Associated Human Response, Volume 1", Wyle Research Report WR-73-8 for the U. S. Department of Transportation, December 1973.

5-14 Environmental Protection Agency, Public Health and Welfare Criteria for Noise. EPA 550/9-73-002, July 27, 1973.

5-15 Welch, B. L. and Welch, A. S. (Eds.), Physiological Effects of Noise. New York, Plenum Press, 1970.

5-16 "Noise-Final Report," Cmnd. 2056, July 1963, Her Majesty's Stationary Office, London.

5-17 Grandjean, E., Graf, P., Lauber, A., Meier, H. P., and Muller, R., "A Survey of Aircraft Noise in Switzerland", Proceedings of the International Congress on Noise as a Public Health Problem, Dubrovnik, Yugoslavia, May 13-18, 1973, pp. 645-659.

5-18 Sorenson, S., Berglund K., and Rylander, R., "Reaction Patterns in Annoyance Response to Aircraft Noise", Proceedings of the International Congress on Noise as a Public Health Problem, Dubrovnik, Yugoslavia, May 13-18, 1973, pp. 669-677.

5-19 Sutherland, L. C., "Indoor Noise Environments Due to Outdoor Noise Sources", Noise Control Engineering, 11(3), 124-137, 1978.

5-20 "Constitution of the World Health Organization", WHO Office of Public Information, Geneva, Switzerland, 1948.

5-21 "Guidelines for Preparing Environmental Impact Statements on Noise," Report of Working Group 69, Committee on Hearing, Bioacoustics and Biomechanics, The National Research Council, Washington , D.C., 1977.

5-22 Schultz, Theodore J., "Synthesis of Social Surveys on Noise Annoyance", The Journal of the Acoustical Society of America, 64(2), 377-405, 1978.

5-23 Fidell, Sanford, "The Urban Noise Survey", EPA Report No. 550/9-77-100, August 1977, and "Nationwide Urban Noise Survey", The Journal of the Acoustical Society of America, 64(17), 198-206, 1978.

5-24 Borsky, Paul N., "The Use of Social Surveys for Measuring Responses to Noise Environments", Transportation Noises: A Symposium on Acceptability Criteria, J. D. Chalupnik (Ed.), University of Washington Press, Seattle, 1970, pp. 209-227.

5-25 Gunn, Walter J., "A General Discussion of 'Reactions to Aircraft Noises'", in Reaction to Aircraft Noises: A Symposium Report, E. A. Allvis (Ed.), Journal of Auditory Research, 15, Supplement 5, pp. 214-217, 1975.

5-26 Hall, F. L., Taylor, S. M., and Birnie, S.F., "Community Response to Road Traffic Noise", McMaster University, Hamilton, Ontario, Canada, December 1977.

5-27 Swing, John W., "A Case for Single-Event Intrusion Criteria in Achieving Noise-Compatible Land Use ", Noise Control Engineering, 11(3), 98, 1978.

5-28 Allen, J. D., Faulkner, L. L., Ren, F. G., and White, A. M., "The Automobile As a Component of Community Noise", Phase 1 Final Report, Battelle Columbia Laboratories, June 1978.

5-29 Rowland, R. H., and Gould, K. E., "Draft Environmental Impact Statement in Proposed Truck Mounted Solid Waste Compactor Noise Regulations", General Electric Company - TEMPO, December, 1976.

5-30 Goldstein, J., "Assessing the Impact of Transportation Noise: Human Response Measures," Proceedings of the 1977 National Conference on Noise Control Engineering, G.C. Maling (ed.), NASA Langley Research Center, Hampton, Virginia 17-19 October 1977, pp. 79-98.

SECTION 5 EXHIBITS

The following Exhibits present tabulations of computations concerning the health and welfare impacts for the various cases being examined for each year and land use type. Results are presented for each of four final regulatory Options (1, 3, 5, and 7), the Base Case (no regulation) and the Silent Case (see Table 5-1).

The Exhibits are presented as follows:

Exhibit 5-A: L_A (Average A-weighted sound level) for Collection Cycle At 7m

Exhibit 5-B: L_{eq} (Equivalent sound level for a 24-hour period) At 7m

Exhibit 5-C: L_{dn} (Day-night sound level) At 7m

Exhibit 5-D: $L_{dn}A$ (Day-night sound level with ambient) At 7m

Exhibit 5-E: LWP and RCI for General Adverse Response

Exhibit 5-F: L_S (Sound Exposure Level) At 7m

Exhibit 5-G: LWP and RCI for Sleep Disturbance

Exhibit 5-H: LWP and RCI for Sleep Awakening

Exhibit 5-I: LWP and RCI for Outdoor Speech Interference

Exhibit 5-J: LWP and RCI for Indoor Speech Interference

Symbols defining columns are as follows:

SSF - Suburban Single Family Detached

SD - Suburban Duplexes

UR - Urban Row Apartments

DU - Dense Urban Apartments

VDU - Very Dense Apartments

Exhibit 5-A: L_A (Average A-Weighted Sound Level) for Collection Cycle at 7 m

Baseline Option

YEAR	SSF	SD	UF	DU	VDU
1976	78.575	78.551	82.577	84.316	84.758
1977	78.575	78.551	82.577	84.316	84.758
1978	78.310	78.284	82.332	84.080	84.546
1979	78.028	78.000	82.073	83.830	84.324
1980	77.727	77.697	81.797	83.564	84.090
1981	77.403	77.370	81.503	83.282	83.843
1982	76.988	76.952	81.129	82.924	83.532
1983	76.530	76.489	80.720	82.534	83.198
1984	76.017	75.971	80.269	82.106	82.837
1985	75.935	75.888	80.197	82.038	82.780
1986	75.852	75.803	80.125	81.970	82.722
1987	75.766	75.717	80.051	81.900	82.664
1988	75.679	75.629	79.975	81.829	82.605
1989	75.679	75.629	79.975	81.829	82.605
1990	75.679	75.629	79.975	81.829	82.605
1991	75.679	75.629	79.975	81.829	82.605
1992	75.679	75.629	79.975	81.829	82.605
1993	75.679	75.629	79.975	81.829	82.605
1994	75.679	75.629	79.975	81.829	82.605
1995	75.679	75.629	79.975	81.829	82.605
1996	75.679	75.629	79.975	81.829	82.605
1997	75.679	75.629	79.975	81.829	82.605
1998	75.679	75.629	79.975	81.829	82.605
1999	75.679	75.629	79.975	81.829	82.605
2000	75.679	75.629	79.975	81.829	82.605

Option 1

YEAR	SSF	SD	UR	DU	VDU
1976	78.575	78.551	82.577	84.316	84.758
1977	78.575	78.551	82.577	84.316	84.758
1978	78.310	78.284	82.332	84.080	84.546
1979	78.028	78.000	82.073	83.830	84.324
1980	77.603	77.576	81.632	83.383	83.859
1981	77.132	77.106	81.142	82.885	83.337
1982	76.406	76.381	80.401	82.139	82.574
1983	75.533	75.510	79.508	81.238	81.647
1984	74.441	74.420	78.383	80.099	80.466
1985	73.822	73.808	77.667	79.343	79.579
1986	73.099	73.096	76.809	78.426	78.463
1987	72.644	72.642	76.347	77.962	77.989
1988	72.136	72.135	75.831	77.442	77.456
1989	72.136	72.135	75.831	77.442	77.456
1990	72.136	72.135	75.831	77.442	77.456
1991	72.136	72.135	75.831	77.442	77.456
1992	72.136	72.135	75.831	77.442	77.456
1993	72.136	72.135	75.831	77.442	77.456
1994	72.136	72.135	75.831	77.442	77.456
1995	72.136	72.135	75.831	77.442	77.456
1996	72.136	72.135	75.831	77.442	77.456
1997	72.136	72.135	75.831	77.442	77.456
1998	72.136	72.135	75.831	77.442	77.456
1999	72.136	72.135	75.831	77.442	77.456
2000	72.136	72.135	75.831	77.442	77.456

Exhibit 5-A: L_A (Average A-weighted sound level) for Collection Cycle at 7 m

Option 3

YEAR	SSF	SD	UR	DU	VDU
1976	78.575	78.551	82.577	84.316	84.758
1977	78.575	78.551	82.577	84.316	84.758
1978	78.310	78.284	82.332	84.080	84.546
1979	78.028	78.000	82.073	83.830	84.324
1980	77.727	77.697	81.797	83.564	84.090
1981	77.403	77.370	81.503	83.282	83.843
1982	76.811	76.778	80.907	82.685	83.241
1983	76.125	76.093	80.216	81.992	82.543
1984	75.311	75.278	79.395	81.168	81.711
1985	74.945	74.917	78.964	80.712	81.178
1986	74.545	74.523	78.487	80.203	80.571
1987	74.104	74.090	77.950	79.626	79.865
1988	73.614	73.608	77.337	78.961	79.021
1989	73.614	73.608	77.337	78.961	79.021
1990	73.614	73.608	77.337	78.961	79.021
1991	73.614	73.608	77.337	78.961	79.021
1992	73.614	73.608	77.337	78.961	79.021
1993	73.614	73.608	77.337	78.961	79.021
1994	73.614	73.608	77.337	78.961	79.021
1995	73.614	73.608	77.337	78.961	79.021
1996	73.614	73.608	77.337	78.961	79.021
1997	73.614	73.608	77.337	78.961	79.021
1998	73.614	73.608	77.337	78.961	79.021
1999	73.614	73.608	77.337	78.961	79.021
2000	73.614	73.608	77.337	78.961	79.021

Option 5

YEAR	SSF	SD	UR	DU	VDU
1976	78.575	78.551	82.577	84.316	84.758
1977	78.575	78.551	82.577	84.316	84.758
1978	78.310	78.284	82.332	84.080	84.546
1979	78.028	78.000	82.073	83.830	84.324
1980	77.727	77.697	81.797	83.564	84.090
1981	77.403	77.370	81.503	83.202	83.843
1982	76.724	76.691	80.827	82.606	83.170
1983	75.920	75.886	80.025	81.806	92.373
1984	74.932	74.898	79.041	80.824	81.397
1985	74.383	74.354	78.433	80.193	80.695
1986	73.755	73.732	77.726	79.454	79.859
1987	73.021	73.006	76.881	78.564	78.821
1988	72.136	72.135	75.831	77.442	77.456
1989	72.136	72.135	75.831	77.442	77.456
1990	72.136	72.135	75.831	77.442	77.456
1991	72.136	72.135	75.831	77.442	77.456
1992	72.136	72.135	75.831	77.442	77.456
1993	72.136	72.135	75.831	77.442	77.456
1994	72.136	72.135	75.831	77.442	77.456
1995	72.136	72.135	75.831	77.442	77.456
1996	72.136	72.135	75.831	77.442	77.456
1997	72.136	72.135	75.831	77.442	77.456
1998	72.136	72.135	75.831	77.442	77.456
1999	72.136	72.135	75.831	77.442	77.456
2000	72.136	72.135	75.831	77.442	77.456

Exhibit 5-A: L_A (Average A-weighted sound level) for Collection Cycle at 7 m

Option 7

YEAR	SSF	SD	UR	DU	VDU
1976	78.575	78.551	82.577	84.316	84.758
1977	78.575	78.551	82.577	84.316	84.758
1978	78.310	78.284	82.332	84.080	84.546
1979	78.028	78.000	82.073	83.830	84.324
1980	77.555	77.528	81.586	83.337	83.815
1981	77.025	76.999	81.038	82.782	83.238
1982	76.279	76.254	80.278	82.017	82.455
1983	75.376	75.355	79.356	81.087	81.500
1984	74.240	74.219	78.184	79.902	80.272
1985	73.589	73.576	77.432	79.107	79.340
1986	72.823	72.821	76.521	78.133	78.151
1987	72.493	72.492	76.190	77.801	77.817
1988	72.136	72.135	75.831	77.442	77.456
1989	72.136	72.135	75.831	77.442	77.456
1990	72.136	72.135	75.831	77.442	77.456
1991	72.136	72.135	75.831	77.442	77.456
1992	72.136	72.135	75.831	77.442	77.456
1993	72.136	72.135	75.831	77.442	77.456
1994	72.136	72.135	75.831	77.442	77.456
1995	72.136	72.135	75.831	77.442	77.456
1996	72.136	72.135	75.831	77.442	77.456
1997	72.136	72.135	75.831	77.442	77.456
1998	72.136	72.135	75.831	77.442	77.456
1999	72.136	72.135	75.831	77.442	77.456
2000	72.136	72.135	75.831	77.442	77.456

Silent Option

YEAR	SSF	SD	UR	DU	VDU
1976	78.575	78.551	82.577	84.316	84.758
1977	78.575	78.551	82.577	84.316	84.758
1978	78.310	78.284	82.332	84.080	84.546
1979	78.028	78.000	82.073	83.830	84.324
1980	77.454	77.427	81.491	83.245	83.730
1981	76.793	76.766	80.819	82.569	83.041
1982	75.930	75.904	79.948	81.694	82.156
1983	74.852	74.828	78.857	80.598	81.043
1984	73.415	73.393	77.397	79.128	79.544
1985	72.456	72.444	76.322	78.006	78.268
1986	71.223	71.227	74.891	76.488	76.454
1987	70.971	70.975	74.639	76.236	76.202
1988	70.703	70.707	74.371	75.968	75.934
1989	70.703	70.707	74.371	75.968	75.934
1990	70.703	70.707	74.371	75.968	75.934
1991	70.703	70.707	74.371	75.968	75.934
1992	70.703	70.707	74.371	75.968	75.934
1993	70.703	70.707	74.371	75.968	75.934
1994	70.703	70.707	74.371	75.968	75.934
1995	70.703	70.707	74.371	75.968	75.934
1996	70.703	70.707	74.371	75.968	75.934
1997	70.703	70.707	74.371	75.968	75.934
1998	70.703	70.707	74.371	75.968	75.934
1999	70.703	70.707	74.371	75.968	75.934
2000	70.703	70.707	74.371	75.968	75.934

Exhibit 5-8: L_{eq} (Equivalent Sound Level for a 24-Hour Period) at 7 m

Baseline Option

YEAR	SSF	SD	UR	DU	VDU
1976	44.997	49.479	57.784	63.990	68.389
1977	45.074	49.557	57.862	64.067	68.467
1978	44.888	49.368	57.696	63.909	68.334
1979	44.684	49.162	57.514	63.737	68.190
1980	44.435	48.911	57.292	63.525	68.009
1981	44.164	48.638	57.051	63.295	67.814
1982	43.803	48.273	56.730	62.991	67.557
1983	43.398	47.863	56.374	62.654	67.276
1984	42.938	47.398	55.976	62.279	66.967
1985	42.903	47.361	55.951	62.258	66.957
1986	42.866	47.323	55.925	62.235	66.947
1987	42.827	47.284	55.897	62.212	66.935
1988	42.787	47.242	55.869	62.198	66.922
1989	42.833	47.269	55.915	62.234	66.969
1990	42.868	47.324	55.950	62.269	67.004
1991	42.904	47.359	55.985	62.304	67.039
1992	42.939	47.394	56.020	62.339	67.074
1993	42.974	47.429	56.055	62.374	67.109
1994	43.009	47.464	56.090	62.410	67.144
1995	43.039	47.494	56.120	62.439	67.174
1996	43.068	47.524	56.150	62.469	67.204
1997	43.098	47.554	56.180	62.499	67.234
1998	43.128	47.584	56.210	62.529	67.264
1999	43.158	47.613	56.240	62.559	67.294
2000	43.188	47.643	56.270	62.589	67.323

Option 1

YEAR	SSF	SD	UR	DU	VDU
1976	44.997	49.479	57.784	63.990	68.389
1977	45.074	49.557	57.862	64.067	68.467
1978	44.888	49.368	57.696	63.909	68.334
1979	44.684	49.162	57.514	63.737	68.190
1980	44.312	48.791	57.127	63.343	67.777
1981	43.893	48.374	56.689	62.898	67.309
1982	43.220	47.702	56.002	62.205	66.599
1983	42.401	46.884	55.162	61.357	65.725
1984	41.362	45.847	54.090	60.272	64.597
1985	40.789	45.282	53.420	59.562	63.757
1986	40.114	44.617	52.609	58.692	62.688
1987	39.705	44.209	52.194	58.274	62.260
1988	39.244	43.749	51.725	57.801	61.773
1989	39.291	43.795	51.771	57.848	61.820
1990	39.326	43.830	51.806	57.883	61.855
1991	39.361	43.865	51.841	57.918	61.890
1992	39.396	43.900	51.876	57.953	61.925
1993	39.431	43.935	51.911	57.988	61.960
1994	39.466	43.970	51.947	58.023	61.995
1995	39.496	44.000	51.976	58.053	62.025
1996	39.525	44.030	52.006	58.083	62.055
1997	39.555	44.060	52.036	58.113	62.085
1998	39.585	44.090	52.066	58.142	62.114
1999	39.615	44.120	52.096	58.172	62.144
2000	39.645	44.150	52.126	58.202	62.174

Exhibit 5-8: L_{eq} (Equivalent sound level for a 24-hour period) at 7 m

Option 3

YEAR	SSF	SD	UR	DU	VDU
1976	44.997	49.479	57.784	63.990	68.389
1977	45.074	49.557	57.862	64.067	68.467
1978	44.888	49.368	57.696	63.909	68.334
1979	44.684	49.162	57.514	63.737	68.190
1980	44.435	48.911	57.292	63.525	68.009
1981	44.164	48.638	57.051	63.295	67.814
1982	43.626	48.099	56.508	62.751	67.266
1983	42.993	47.467	55.870	62.112	66.621
1984	42.232	46.706	55.102	61.340	65.842
1985	41.913	46.391	54.718	60.932	65.356
1986	41.559	46.044	54.287	60.469	64.795
1987	41.165	45.657	53.796	59.939	64.136
1988	40.721	45.222	53.230	59.320	63.339
1989	40.768	45.269	53.277	59.367	63.385
1990	40.803	45.304	53.312	59.402	63.420
1991	40.838	45.339	53.347	59.437	63.455
1992	40.873	45.374	53.382	59.472	63.490
1993	40.908	45.409	53.417	59.507	63.525
1994	40.943	45.444	53.452	59.542	63.560
1995	40.973	45.474	53.482	59.572	63.590
1996	41.003	45.504	53.512	59.602	63.620
1997	41.033	45.534	53.542	59.632	63.650
1998	41.063	45.564	53.571	59.662	63.680
1999	41.093	45.593	53.601	59.691	63.710
2000	41.122	45.623	53.631	59.721	63.740

Option 5

YEAR	SSF	SD	UR	DU	VDU
1976	44.997	49.479	57.784	63.990	68.389
1977	45.074	49.557	57.862	64.067	68.467
1978	44.888	49.368	57.696	63.909	68.334
1979	44.684	49.162	57.514	63.737	68.190
1980	44.435	48.911	57.292	63.525	68.009
1981	44.164	48.638	57.051	63.295	67.814
1982	43.539	48.012	56.427	62.673	67.194
1983	42.788	47.260	55.679	61.925	66.451
1984	41.853	46.325	54.748	60.997	65.528
1985	41.351	45.828	54.187	60.412	64.873
1986	40.770	45.253	53.527	59.720	64.083
1987	40.082	44.574	52.728	58.876	63.092
1988	39.244	43.749	51.725	57.801	61.773
1989	39.291	43.795	51.771	57.848	61.820
1990	39.326	43.830	51.806	57.883	61.855
1991	39.361	43.865	51.841	57.918	61.890
1992	39.396	43.900	51.876	57.953	61.925
1993	39.431	43.935	51.911	57.988	61.960
1994	39.466	43.970	51.947	58.023	61.995
1995	39.496	44.000	51.976	58.053	62.025
1996	39.525	44.030	52.006	58.083	62.055
1997	39.555	44.060	52.036	58.113	62.085
1998	39.585	44.090	52.066	58.142	62.114
1999	39.615	44.120	52.096	58.172	62.144
2000	39.645	44.150	52.126	58.202	62.174

Exhibit 5-8: L_{eq} (Equivalent sound level for a 24-hour period) at 7 m

Option 7

YEAR	SSF	SD	UR	DU	VDU
1976	44.997	49.479	57.784	63.990	68.389
1977	45.074	49.557	57.962	64.067	68.467
1978	44.888	49.368	57.696	63.909	68.334
1979	44.684	49.162	57.514	63.737	68.190
1980	44.264	48.743	57.081	63.298	67.734
1981	43.786	48.267	56.565	62.795	67.210
1982	43.094	47.575	55.878	62.083	66.480
1983	42.246	46.729	55.010	61.206	65.577
1984	41.161	45.646	53.891	60.074	64.403
1985	40.557	45.050	53.185	59.326	63.517
1986	39.838	44.342	52.321	58.399	62.375
1987	39.554	44.059	52.037	58.114	62.088
1988	39.244	43.749	51.725	57.801	61.773
1989	39.291	43.795	51.771	57.848	61.820
1990	39.326	43.830	51.806	57.883	61.855
1991	39.361	43.865	51.841	57.918	61.890
1992	39.396	43.900	51.876	57.953	61.925
1993	39.431	43.935	51.911	57.988	61.960
1994	39.466	43.970	51.947	58.023	61.995
1995	39.496	44.000	51.976	58.053	62.025
1996	39.525	44.030	52.006	58.083	62.055
1997	39.555	44.060	52.036	58.113	62.085
1998	39.585	44.090	52.066	58.142	62.114
1999	39.615	44.120	52.096	58.172	62.144
2000	39.645	44.150	52.126	58.202	62.174

Silent Option

YEAR	SSF	SD	UR	DU	VDU
1976	44.997	49.479	57.784	63.990	68.389
1977	45.074	49.557	57.862	64.067	68.467
1978	44.888	49.368	57.696	63.909	68.334
1979	44.684	49.162	57.514	63.737	68.190
1980	44.163	48.642	56.986	63.205	67.648
1981	43.555	48.034	56.367	62.582	67.012
1982	42.745	47.225	55.549	61.761	66.181
1983	41.720	46.202	54.511	60.717	65.121
1984	40.337	44.820	53.104	59.301	63.675
1985	39.424	43.917	52.076	58.225	62.446
1986	38.238	42.747	50.692	56.754	60.678
1987	38.032	42.542	50.486	56.548	60.473
1988	37.811	42.321	50.265	56.327	60.251
1989	37.858	42.367	50.311	56.374	60.298
1990	37.893	42.402	50.346	56.409	60.333
1991	37.928	42.437	50.381	56.444	60.368
1992	37.963	42.472	50.416	56.479	60.403
1993	37.998	42.507	50.452	56.514	60.438
1994	38.033	42.542	50.487	56.549	60.473
1995	38.063	42.572	50.516	56.579	60.503
1996	38.093	42.602	50.546	56.609	60.533
1997	38.123	42.632	50.576	56.638	60.563
1998	38.152	42.662	50.606	56.668	60.593
1999	38.182	42.692	50.636	56.698	60.622
2000	38.212	42.722	50.666	56.728	60.652

Exhibit 5-C: L_{dn} (Day-Night Sound Level) at 7 m

Baseline Option

YEAR	SSF	SD	UR	DU	VDU
1976	45.499	51.355	62.744	71.204	75.604
1977	45.577	51.433	62.822	71.282	75.682
1978	45.390	51.244	62.655	71.124	75.549
1979	45.186	51.038	62.474	70.952	75.404
1980	44.938	50.768	62.251	70.739	75.223
1981	44.667	50.514	62.010	70.510	75.029
1982	44.305	50.149	61.690	70.205	74.772
1983	43.900	49.739	61.334	69.869	74.491
1984	43.441	49.274	60.936	69.493	74.182
1985	43.405	49.238	60.911	69.472	74.172
1986	43.368	49.200	60.884	69.450	74.161
1987	43.330	49.160	60.857	69.427	74.150
1988	43.289	49.119	60.828	69.402	74.137
1989	43.336	49.165	60.875	69.449	74.184
1990	43.371	49.200	60.910	69.484	74.219
1991	43.406	49.235	60.945	69.519	74.254
1992	43.441	49.270	60.980	69.554	74.289
1993	43.476	49.305	61.015	69.589	74.324
1994	43.511	49.340	61.050	69.624	74.359
1995	43.541	49.370	61.080	69.654	74.389
1996	43.571	49.400	61.110	69.684	74.419
1997	43.601	49.430	61.140	69.714	74.449
1998	43.630	49.460	61.170	69.744	74.478
1999	43.660	49.490	61.199	69.774	74.508
2000	43.690	49.520	61.229	69.803	74.538

Option 1

YEAR	SSF	SD	UR	DU	VDU
1976	45.499	51.355	62.744	71.204	75.604
1977	45.577	51.433	62.822	71.282	75.682
1978	45.390	51.244	62.655	71.124	75.549
1979	45.186	51.038	62.474	70.952	75.404
1980	44.814	50.667	62.086	70.558	74.992
1981	44.396	50.250	61.649	70.113	74.524
1982	43.723	49.578	60.962	69.420	73.813
1983	42.904	48.761	60.122	68.572	72.939
1984	41.865	47.723	59.049	67.486	71.812
1985	41.292	47.159	58.380	66.777	70.972
1986	40.617	46.493	57.569	65.907	69.902
1987	40.208	46.086	57.154	65.489	69.474
1988	39.747	45.625	56.684	65.016	68.988
1989	39.794	45.672	56.731	65.063	69.035
1990	39.829	45.707	56.766	65.098	69.070
1991	39.864	45.742	56.801	65.133	69.105
1992	39.899	45.777	56.836	65.168	69.140
1993	39.934	45.812	56.871	65.203	69.175
1994	39.969	45.847	56.906	65.238	69.210
1995	39.999	45.877	56.936	65.268	69.240
1996	40.029	45.907	56.966	65.297	69.269
1997	40.058	45.937	56.996	65.327	69.299
1998	40.088	45.966	57.026	65.357	69.329
1999	40.118	45.996	57.055	65.387	69.359
2000	40.148	46.026	57.085	65.417	69.389

Exhibit 5-C: L_{dn} (Day-night sound level) at 7 m

Option 3

YEAR	SSF	SD	UR	DU	VDU
1976	45.499	51.355	62.744	71.204	75.604
1977	45.577	51.433	62.822	71.282	75.682
1978	45.390	51.244	62.655	71.124	75.549
1979	45.186	51.038	62.474	70.952	75.404
1980	44.938	50.788	62.251	70.739	75.223
1981	44.667	50.514	62.010	70.510	75.029
1982	44.128	49.975	61.467	69.966	74.481
1983	43.496	49.343	60.830	69.326	73.836
1984	42.735	48.582	60.061	68.555	73.057
1985	42.415	48.267	59.677	68.146	72.571
1986	42.062	47.920	59.246	67.684	72.010
1987	41.668	47.533	58.756	67.154	71.351
1988	41.224	47.099	58.190	66.535	70.553
1989	41.271	47.145	58.236	66.582	70.600
1990	41.306	47.180	58.271	66.617	70.635
1991	41.341	47.215	58.306	66.652	70.670
1992	41.376	47.250	58.342	66.687	70.705
1993	41.411	47.285	58.377	66.722	70.740
1994	41.446	47.320	58.412	66.757	70.775
1995	41.476	47.350	58.441	66.787	70.805
1996	41.506	47.380	58.471	66.817	70.835
1997	41.536	47.410	58.501	66.846	70.865
1998	41.565	47.440	58.531	66.876	70.895
1999	41.595	47.470	58.561	66.906	70.925
2000	41.625	47.500	58.591	66.936	70.954

Option 5

YEAR	SSF	SD	UR	DU	VDU
1976	45.499	51.355	62.744	71.204	75.604
1977	45.577	51.433	62.822	71.282	75.682
1978	45.390	51.244	62.655	71.124	75.549
1979	45.186	51.038	62.474	70.952	75.404
1980	44.938	50.788	62.251	70.739	75.223
1981	44.667	50.514	62.010	70.510	75.029
1982	44.041	49.889	61.387	69.887	74.409
1983	43.290	49.137	60.638	69.140	73.666
1984	42.355	48.201	59.708	68.212	72.742
1985	41.854	47.704	59.147	67.627	72.088
1986	41.272	47.129	58.486	66.935	71.298
1987	40.585	46.450	57.688	66.091	70.307
1988	39.747	45.625	56.684	65.016	68.988
1989	39.794	45.672	56.731	65.063	69.035
1990	39.829	45.707	56.766	65.098	69.070
1991	39.864	45.742	56.801	65.133	69.105
1992	39.899	45.777	56.836	65.168	69.140
1993	39.934	45.812	56.871	65.203	69.175
1994	39.969	45.847	56.906	65.238	69.210
1995	39.999	45.877	56.936	65.268	69.240
1996	40.029	45.907	56.966	65.297	69.269
1997	40.058	45.937	56.996	65.327	69.299
1998	40.088	45.966	57.026	65.357	69.329
1999	40.118	45.996	57.055	65.387	69.359
2000	40.148	46.026	57.085	65.417	69.389

Exhibit 5-C: L_{dn} (Day-night sound level) at 7 m

Option 7

YEAR	SSF	SD	UR	DU	VDU
1976	45.499	51.355	62.744	71.204	75.604
1977	45.577	51.433	62.822	71.292	75.682
1978	45.390	51.244	62.655	71.124	75.549
1979	45.186	51.038	62.474	70.952	75.404
1980	44.766	50.620	62.040	70.512	74.948
1981	44.289	50.143	61.545	70.010	74.425
1982	43.596	49.451	60.838	69.298	73.695
1983	42.748	48.605	59.969	68.421	72.792
1984	41.664	47.523	58.851	67.289	71.618
1985	1.060	46.926	58.145	66.541	70.732
1986	40.341	46.218	57.281	65.614	69.590
1987	40.057	45.935	56.996	65.328	69.303
1988	39.747	45.625	56.684	65.016	68.988
1989	39.794	45.672	56.731	65.063	69.035
1990	39.829	45.707	56.766	65.098	69.070
1991	39.864	45.742	56.801	65.133	69.105
1992	39.899	45.777	56.836	65.168	69.140
1993	39.934	45.812	56.871	65.203	69.175
1994	39.969	45.847	56.906	65.238	69.210
1995	39.999	45.877	56.936	65.268	69.240
1996	40.029	45.907	56.966	65.297	69.269
1997	40.058	45.937	56.996	65.327	69.299
1998	40.088	45.966	57.026	65.357	69.329
1999	40.118	45.996	57.055	65.387	69.359
2000	40.148	46.026	57.085	65.417	69.389

Silent Option

YEAR	SSF	SD	UR	DU	VDU
1976	45.499	51.355	62.744	71.204	75.604
1977	45.577	51.433	62.822	71.282	75.682
1978	45.390	51.244	62.655	71.124	75.549
1979	45.186	51.038	62.474	70.952	75.404
1980	44.665	50.518	61.945	70.420	74.863
1981	44.057	49.911	61.326	69.797	74.227
1982	43.247	49.102	60.508	68.975	73.395
1983	42.223	48.078	59.471	67.932	72.336
1984	40.839	46.697	58.063	66.516	70.890
1985	39.927	45.794	57.036	65.440	69.661
1986	38.742	44.674	55.651	63.969	67.893
1987	38.536	44.418	55.446	63.763	67.687
1988	38.315	44.197	55.224	63.542	67.466
1989	38.362	44.244	55.271	63.598	67.513
1990	38.397	44.279	55.306	63.624	67.548
1991	38.432	44.314	55.341	63.659	67.583
1992	38.467	44.349	55.376	63.694	67.618
1993	38.502	44.384	55.411	63.729	67.653
1994	36.537	44.419	55.446	63.764	67.688
1995	38.567	44.449	55.476	63.793	67.718
1996	38.596	44.479	55.506	63.823	67.748
1997	38.626	44.509	55.536	63.853	67.777
1998	38.656	44.538	55.566	63.883	67.807
1999	38.686	44.568	55.595	63.913	67.837
2000	38.716	44.598	55.625	63.943	67.867

Exhibit 5-D: $L_{dn}A$ (Day-Night Sound Level With Ambient) at 7 m

Baseline Option

YEAR	SSF	SD	UR	DU	VDU
1976	54.574	55.886	63.268	71.286	75.634
1977	54.583	55.914	63.357	71.363	75.711
1978	54.560	55.847	63.210	71.207	75.579
1979	54.536	55.777	63.051	71.038	75.436
1980	54.508	55.695	62.857	70.830	75.256
1981	54.479	55.608	62.648	70.606	75.063
1982	54.443	55.498	62.372	70.308	74.808
1983	54.405	55.383	62.070	69.979	74.530
1984	54.366	55.261	61.737	69.614	74.224
1985	54.363	55.252	61.716	69.594	74.214
1986	54.360	55.242	61.694	69.572	74.203
1987	54.357	55.232	61.671	69.550	74.191
1988	54.354	55.222	61.647	69.526	74.179
1989	54.358	55.234	61.686	69.571	74.225
1990	54.360	55.242	61.715	69.605	74.260
1991	54.363	55.251	61.744	69.639	74.295
1992	54.366	55.260	61.773	69.673	74.329
1993	54.369	55.269	61.803	69.707	74.364
1994	54.372	55.276	61.832	69.742	74.399
1995	54.374	55.285	61.857	69.771	74.428
1996	54.377	55.293	61.882	69.800	74.458
1997	54.379	55.301	61.907	69.829	74.488
1998	54.382	55.308	61.932	69.858	74.517
1999	54.384	55.316	61.957	69.887	74.547
2000	54.387	55.324	61.982	69.916	74.576

Option 1

YEAR	SSF	SD	UR	DU	VDU
1976	54.574	55.886	63.288	71.286	75.634
1977	54.583	55.914	63.357	71.363	75.711
1978	54.560	55.847	63.210	71.207	75.579
1979	54.536	55.777	63.051	71.038	75.436
1980	54.495	55.656	62.713	70.653	75.026
1981	54.451	55.528	62.337	70.218	74.562
1982	54.389	55.339	61.758	69.543	73.858
1983	54.325	55.137	61.071	68.721	72.994
1984	54.258	54.919	60.231	67.677	71.883
1985	54.227	54.817	59.730	67.000	71.058
1986	54.195	54.710	59.151	66.178	70.012
1987	54.178	54.651	58.867	65.787	69.595
1988	54.160	54.589	58.557	65.347	69.123
1989	54.162	54.595	58.587	65.390	69.169
1990	54.163	54.600	58.610	65.422	69.203
1991	54.164	54.604	58.633	65.455	69.237
1992	54.166	54.609	58.656	65.487	69.271
1993	54.167	54.614	58.679	65.520	69.305
1994	54.168	54.618	58.702	65.553	69.339
1995	54.169	54.622	58.722	65.580	69.368
1996	54.171	54.626	58.742	65.608	69.397
1997	54.172	54.630	58.761	65.636	69.426
1998	54.173	54.634	58.781	65.654	69.455
1999	54.174	54.638	58.801	65.692	69.484
2000	54.175	54.642	58.821	65.719	69.513

Exhibit 5-D: $L_{dn}A$ (Day-night sound level with ambient) at 7 m

Option 3

YEAR	SSF	SD	UR	DU	VDU
1976	54.574	55.886	63.288	71.286	75.634
1977	54.583	55.914	63.357	71.363	75.711
1978	54.560	55.847	63.210	71.207	75.579
1979	54.536	55.777	63.051	71.038	75.436
1980	54.508	55.695	62.857	70.830	75.256
1981	54.479	55.608	62.648	70.606	75.063
1982	54.426	55.448	62.183	70.074	74.520
1983	54.370	55.278	61.649	69.452	73.881
1984	54.313	55.096	61.072	68.705	73.110
1985	54.291	55.028	60.717	68.310	72.631
1986	54.269	54.957	60.382	67.866	72.078
1987	54.247	54.883	60.009	67.359	71.430
1988	54.223	54.807	59.592	66.771	70.648
1989	54.226	54.815	59.626	66.815	70.694
1990	54.227	54.821	59.651	66.848	70.728
1991	54.229	54.827	59.677	66.881	70.762
1992	54.231	54.833	59.702	66.915	70.797
1993	54.233	54.839	59.728	66.948	70.831
1994	54.235	54.845	59.754	66.981	70.865
1995	54.236	54.850	59.776	67.010	70.895
1996	54.238	54.856	59.798	67.038	70.924
1997	54.239	54.861	59.820	67.066	70.953
1998	54.241	54.866	59.842	67.095	70.982
1999	54.243	54.872	59.864	67.123	71.012
2000	54.244	54.877	59.886	67.151	71.041

Option 5

YEAR	SSF	SD	UR	DU	VDU
1976	54.574	55.886	63.288	71.286	75.634
1977	54.583	55.914	63.357	71.363	75.711
1978	54.560	55.847	63.210	71.207	75.579
1979	54.536	55.777	63.051	71.038	75.436
1980	54.508	55.695	62.857	70.830	75.256
1981	54.479	55.608	62.648	70.606	75.063
1982	54.418	55.424	62.115	69.998	74.448
1983	54.354	55.227	61.491	69.271	73.712
1984	54.288	55.014	60.741	68.373	72.800
1985	54.257	54.915	60.305	67.811	72.155
1986	54.226	54.812	59.809	67.150	71.378
1987	54.193	54.703	59.234	66.351	70.407
1988	54.160	54.589	58.557	65.347	69.123
1989	54.162	54.595	58.587	65.390	69.169
1990	54.163	54.600	58.610	65.422	69.203
1991	54.164	54.604	58.633	65.455	69.237
1992	54.166	54.609	58.656	65.487	69.271
1993	54.167	54.614	58.679	65.520	69.305
1994	54.168	54.618	58.702	65.553	69.339
1995	54.169	54.622	58.722	65.580	69.368
1996	54.171	54.626	58.742	65.608	69.397
1997	54.172	54.630	58.761	65.636	69.426
1998	54.173	54.634	58.781	65.664	69.455
1999	54.174	54.638	58.801	65.692	69.484
2000	54.175	54.642	58.821	65.719	69.513

Exhibit 5-D: L_{dn}A (Day-night sound level with ambient) at 7 m

Option 7

YEAR	SSF	SD	UR	DU	VDU
1976	54.574	55.886	63.288	71.286	75.634
1977	54.583	55.914	63.357	71.363	75.711
1978	54.560	55.847	63.210	71.207	75.579
1979	54.536	55.777	63.051	71.038	75.436
1980	54.489	55.641	62.674	70.608	74.983
1981	54.441	55.497	62.249	70.118	74.464
1982	54.379	55.306	61.655	69.424	73.741
1983	54.314	55.102	60.949	68.575	72.849
1984	54.246	54.881	60.080	67.488	71.692
1985	54.215	54.778	59.560	66.776	70.823
1986	54.183	54.669	58.953	65.903	69.708
1987	54.172	54.630	58.762	65.637	69.429
1988	54.160	54.589	58.557	65.347	69.123
1989	54.162	54.595	58.587	65.390	69.169
1990	54.163	54.600	58.610	65.422	69.203
1991	54.164	54.604	58.633	65.455	69.237
1992	54.166	54.609	58.656	65.487	69.271
1993	54.167	54.614	58.679	65.520	69.305
1994	54.168	54.618	58.702	65.553	69.339
1995	54.169	54.622	58.722	65.580	69.368
1996	54.171	54.626	58.742	65.608	69.397
1997	54.172	54.630	58.761	65.636	69.426
1998	54.173	54.634	58.781	65.664	69.455
1999	54.174	54.638	58.801	65.692	69.484
2000	54.175	54.642	58.821	65.719	69.513

Silent Option

YEAR	SSF	SD	UR	DU	VDU
1976	54.574	55.886	63.288	71.286	75.634
1977	54.583	55.914	63.357	71.363	75.711
1978	54.560	55.847	63.210	71.207	75.579
1979	54.536	55.777	63.051	71.038	75.436
1980	54.479	55.609	62.592	70.518	74.898
1981	54.419	55.430	62.064	69.909	74.268
1982	54.351	55.218	61.384	69.111	73.445
1983	54.279	54.989	60.555	68.104	72.399
1984	54.205	54.741	59.501	66.752	70.978
1985	54.167	54.611	58.788	65.741	69.777
1986	54.128	54.475	57.914	64.386	68.067
1987	54.122	54.454	57.793	64.199	67.869
1988	54.116	54.432	57.665	63.999	67.657
1989	54.117	54.437	57.692	64.041	67.702
1990	54.118	54.440	57.712	64.073	67.735
1991	54.119	54.443	57.732	64.105	67.769
1992	54.120	54.447	57.753	64.136	67.803
1993	54.121	54.450	57.773	64.168	67.836
1994	54.122	54.454	57.793	64.200	67.870
1995	54.123	54.457	57.811	64.227	67.898
1996	54.123	54.460	57.828	64.254	67.927
1997	54.124	54.463	57.846	64.281	67.956
1998	54.125	54.466	57.863	64.308	67.984
1999	54.126	54.469	57.881	64.335	68.013
2000	54.127	54.472	57.899	64.362	68.042

Exhibit 5-E: LWP and RCI for General Adverse Response

Baseline Option

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	0.0	0.0	575078.9	1174101.0	363450.9	2112629.0	0.0
1977	0.0	0.0	587007.2	1192015.0	368493.9	2147515.0	-1.7
1978	0.0	0.0	561782.6	1155822.0	359902.2	2077506.0	1.7
1979	0.0	0.0	535539.9	1117721.0	350831.4	2004091.0	5.1
1980	0.0	0.0	504287.5	1072097.0	339755.2	1916139.0	9.3
1981	0.0	0.0	472180.8	1024695.3	328243.6	1825119.0	13.6
1982	0.0	0.0	432597.6	964909.4	313535.1	1711031.0	19.0
1983	0.0	0.0	392448.9	902658.4	298174.4	1593281.0	24.6
1984	0.0	0.0	350623.8	837273.1	282124.1	1470020.0	30.4
1985	0.0	0.0	348123.1	833737.4	281615.1	1463475.0	30.7
1986	0.0	0.0	345530.1	830027.7	281070.0	1456627.0	31.1
1987	0.0	0.0	342832.5	826156.6	280479.2	1449468.0	31.4
1988	0.0	0.0	340025.9	822108.0	279856.4	1441989.0	31.7
1989	0.0	0.0	344589.2	829859.3	282211.5	1456659.0	31.0
1990	0.0	0.0	348055.1	835711.7	283988.1	1467754.0	30.5
1991	0.0	0.0	351557.1	841606.8	285778.9	1478941.0	30.0
1992	0.0	0.0	355091.9	847550.1	287576.7	1490218.0	29.5
1993	0.0	0.0	358660.7	853522.1	289388.9	1501570.0	28.9
1994	0.0	0.0	362269.2	859544.4	291212.5	1513025.0	28.4
1995	0.0	0.0	365370.7	864700.0	292772.3	1522842.0	27.9
1996	0.0	0.0	368494.7	869897.6	294343.4	1532735.0	27.4
1997	0.0	0.0	371649.6	875124.6	295922.7	1542696.0	27.0
1998	0.0	0.0	374829.4	880369.7	297507.0	1552706.0	26.5
1999	0.0	0.0	378036.9	885656.7	299102.6	1562795.0	26.0
2000	0.0	0.0	381270.3	890974.5	300706.6	1572950.0	25.5

Exhibit 5-E: LWP and RCI for General Adverse Response

Option 1

YEAR	SSF	SO	UR	DU	VDU	TOTAL	RCI
1976	0.0	0.0	575078.9	1174101.0	363450.9	2112629.0	0.0
1977	0.0	0.0	587007.2	1192015.0	368493.9	2147515.0	-1.7
1978	0.0	0.0	561782.6	1155822.0	359902.2	2077506.0	1.7
1979	0.0	0.0	535539.9	1117721.0	350831.4	2004091.0	5.1
1980	0.0	0.0	482093.4	1034460.8	326095.6	1842649.0	12.8
1981	0.0	0.0	427791.2	947455.4	299933.6	1675179.0	20.7
1982	0.0	0.0	353224.6	825035.6	264003.4	1442263.0	31.7
1983	0.0	0.0	277779.9	694855.4	225291.8	1197927.0	43.3
1984	0.0	0.0	201118.1	555203.6	183061.8	939383.6	55.5
1985	0.0	0.0	162894.0	478194.7	156453.6	797542.4	62.2
1986	0.0	0.0	125178.0	396450.3	127680.4	649308.7	69.3
1987	0.0	0.0	108702.4	361749.2	117535.5	587987.1	72.2
1988	0.0	0.0	91809.5	325627.6	106935.6	524372.6	75.2
1989	0.0	0.0	93358.6	329027.1	107911.4	530297.1	74.9
1990	0.0	0.0	94540.6	331601.4	108648.6	534790.6	74.7
1991	0.0	0.0	95737.6	334197.7	109392.2	539327.5	74.5
1992	0.0	0.0	96950.2	336811.7	110140.3	543902.2	74.3
1993	0.0	0.0	98178.4	339447.1	110892.5	548518.0	74.0
1994	0.0	0.0	99423.6	342099.6	111650.6	553173.8	73.8
1995	0.0	0.0	100498.0	344377.9	112299.7	557175.6	73.6
1996	0.0	0.0	101583.0	346670.9	112953.4	561207.2	73.4
1997	0.0	0.0	102681.4	348975.7	113611.3	565268.4	73.2
1998	0.0	0.0	103791.8	351298.1	114271.2	569361.1	73.0
1999	0.0	0.0	104914.5	353635.4	114935.7	573485.7	72.9
2000	0.0	0.0	106049.2	355987.8	115604.2	577641.2	72.7

Exhibit 5-E: LWP and RCI for General Adverse Response
Option 3

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	0.0	0.0	575078.9	1174101.0	363450.9	2112629.0	0.0
1977	0.0	0.0	587007.2	1192015.0	368493.9	2147515.0	-1.7
1978	0.0	0.0	561782.6	1155822.0	359902.2	2077506.0	1.7
1979	0.0	0.0	535539.9	1117721.0	350831.4	2004091.0	5.1
1980	0.0	0.0	504287.5	1072097.0	339755.2	1916139.0	9.3
1981	0.0	0.0	472180.8	1024695.3	328243.6	1825119.0	13.6
1982	0.0	0.0	407074.4	920251.4	297634.0	1624959.0	23.1
1983	0.0	0.0	340177.4	809628.1	265081.1	1414886.0	33.0
1984	0.0	0.0	273022.5	692481.2	230157.6	1195661.0	43.4
1985	0.0	0.0	243212.4	636738.1	210562.7	1090513.0	48.4
1986	0.0	0.0	213467.7	578651.3	189913.8	982032.8	53.5
1987	0.0	0.0	184074.0	517733.4	167959.3	869766.7	58.8
1988	0.0	0.0	153122.2	453992.6	144540.2	751655.1	64.4
1989	0.0	0.0	155464.1	458566.7	145828.6	759859.4	64.0
1990	0.0	0.0	157246.6	462036.2	146800.6	766083.4	63.7
1991	0.0	0.0	159049.4	465532.1	147780.6	772362.0	63.4
1992	0.0	0.0	160875.3	469052.7	148764.9	778692.9	63.1
1993	0.0	0.0	162720.0	472592.1	149757.6	785069.7	62.8
1994	0.0	0.0	164587.8	476163.2	150756.6	791507.6	62.5
1995	0.0	0.0	166195.2	479210.3	151613.0	797018.5	62.3
1996	0.0	0.0	167820.6	482236.1	152472.4	802529.1	62.0
1997	0.0	0.0	169460.6	485286.3	153338.4	808085.2	61.7
1998	0.0	0.0	171117.3	488348.9	154207.0	813673.2	61.5
1999	0.0	0.0	172790.1	491433.6	155079.1	819302.7	61.2
2000	0.0	0.0	174477.5	494538.1	155950.8	824966.4	61.0

Exhibit 5-E: LWP and RCI for General Adverse Response

Option 5

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	0.0	0.0	575078.9	1174101.0	363450.9	2112629.0	0.0
1977	0.0	0.0	587007.2	1192015.0	368493.9	2147515.0	-1.7
1978	0.0	0.0	561782.6	1155822.0	359902.2	2077506.0	1.7
1979	0.0	0.0	535539.9	1117721.0	350831.4	2004091.0	5.1
1980	0.0	0.0	504287.5	1072097.0	339755.2	1916139.0	9.3
1981	0.0	0.0	472180.8	1024695.3	328243.6	1825119.0	13.6
1982	0.0	0.0	398183.0	906064.1	293837.7	1598084.0	24.4
1983	0.0	0.0	322055.5	779850.7	257041.2	1358947.0	35.7
1984	0.0	0.0	245457.2	645335.8	217305.4	1108098.0	47.5
1985	0.0	0.0	207120.9	571801.6	192656.3	971578.8	54.0
1986	0.0	0.0	168631.4	494421.9	166306.5	829359.8	60.7
1987	0.0	0.0	130097.9	412534.9	137922.4	680555.2	67.8
1988	0.0	0.0	91809.5	325627.6	106935.6	524372.6	75.2
1989	0.0	0.0	93358.6	329027.1	107911.4	530297.1	74.9
1990	0.0	0.0	94540.6	331601.4	108648.6	534790.6	74.7
1991	0.0	0.0	95737.6	334197.7	109392.2	539327.5	74.5
1992	0.0	0.0	96950.2	336811.7	110140.3	543902.2	74.3
1993	0.0	0.0	98178.4	339447.1	110892.5	548518.0	74.0
1994	0.0	0.0	99423.6	342099.6	111650.6	553173.8	73.8
1995	0.0	0.0	100498.0	344377.9	112299.7	557175.6	73.6
1996	0.0	0.0	101583.0	346670.9	112953.4	561207.2	73.4
1997	0.0	0.0	102681.4	348975.7	113611.3	565268.4	73.2
1998	0.0	0.0	103791.8	351298.1	114271.2	569361.1	73.0
1999	0.0	0.0	104914.5	353635.4	114935.7	573485.7	72.9
2000	0.0	0.0	106049.2	355967.8	115604.2	577641.2	72.7

Exhibit 5-E: LWP and RCI for General Adverse Response
Option 7

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	0.0	0.0	575078.9	1174101.0	363450.9	2112629.0	0.0
1977	0.0	0.0	587007.2	1192015.0	368493.9	2147515.0	-1.7
1978	0.0	0.0	561782.6	1155822.0	359902.2	2077506.0	1.7
1979	0.0	0.0	535539.9	1117721.0	350831.4	2004091.0	5.1
1980	0.0	0.0	476064.4	1025217.4	323571.6	1824852.0	13.6
1981	0.0	0.0	415798.8	928378.1	294654.4	1638830.0	22.4
1982	0.0	0.0	340975.7	804982.6	258404.7	1404362.0	33.5
1983	0.0	0.0	265665.2	673670.7	219295.6	1158631.0	45.2
1984	0.0	0.0	189420.1	532672.9	176554.8	898647.7	57.5
1985	0.0	0.0	150905.7	454542.4	149531.9	754980.0	64.3
1986	0.0	0.0	113785.9	371859.7	120204.6	605850.2	71.3
1987	0.0	0.0	102698.4	349068.2	113690.4	565456.9	73.2
1988	0.0	0.0	91809.5	325627.6	106935.6	524372.6	75.2
1989	0.0	0.0	93358.6	329027.1	107911.4	530297.1	74.9
1990	0.0	0.0	94540.6	331601.4	108648.6	534790.6	74.7
1991	0.0	0.0	95737.6	334197.7	109392.2	539327.5	74.5
1992	0.0	0.0	96950.2	336811.7	110140.3	543902.2	74.3
1993	0.0	0.0	98178.4	339447.1	110892.5	548518.0	74.0
1994	0.0	0.0	99423.6	342099.6	111650.6	553173.8	73.8
1995	0.0	0.0	100498.0	344377.9	112299.7	557175.6	73.6
1996	0.0	0.0	101583.0	346670.9	112953.4	561207.2	73.4
1997	0.0	0.0	102681.4	348975.7	113611.3	565268.4	73.2
1998	0.0	0.0	103791.8	351298.1	114271.2	569361.1	73.0
1999	0.0	0.0	104914.5	353635.4	114935.7	573485.7	72.9
2000	0.0	0.0	106049.2	355987.8	115604.2	577641.2	72.7

Exhibit 5-E: LWP and RCI for General Adverse Response
Silent Option

YEAR	SSF	SD	UR	DU	VDD	TOTAL	RCI
1976	0.0	0.0	575078.9	1174101.0	363450.9	2112629.0	0.0
1977	0.0	0.0	587007.2	1192015.0	368493.9	2147515.0	-1.7
1978	0.0	0.0	561782.6	1155822.0	359902.2	2077506.0	1.7
1979	0.0	0.0	535539.9	1117721.0	350831.4	2004091.0	5.1
1980	0.0	0.0	463883.6	1006652.9	318671.8	1789207.0	15.3
1981	0.0	0.0	391643.1	889757.1	284399.9	1565799.0	25.9
1982	0.0	0.0	310289.5	754363.2	244755.2	1309407.0	38.0
1983	0.0	0.0	228452.2	609304.9	201668.4	1039425.6	50.8
1984	0.0	0.0	146960.0	452093.9	154065.7	753119.6	64.4
1985	0.0	0.0	104166.1	357803.4	121853.9	583823.4	72.4
1986	0.0	0.0	63079.5	256642.4	86092.0	405813.9	80.8
1987	0.0	0.0	57861.4	244756.2	82596.1	385213.6	81.8
1988	0.0	0.0	52743.5	232568.1	78966.5	364278.1	82.8
1989	0.0	0.0	53781.9	235087.9	79718.1	368587.9	82.6
1990	0.0	0.0	54575.9	236998.5	80287.7	371862.1	82.4
1991	0.0	0.0	55381.4	238921.8	80861.6	375164.7	82.2
1992	0.0	0.0	56199.9	240861.4	81438.0	378499.3	82.1
1993	0.0	0.0	57031.0	242817.2	82019.5	381867.7	81.9
1994	0.0	0.0	57874.7	244786.7	82604.8	385266.2	81.8
1995	0.0	0.0	58604.1	246479.0	83106.2	388189.3	81.6
1996	0.0	0.0	59343.0	248182.9	83611.4	391137.3	81.5
1997	0.0	0.0	60091.4	249898.1	84119.5	394108.9	81.3
1998	0.0	0.0	60849.3	251623.1	84630.6	397102.9	81.2
1999	0.0	0.0	61617.3	253360.9	85139.9	400118.0	81.1
2000	0.0	0.0	62394.8	255110.9	85647.3	403153.0	80.9

Exhibit 5-F: L_S (Sound Exposure Level) at 7 m

Baseline Option

YEAR	SSF	SD	UR	DU	VDU
1976	99.26	99.23	103.39	105.18	105.75
1977	99.26	99.23	103.39	105.18	105.75
1978	98.99	98.95	103.15	104.94	105.54
1979	98.69	98.65	102.88	104.69	105.32
1980	98.38	98.33	102.60	104.42	105.09
1981	98.04	97.99	102.31	104.14	104.85
1982	97.60	97.55	101.92	103.78	104.54
1983	97.11	97.05	101.51	103.39	104.22
1984	96.56	96.50	101.04	102.95	103.86
1985	96.43	96.36	100.94	102.85	103.78
1986	96.29	96.22	100.82	102.75	103.69
1987	96.15	96.08	100.71	102.64	103.61
1988	96.01	95.94	100.59	102.53	103.52
1989	95.96	95.89	100.55	102.50	103.49
1990	95.91	95.84	100.51	102.46	103.47
1991	95.87	95.79	100.48	102.43	103.44
1992	95.87	95.79	100.48	102.43	103.44
1993	95.87	95.79	100.48	102.43	103.44
1994	95.87	95.79	100.48	102.43	103.44
1995	95.87	95.79	100.48	102.43	103.44
1996	95.87	95.79	100.48	102.43	103.44
1997	95.87	95.79	100.48	102.43	103.44
1998	95.87	95.79	100.48	102.43	103.44
1999	95.87	95.79	100.48	102.43	103.44
2000	95.87	95.79	100.48	102.43	103.44

Option 1

YEAR	SSF	SD	UR	DU	VDU
1976	99.26	99.23	103.39	105.18	105.75
1977	99.26	99.23	103.39	105.18	105.75
1978	98.99	98.95	103.15	104.94	105.54
1979	98.69	98.65	102.88	104.69	105.32
1980	98.23	98.20	102.41	104.21	104.82
1981	97.72	97.68	101.87	103.67	104.26
1982	96.92	96.89	101.06	102.85	103.43
1983	95.95	95.91	100.07	101.85	102.40
1984	94.68	94.65	98.77	100.54	101.06
1985	93.85	93.83	97.81	99.53	99.90
1986	92.81	92.80	96.56	98.20	98.30
1987	92.09	92.08	95.83	97.46	97.55
1988	91.22	91.22	94.95	96.58	96.66
1989	91.08	91.08	94.82	96.44	96.52
1990	90.93	90.93	94.67	96.30	96.38
1991	90.78	90.78	94.52	96.15	96.23
1992	90.78	90.78	94.52	96.15	96.23
1993	90.78	90.78	94.52	96.15	96.23
1994	90.78	90.78	94.52	96.15	96.23
1995	90.78	90.78	94.52	96.15	96.23
1996	90.78	90.78	94.52	96.15	96.23
1997	90.78	90.78	94.52	95.15	96.23
1998	90.78	90.78	94.52	96.15	96.23
1999	90.78	90.78	94.52	95.15	96.23
2000	90.78	90.78	94.52	96.15	96.23

Exhibit 5-F: L_S (Sound Exposure Level) at 7 m

Option 3						Option 5					
YEAR	SSF	SD	UR	DU	VDU	YEAR	SSF	SD	UR	DU	VDU
1976	99.26	99.23	103.39	105.18	105.75	1976	99.26	99.23	103.39	105.18	105.75
1977	99.26	99.23	103.39	105.18	105.75	1977	99.26	99.23	103.39	105.18	105.75
1978	98.99	98.95	103.15	104.94	105.54	1978	98.99	98.95	103.15	104.94	105.54
1979	98.69	98.65	102.88	104.69	105.32	1979	98.69	98.65	102.88	104.69	105.32
1980	98.38	98.33	102.60	104.42	105.09	1980	98.38	98.33	102.60	104.42	105.09
1981	98.04	97.99	102.31	104.14	104.85	1981	98.04	97.99	102.31	104.14	104.85
1982	97.39	97.35	101.66	103.50	104.21	1982	97.30	97.25	101.58	103.42	104.14
1983	96.64	96.60	100.91	102.75	103.46	1983	96.41	96.37	100.71	102.55	103.28
1984	95.73	95.68	100.00	101.84	102.55	1984	95.30	95.25	99.61	101.47	102.22
1985	95.24	95.20	99.44	101.25	101.88	1985	94.58	94.54	98.83	100.66	101.36
1986	94.69	94.66	98.79	100.56	101.09	1986	93.72	93.69	97.88	99.68	100.27
1987	94.06	94.04	98.02	99.74	100.12	1987	92.65	92.62	96.66	98.40	98.83
1988	93.32	93.31	97.09	98.74	98.87	1988	91.22	91.22	94.95	96.58	96.66
1989	93.23	93.23	97.01	98.65	98.79	1989	91.08	91.08	94.82	96.44	96.52
1990	93.14	93.14	96.92	98.57	98.70	1990	90.93	90.93	94.67	96.30	96.38
1991	93.05	93.05	96.83	98.48	98.62	1991	90.78	90.78	94.52	96.15	96.23
1992	93.05	93.05	96.83	98.48	98.62	1992	90.78	90.78	94.52	96.15	96.23
1993	93.05	93.05	96.83	98.48	98.62	1993	90.78	90.78	94.52	96.15	96.23
1994	93.05	93.05	96.83	98.48	98.62	1994	90.78	90.78	94.52	96.15	96.23
1995	93.05	93.05	96.83	98.48	98.62	1995	90.78	90.78	94.52	96.15	96.23
1996	93.05	93.05	96.83	98.48	98.62	1996	90.78	90.78	94.52	96.15	96.23
1997	93.05	93.05	96.83	98.48	98.62	1997	90.78	90.78	94.52	96.15	96.23
1998	93.05	93.05	96.83	98.48	98.62	1998	90.78	90.78	94.52	96.15	96.23
1999	93.05	93.05	96.83	98.48	98.62	1999	90.78	90.78	94.52	96.15	96.23
2000	93.05	93.05	96.83	98.48	98.62	2000	90.78	90.78	94.52	96.15	96.23

Exhibit 5-F: L_S (Sound Exposure Level) at 7 m

Option 7						Silent Option					
YEAR	SSF	SD	UR	DU	VDU	YEAR	SSF	SD	UR	DU	VDU
1976	99.26	99.23	103.39	105.18	105.75	1976	99.26	99.23	103.39	105.18	105.75
1977	99.26	99.23	103.39	105.18	105.75	1977	99.26	99.23	103.39	105.18	105.75
1978	98.99	98.95	103.15	104.94	105.54	1978	98.99	98.95	103.15	104.94	105.54
1979	98.69	98.65	102.88	104.69	105.32	1979	98.69	98.65	102.88	104.69	105.32
1980	98.18	98.15	102.36	104.16	104.78	1980	98.07	98.04	102.26	104.07	104.69
1981	97.61	97.57	101.77	103.56	104.15	1981	97.35	97.32	101.53	103.33	103.95
1982	96.79	96.75	100.93	102.72	103.31	1982	96.40	96.36	100.57	102.38	102.99
1983	95.78	95.74	99.90	101.69	102.25	1983	95.17	95.13	99.34	101.15	101.76
1984	94.46	94.43	98.55	100.32	100.85	1984	93.45	93.42	97.62	99.42	100.03
1985	93.57	93.55	97.53	99.25	99.62	1985	92.08	92.06	96.11	97.85	98.30
1986	92.45	92.45	96.19	97.81	97.89	1986	90.08	90.08	93.76	95.37	95.37
1987	91.88	91.88	95.61	97.24	97.32	1987	89.46	89.46	93.14	94.75	94.76
1988	91.22	91.22	94.95	96.58	96.66	1988	88.74	88.74	92.42	94.03	94.03
1989	91.08	91.09	94.82	96.44	96.52	1989	88.48	88.48	92.17	93.78	93.78
1990	90.93	90.93	94.67	96.30	96.38	1990	88.21	88.21	91.90	93.51	93.51
1991	90.78	90.78	94.52	96.15	96.23	1991	87.93	87.93	91.61	93.22	93.22
1992	90.78	90.78	94.52	96.15	96.23	1992	87.93	87.93	91.61	93.22	93.22
1993	90.78	90.78	94.52	96.15	96.23	1993	87.93	87.93	91.61	93.22	93.22
1994	90.78	90.78	94.52	96.15	96.23	1994	87.93	87.93	91.61	93.22	93.22
1995	90.78	90.78	94.52	96.15	96.23	1995	87.93	87.93	91.61	93.22	93.22
1996	90.78	90.78	94.52	96.15	96.23	1996	87.93	87.93	91.61	93.22	93.22
1997	90.78	90.78	94.52	96.15	96.23	1997	87.93	87.93	91.61	93.22	93.22
1998	90.78	90.78	94.52	96.15	96.23	1998	87.93	87.93	91.61	93.22	93.22
1999	90.78	90.78	94.52	96.15	96.23	1999	87.93	87.93	91.61	93.22	93.22
2000	90.78	90.78	94.52	96.15	96.23	2000	87.93	87.93	91.61	93.22	93.22

Exhibit 5-G: LWP and RCI for Sleep Disturbance

Baseline Option

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RC
1976	155782.75	315156.37	4954231.00	6654873.00	1768332.00	13848375.0	0.
1977	158601.69	320839.44	5040630.00	6750661.00	1787498.00	14058230.0	-1.
1978	152761.31	308850.25	4861377.00	6566643.00	1745696.00	13635327.0	1.
1979	146546.19	296125.44	4673404.00	6371480.00	1701799.00	13189354.0	4.
1980	139176.50	281056.06	4451188.00	6137116.00	1650141.00	12658677.0	8.
1981	131506.31	265404.94	4271657.00	5892739.00	1596557.00	12107864.0	12.
1982	121797.87	245538.62	3933436.00	5581698.00	1528832.00	11411302.0	17.
1983	111653.12	224801.19	3635056.00	5255710.00	1458285.00	10685505.0	22.
1984	101054.62	203149.06	3326475.00	4914045.00	1384738.00	9929461.00	28.
1985	99446.00	199807.50	3282419.00	4866543.00	1374392.00	9822607.00	29.
1986	97767.87	196348.81	3236547.00	4817365.00	1363734.00	9711762.00	29.
1987	96032.06	192768.44	3189195.00	4766353.00	1352734.00	9597082.00	30.7
1988	94236.94	189096.19	3140346.00	4713485.00	1341402.00	9478566.00	31.5
1989	94369.50	189290.44	3146893.00	4723429.00	1343378.00	9497359.00	31.4
1990	94223.06	188958.44	3145088.00	4723299.00	1343263.00	9494831.00	31.4
1991	94066.12	188606.81	3143093.00	4722830.00	1343082.00	9491677.00	31.4
1992	94826.12	190128.25	3167486.00	4752293.00	1349181.00	9553914.00	31.0
1993	95592.37	191661.37	3192060.00	4781889.00	1355285.00	9616487.00	30.5
1994	96366.94	193206.44	3216817.00	4811610.00	1361398.00	9679398.00	30.1
1995	97033.31	194534.12	3238064.00	4837045.00	1366611.00	9733287.00	29.7
1996	97702.69	195869.31	3259443.00	4862573.00	1371832.00	9787420.00	29.3
1997	98375.50	197215.12	3280959.00	4888199.00	1377054.00	9841801.00	28.9
1998	99053.62	198569.44	3302610.00	4913911.00	1382282.00	9896426.00	28.5
1999	99737.31	199933.25	3324396.00	4939717.00	1387511.00	9951294.00	28.1
2000	100425.31	201306.25	3346321.00	4965617.00	1392743.00	10006412.0	27.7

Exhibit 5-6: LWP and RCI for Sleep Disturbance

Option 1

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	155782.75	315156.37	4954231.00	6654873.00	1768332.00	13848375.0	0.0
1977	158601.69	320839.44	5040630.00	6750661.00	1787498.00	14058230.0	-1.52
1978	152761.31	308850.25	4861377.00	6566643.00	1745696.00	13635327.0	1.54
1979	146546.19	296125.44	4673404.00	6371480.00	1701799.00	13189354.0	4.76
1980	135190.12	273245.19	4265750.00	5907142.00	1577910.00	12159237.0	12.20
1981	123344.19	249376.31	3844121.00	5417654.00	1447082.00	11081577.0	19.98
1982	106195.62	214751.37	3262249.00	4733530.00	1270237.00	9586963.00	30.77
1983	88078.75	178162.19	2656740.00	3996370.00	1078711.00	7998061.00	42.25
1984	68800.12	139240.37	2024445.00	3191530.00	867762.00	6291777.00	54.57
1985	58496.56	118623.31	1652379.00	2677757.00	717209.06	5224464.00	62.27
1986	47631.51	96905.69	1265332.00	2118123.00	549606.19	4077598.00	70.56
1987	41377.12	84191.75	1085942.00	1866874.00	486874.31	3565258.00	74.26
1988	34835.82	70894.50	900323.00	1598788.00	419589.94	3024430.00	78.16
1989	34167.30	69531.37	881192.69	1571059.00	412323.44	2968273.00	78.57
1990	33402.54	67970.75	859311.62	1539130.00	404214.12	2904028.00	79.03
1991	32601.98	66338.94	836971.19	1506407.00	395916.87	2838235.00	79.50
1992	32865.36	66874.31	843494.62	1516037.00	397790.31	2857061.00	79.37
1993	33130.91	67413.75	850066.62	1525713.00	399665.81	2875989.00	79.23
1994	33399.41	67957.44	856687.75	1535436.00	401543.69	2895023.00	79.09
1995	33630.39	68424.69	862371.31	1543757.00	403146.25	2911329.00	78.98
1996	33862.37	68894.50	868089.25	1552110.00	404750.12	2927706.00	78.86
1997	34095.52	69368.05	873845.06	1560494.00	406355.56	2944157.00	78.74
1998	34330.60	69844.56	879637.37	1568913.00	407962.37	2960687.00	78.62
1999	34567.56	70324.50	885465.69	1577362.00	409570.81	2977289.00	78.50
2000	34806.00	70807.69	891331.25	1585845.00	411180.37	2993969.00	78.38

Exhibit 5-G: LWP and RCI for Sleep Disturbance

Option 3

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	155782.75	315156.37	4954231.00	6654873.00	1768332.00	13848375.0	0.0
1977	158601.69	320839.44	5040630.00	6750661.00	1787498.00	14058230.0	-1.52
1978	152761.31	308850.25	4861377.00	6566643.00	1745696.00	13635327.0	1.54
1979	146546.19	296125.44	4673404.00	6371480.00	1701799.00	13189354.0	4.76
1980	139176.50	281056.06	4451188.00	6137116.00	1650141.00	12658677.0	8.59
1981	131506.31	265404.94	4221657.00	5892739.00	1596557.00	12107864.0	12.57
1982	116871.37	235835.94	3717557.00	5311107.00	1446186.00	10827557.0	21.81
1983	101498.31	204797.25	3194311.00	4691688.00	1285778.00	9478072.00	31.56
1984	85273.62	172052.25	2649762.00	4027170.00	1113122.00	8047379.00	41.89
1985	77970.37	157502.44	2365785.00	3651896.00	1001435.06	7254588.00	47.61
1986	70371.06	142382.50	2072497.00	3255036.00	882270.25	6422556.00	53.62
1987	62427.48	126579.87	1768762.00	2832545.00	753918.06	5544232.00	59.96
1988	54134.14	110085.12	1454387.00	2378911.00	613586.81	4611103.00	66.70
1989	53737.05	109274.37	1441934.00	2362403.00	608881.87	4576229.00	66.95
1990	53181.89	108137.62	1425753.00	2340363.00	603097.00	4530532.00	67.28
1991	52610.63	106970.44	1408800.00	2317729.00	597189.00	4483299.00	67.63
1992	53035.72	107833.44	1419758.00	2332387.00	599963.81	4512977.00	67.41
1993	53464.23	108703.25	1430798.00	2347109.00	602741.62	4542815.00	67.20
1994	53897.52	109579.69	1441920.00	2361898.00	605522.75	4572817.00	66.98
1995	54270.21	110332.81	1451466.00	2374556.00	607895.31	4598520.00	66.79
1996	54644.60	111090.37	1461072.00	2387261.00	610270.19	4624337.00	66.61
1997	55020.95	111853.81	1470739.00	2400014.00	612646.81	4650273.00	66.42
1998	55400.17	112622.06	1480467.00	2412814.00	615025.62	4676328.00	66.23
1999	55782.54	113395.69	1490257.00	2425664.00	617406.37	4702505.00	66.04
2000	56167.37	114174.62	1500108.00	2438558.00	619788.87	4728796.00	65.85

Exhibit 5-6: LWP and RCI for Sleep Disturbance

Option 5

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	155782.75	315156.37	4954231.00	6654873.00	1768332.00	13848375.0	0.0
1977	158601.69	320839.44	5040630.00	6750661.00	1787498.00	14058230.0	-1.52
1978	152761.31	308850.25	4861377.00	6566643.00	1745696.00	13635327.0	1.54
1979	146546.19	296125.44	4673404.00	6371480.00	1701799.00	13189354.0	4.76
1980	139176.50	281056.06	4451188.00	6137116.00	1650141.00	12658677.0	8.59
1981	131506.31	265404.94	4221657.00	5892739.00	1596557.00	12107864.0	12.57
1982	114659.81	231336.81	3649601.00	5234631.00	1428793.00	10659021.0	23.03
1983	96903.69	195452.56	3054892.00	4529907.00	1248783.00	9125938.00	34.10
1984	78072.19	157406.50	2434958.00	3767849.00	1053406.00	7491691.00	45.90
1985	68096.75	137428.37	2073101.00	3289452.00	917065.87	6485143.00	53.17
1986	57620.52	116465.81	1697911.00	2776086.00	769303.87	5417386.00	60.88
1987	46573.99	94366.69	1307707.00	2218200.00	606136.81	4272983.00	69.14
1988	34835.82	70894.50	900323.00	1598788.00	419589.94	3024430.00	78.16
1989	34167.30	69531.37	881192.69	1571059.00	412323.44	2968273.00	78.57
1990	33402.54	67970.75	859311.62	1539130.00	404214.12	2904028.00	79.03
1991	32601.58	66338.94	836971.19	1506407.00	395916.87	2838235.00	79.50
1992	32865.36	66874.31	843494.62	1516037.00	397790.31	2857061.00	79.37
1993	33130.91	67413.75	850066.62	1525713.00	399665.81	2875989.00	79.23
1994	33399.41	67957.44	856687.75	1535436.00	401543.69	2895023.00	79.09
1995	33630.39	68424.69	862371.31	1543757.00	403146.25	2911329.00	78.98
1996	33862.37	68894.50	868089.25	1552110.00	404750.12	2927706.00	78.86
1997	34095.52	69368.06	873845.06	1560494.00	406355.56	2944157.00	78.74
1998	34330.60	69844.56	879637.37	1568913.00	407962.37	2960687.00	78.62
1999	34567.56	70324.50	885465.69	1577362.00	409570.81	2977289.00	78.50
2000	34806.00	70807.69	891331.25	1585845.00	411180.37	2993969.00	78.38

Exhibit 5-6: LWP and RCI for Sleep Disturbance
Option 7

YEAR	SSF	SD	UR	DO	VDO	TOTAL	RCI
1976	155782.75	315156.37	4954231.00	6654873.00	1768332.00	13848375.0	0.0
1977	158601.69	320839.44	5040630.00	6750661.00	1787498.00	14058230.0	-1.5
1978	152761.31	308850.25	4861377.00	6566643.00	1745696.00	13635327.0	1.5
1979	146546.19	296125.44	4673404.00	6371480.00	1701799.00	13189354.0	4.7
1980	133853.94	270537.44	4222624.00	5859114.00	1566480.00	12052609.0	12.9
1981	120592.94	243794.37	3756077.00	5317499.00	1423118.00	10861081.0	21.5
1982	103336.87	208953.94	3172278.00	4627483.00	1244720.00	9356771.00	32.4
1983	85092.37	172107.94	2564138.00	3882912.00	1051134.00	7755384.00	44.0
1984	65654.37	132861.37	1928260.00	3067944.00	837317.69	6032036.00	56.4
1985	55230.82	112003.75	1553623.00	2545563.00	683969.87	4950389.00	64.2
1986	44221.01	89996.94	1163517.00	1974338.00	512217.25	3784289.00	72.67
1987	39635.86	80664.31	1033993.12	1791514.00	467206.37	3413013.00	75.35
1988	34835.82	70894.50	900323.00	1598788.00	419589.94	3024430.00	78.16
1989	34167.30	69531.37	881192.69	1571059.00	412323.44	2968273.00	78.57
1990	33402.54	67970.75	859311.62	1539130.00	404214.12	2904028.00	79.03
1991	32601.98	66338.94	836971.19	1506407.00	395916.87	2838235.00	79.50
1992	32865.36	66874.31	843494.62	1516037.00	397790.31	2857061.00	79.37
1993	33130.91	67413.75	850066.62	1525713.00	399665.81	2875989.00	79.23
1994	33399.41	67957.44	856687.75	1535436.00	401543.69	2895023.00	79.09
1995	33630.39	68424.69	862371.31	1543757.00	403146.25	2911329.00	78.98
1996	33862.37	68894.50	868089.25	1552110.00	404750.12	2927706.00	78.86
1997	34095.52	69368.06	873845.06	1560494.00	406355.56	2944157.00	78.74
1998	34330.60	69844.56	879637.37	1568913.00	407962.37	2960687.00	78.62
1999	34567.56	70324.50	885465.69	1577362.00	409570.81	2977289.00	78.50
2000	34806.00	70807.69	891331.25	1585845.00	411180.37	2993969.00	78.38

Exhibit 5-G: LWP and RCI for Sleep Disturbance

Silent Option

YEAR	SSF	SO	UR	DU	VDU	TOTAL	RCI
1976	155782.75	315156.37	4954231.00	6654873.00	1768332.00	13848375.0	0.0
1977	158601.69	320839.44	5040630.00	6750661.00	1787498.00	14058230.0	-1.52
1978	152761.31	308850.25	4861377.00	6566643.00	1745696.00	13635327.0	1.54
1979	146546.19	296125.44	4673404.00	6371480.00	1701799.00	13189354.0	4.76
1980	130907.56	264539.31	4131654.00	5759171.00	1543939.00	11830210.0	14.57
1981	114501.50	231402.69	3569806.00	5107823.00	1375579.00	10399112.0	24.91
1982	95407.31	192822.00	2933023.00	4348909.00	1181060.00	8751221.00	36.81
1983	75114.19	151807.31	2268042.00	3522875.00	968010.37	6985848.00	49.55
1984	53319.60	107769.31	1570181.00	2605487.00	728775.12	5065531.00	63.42
1985	40487.97	82025.62	1131744.00	1977040.00	546195.19	3772492.00	72.76
1986	26701.31	54390.75	671470.25	1250841.00	330727.62	2334130.00	83.15
1987	23615.32	48105.52	587782.44	1121485.00	298284.37	2079272.00	84.99
1988	20395.17	41546.61	501831.87	984201.31	263799.56	1811773.00	86.92
1989	19492.48	39708.11	477567.69	945333.62	253664.81	1735765.00	87.47
1990	18510.75	37708.08	451862.69	902708.06	242751.50	1653540.00	88.06
1991	17519.07	35697.99	425225.44	858754.52	231505.37	1568692.00	88.67
1992	17660.62	35976.04	428550.06	864343.56	232636.81	1579166.00	88.60
1993	17803.32	36266.34	431900.00	869959.12	233769.37	1589697.00	88.52
1994	17947.60	36558.91	435274.56	875601.87	234904.00	1600286.00	88.44
1995	18071.76	36810.32	438171.19	880431.19	235872.00	1609356.00	88.38
1996	18196.40	37063.17	441086.50	885281.44	236841.25	1618468.00	88.31
1997	18321.70	37318.05	444020.44	890151.25	237811.69	1627622.00	88.25
1998	18448.00	37574.48	446972.75	895041.31	238783.12	1636819.00	88.18
1999	18575.36	37832.75	449944.56	899951.00	239755.62	1646058.00	88.11
2000	18703.50	38092.72	452935.19	904879.50	240729.06	1655339.00	88.05

Exhibit 5-H: LWP and RCI for Sleep Awakening

Baseline Option

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	125112.31	253299.69	4012619.00	5569369.00	1543902.00	11504302.0	0.0
1977	127379.75	257869.94	4083126.00	5653096.00	1562110.00	11683581.0	-1.56
1978	122685.75	248246.44	3938511.00	5502239.00	1526925.00	11338607.0	1.44
1979	117707.94	238034.50	3786764.00	5341806.00	1489841.00	10974153.0	4.61
1980	111795.44	225934.37	3607101.00	5147231.00	1445442.00	10537503.0	8.40
1981	105635.25	213366.44	3421495.00	4944084.00	1399307.00	10083887.0	12.35
1982	97851.25	197412.81	3188254.00	4684779.00	1340680.00	9508977.00	17.34
1983	89703.87	180759.12	2946746.00	4412637.00	1279499.00	8909345.00	22.56
1984	81204.81	163367.19	2696926.00	4127132.00	1215608.00	8284238.00	27.99
1985	79909.25	160685.56	2661437.00	4088730.00	1207182.00	8197943.00	28.74
1986	78564.56	157909.75	2624487.00	4048897.00	1198476.00	8108334.00	29.52
1987	77170.00	155037.06	2586329.00	4007487.00	1189458.00	8015481.00	30.33
1988	75728.62	152087.69	2546951.00	3964491.00	1180137.00	7919395.00	31.16
1989	75837.56	152246.56	2552488.00	3974427.00	1182549.00	7937548.00	31.00
1990	75721.81	151982.75	2551197.00	3975489.00	1182953.00	7937343.00	31.01
1991	75593.87	151702.75	2549754.00	3976269.00	1183297.00	7936616.00	31.01
1992	76208.44	152927.00	2569715.00	4002318.00	1189192.00	7990360.00	30.54
1993	76825.87	154161.50	2589825.00	4028498.00	1195099.00	8044409.00	30.07
1994	77448.75	155405.75	2610087.00	4054805.00	1201015.00	8098761.00	29.60
1995	77981.62	156473.87	2627479.00	4077332.00	1206068.00	8145334.00	29.20
1996	78519.50	157549.87	2644982.00	4099955.00	1211126.00	8192132.00	28.79
1997	79060.62	158633.12	2662599.00	4122669.00	1216196.00	8239157.00	28.38
1998	79608.37	159723.00	2680327.00	4145481.00	1221269.00	8286408.00	27.97
1999	80156.00	160821.56	2698171.00	4168385.00	1226351.00	8333884.00	27.56
2000	80705.94	161926.31	2716128.00	4191385.00	1231439.00	8381584.00	27.14

Exhibit 5-H: LWP and RCI for Sleep Awakening

Option 1

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	125112.31	253299.69	4012619.00	5569369.00	1543902.00	11504302.0	0.0
1977	127379.75	257869.94	4083126.00	5653096.00	1562110.00	11683581.0	-1.56
1978	122685.75	248246.44	3938511.00	5502239.00	1526925.00	11338607.0	1.44
1979	117707.94	238034.50	3786764.00	5341806.00	1489841.00	10974153.0	4.61
1980	108596.31	219660.69	3456880.00	4954063.00	1382049.00	10121249.0	12.02
1981	99083.75	200491.75	3115578.00	4544919.00	1268027.00	9228099.00	19.79
1982	85327.19	172679.75	2644353.00	3971829.00	1113435.00	7987623.00	30.57
1983	70779.87	143287.31	2153872.00	3353690.00	945735.94	6667364.00	42.04
1984	55308.82	112016.12	1641557.00	2678163.00	760756.75	5247800.00	54.38
1985	47032.31	95448.87	1340070.00	2246946.00	628691.81	4358188.00	62.12
1986	38307.87	77994.62	1026372.81	1776892.00	481483.69	3401050.00	70.44
1987	33284.16	67776.75	880988.56	1566127.00	426510.69	2974686.00	74.14
1988	28029.14	57086.62	730521.44	1341069.00	367475.94	2524181.00	78.06
1989	27493.62	55991.95	715066.25	1318197.00	361274.12	2478022.00	78.46
1990	26879.35	54736.92	697361.56	1291656.00	354273.19	2424906.00	78.92
1991	26235.52	53425.93	679283.25	1264435.00	347101.12	2370480.00	79.39
1992	26448.89	53857.21	684618.31	1272891.00	348899.19	2386714.00	79.25
1993	26663.18	54292.09	689994.31	1281388.00	350701.06	2403038.00	79.11
1994	26879.35	54730.41	695410.50	1289932.00	352506.62	2419458.00	78.97
1995	27064.29	55106.74	700060.00	1297249.00	354048.56	2433528.00	78.85
1996	27250.98	55485.80	704738.62	1304599.00	355593.00	2447667.00	78.72
1997	27438.73	55867.45	709449.00	1311979.00	357140.50	2461874.00	78.60
1998	27628.89	56251.39	714169.25	1319394.00	358690.06	2476153.00	78.48
1999	27818.95	56638.37	718959.81	1326840.00	360242.56	2490499.00	78.35
2000	28009.72	57027.54	723761.31	1334318.00	361797.25	2504913.00	78.23

Exhibit 5-H: LWP and RCI for Sleep Awakening
Option 3

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	125112.31	253299.69	4012619.00	5569369.00	1543902.00	11504302.0	0.0
1977	127379.75	257869.94	4083126.00	5653096.00	1562110.00	11683581.0	-1.56
1978	122685.75	248246.44	3938511.00	5502239.00	1526925.00	11338607.0	1.44
1979	117707.94	238034.50	3786764.00	5341806.00	1489841.00	10974153.0	4.61
1980	111795.44	225934.37	3607101.00	5147231.00	1445442.00	10537503.0	8.40
1981	105635.25	213366.44	3421495.00	4944084.00	1399307.00	10083887.0	12.35
1982	93897.12	189618.94	3013318.00	4457304.00	1268047.00	9022185.00	21.58
1983	81552.31	164687.44	2589541.00	3938347.00	1127811.00	7901938.00	31.31
1984	68535.56	138381.94	2148427.00	3381034.00	976617.06	6712995.00	41.65
1985	62669.02	126694.19	1918406.00	3066492.00	878852.37	6053113.00	47.38
1986	56568.95	114545.50	1680795.00	2733618.00	774388.81	5359915.00	53.41
1987	50190.21	101849.31	1434671.00	2378928.00	661730.94	4627368.00	59.78
1988	43529.95	88593.31	1179862.00	1997793.00	538413.81	3848191.00	66.55
1989	43213.29	87943.50	1169865.00	1984625.00	534565.94	3820211.00	66.79
1990	42768.70	87031.62	1156810.00	1966607.00	529687.44	3782904.00	67.12
1991	42308.86	86094.94	1143135.00	1948077.00	524696.00	3744311.00	67.45
1992	42652.86	86789.81	1152099.00	1960986.00	527368.19	3769895.00	67.23
1993	42998.43	87490.56	1161131.00	1973959.00	530046.06	3795624.00	67.01
1994	43347.07	88196.87	1170231.00	1986997.00	532728.62	3821499.00	66.78
1995	43645.38	88803.19	1178043.00	1998166.00	535019.56	3843676.00	66.59
1996	43946.41	89413.94	1185905.00	2009380.00	537314.06	3865959.00	66.40
1997	44249.17	90028.81	1193818.00	2020644.00	539612.44	3888351.00	66.20
1998	44555.78	90647.44	1201781.00	2031954.00	541914.25	3910852.00	66.01
1999	44862.32	91271.00	1209797.00	2043313.00	544219.50	3933462.00	65.81
2000	45170.04	91898.00	1217863.00	2054721.00	546528.31	3956180.00	65.61

Exhibit 5-H: LWP and RCI for Sleep Awakening
Option 5

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	125112.31	253299.69	4012619.00	5569369.00	1543902.00	11504302.0	0.0
1977	127379.75	257869.94	4083126.00	5653096.00	1562110.00	11683581.0	-1.5
1978	122685.75	248246.44	3938511.00	5502239.00	1526925.00	11338607.0	1.4
1979	117707.94	238034.50	3786764.00	5341806.00	1489841.00	10974153.0	4.61
1980	111795.44	225934.37	3607101.00	5147231.00	1445442.00	10537503.0	8.4
1981	105635.25	213366.44	3421495.00	4944084.00	1399307.00	10083887.0	12.3
1982	92122.12	186004.75	2958248.00	4393014.00	1252765.00	8882153.00	22.7
1983	77864.50	157180.19	2476552.00	3802295.00	1095278.00	7609169.00	33.06
1984	62754.03	126614.62	1974310.00	3162881.00	924074.94	6250633.00	45.67
1985	54741.31	110562.37	1681139.00	2761549.00	804582.56	5412573.00	52.95
1986	46330.39	93716.94	1377100.00	2330526.00	674908.87	4522581.00	60.69
1987	37458.01	75955.94	1060819.00	1861772.00	531549.31	3567553.00	68.99
1988	28029.14	57086.62	730521.44	1341069.00	367475.94	2524181.00	78.06
1989	27493.62	55991.95	715066.25	1318197.00	361274.12	2478022.00	78.46
1990	26879.35	54736.92	697361.56	1291656.00	354273.19	2424906.00	78.92
1991	26235.52	53425.93	679283.25	1264435.00	347101.12	2370480.00	79.39
1992	26448.09	53857.21	684618.31	1272891.00	348899.19	2386714.00	79.25
1993	26663.18	54292.09	689994.31	1281388.00	350701.06	2403038.00	79.11
1994	26879.35	54730.41	695410.50	1289932.00	352506.62	2419458.00	78.97
1995	27064.29	55106.74	700060.00	1297249.00	354048.56	2433528.00	78.85
1996	27250.98	55485.80	704738.62	1304599.00	355593.00	2447667.00	78.72
1997	27438.73	55867.45	709449.00	1311979.00	357140.50	2461874.00	78.60
1998	27628.89	56251.39	714189.25	1319394.00	358690.06	2476153.00	78.48
1999	27818.95	56638.37	718959.81	1326840.00	360242.56	2490499.00	78.35
2000	28009.72	57027.54	723761.31	1334319.00	361797.25	2504913.00	78.23

Exhibit 5-H: LWP and RCI for Sleep Awakening

Option 7

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	125112.31	253299.69	4012619.00	5569369.00	1543902.00	11504302.0	0.0
1977	127379.75	257869.94	4083126.00	5653096.00	1562110.00	11683581.0	-1.5
1978	122685.75	248246.44	3938511.00	5502239.00	1526925.00	11338607.0	1.4
1979	117707.94	238034.50	3786764.00	5341806.00	1489841.00	10974153.0	4.6
1980	107523.75	217485.69	3421945.00	4913724.00	1372019.00	10032697.0	12.7
1981	96875.75	196008.12	3044244.00	4460762.00	1246981.00	9044870.00	21.3
1982	83032.56	168022.44	2571436.00	3882690.00	1091010.00	7796191.00	32.2
1983	68382.62	138423.31	2078814.00	3256286.00	921487.56	6465392.00	43.8
1984	52782.98	106890.31	1563593.00	2574216.00	733984.31	5031466.00	56.2
1985	44409.98	90129.06	1260011.00	2135737.00	599438.69	4129725.00	64.1
1986	35568.82	72441.37	943822.19	1655972.00	448592.19	3156386.00	72.5
1987	31884.82	64939.76	838862.69	1502712.00	409190.06	2847589.00	75.25
1988	28029.14	57086.62	730521.44	1341069.00	367475.94	2524181.00	78.06
1989	27493.62	55991.95	715066.25	1316197.00	361274.12	2478022.00	78.46
1990	26879.35	54736.92	697361.56	1291656.00	354273.19	2424906.00	78.92
1991	26235.52	53425.93	679283.25	1264435.00	347101.12	2370480.00	79.39
1992	26448.89	53857.21	684618.31	1272891.00	348899.19	2386714.00	79.25
1993	26663.18	54292.09	689994.31	1281388.00	350701.06	2403038.00	79.11
1994	26879.35	54730.41	695410.50	1289932.00	352506.62	2419458.00	78.97
1995	27064.29	55106.74	700060.00	1297249.00	354048.56	2433528.00	78.85
1996	27250.98	55485.80	704738.62	1304599.00	355593.00	2447667.00	78.72
1997	27438.73	55867.45	709449.00	1311979.00	357140.50	2461874.00	78.60
1998	27626.89	56251.39	714189.25	1319394.00	358690.06	2476153.00	78.48
1999	27818.95	56638.37	718959.81	1326840.00	360242.56	2490499.00	78.35
2000	28009.72	57027.54	723761.31	1334318.00	361797.25	2504913.00	78.23

Exhibit 5-H: LWP and RCI for Sleep Awakening

Silent Option

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	125112.31	253299.69	4012619.00	5569369.00	1543902.00	11504302.0	0.0
1977	127379.75	257869.94	4083126.00	5653096.00	1562110.00	11683581.0	-1.56
1978	122685.75	248246.44	3938511.00	5502239.00	1526925.00	11338607.0	1.44
1979	117707.94	238034.50	3786764.00	5341806.00	1489841.00	10974153.0	4.61
1980	105159.19	212667.94	3348241.00	4829776.00	1352233.00	9848077.00	14.40
1981	91987.00	186054.25	2893311.00	4284575.00	1205237.00	8661164.00	24.71
1982	76667.50	155063.06	2377555.00	3648531.00	1035074.94	7292890.00	36.61
1983	60372.62	122112.56	1838839.00	2955564.00	848410.37	5825298.00	49.36
1984	42877.42	86724.12	1273329.00	2185348.00	638503.75	4226781.00	63.26
1985	32569.36	66032.19	917983.69	1653448.00	478215.00	3148248.00	72.63
1986	21493.33	43811.96	544820.56	1047612.37	288905.94	1946643.00	83.08
1987	19012.54	38757.15	476990.94	939240.81	260528.81	1734529.00	84.92
1988	16423.91	33481.21	407305.81	824106.81	230317.69	1511634.00	86.86
1989	15699.21	32002.94	387654.12	791728.94	221532.06	1448617.00	87.41
1990	14910.54	30394.59	366818.19	756065.62	212009.62	1380197.00	88.00
1991	14112.36	28768.77	345227.06	719271.00	202187.62	1309566.00	88.62
1992	14227.18	29001.03	347945.19	724150.50	203265.81	1318588.00	88.54
1993	14342.46	29235.24	350684.00	729056.31	204346.50	1327664.00	88.46
1994	14458.77	29471.35	353443.62	733987.94	205429.50	1336790.00	88.38
1995	14558.24	29674.00	355812.87	738212.69	206354.94	1344611.00	88.31
1996	14658.64	29878.21	358197.00	742457.00	207281.81	1352471.00	88.24
1997	14759.65	30093.76	360596.94	746721.56	208210.69	1360371.00	88.18
1998	14861.97	30290.54	363012.00	751003.62	209141.37	1368309.00	88.11
1999	14964.19	30498.98	365443.25	755306.62	210073.56	1376286.00	88.04
2000	15066.77	30708.65	367890.87	759628.56	211007.62	1384301.00	87.97

Exhibit 5-1: LWP and RCI for Outdoor Speech Interference

Baseline Option

YEAR	SSF	SD	UR	DU	VDD	TOTAL	RCI
1976	7245359.00	2078238.00	13101522.0	5922344.00	1281447.00	29628880.0	0.0
1977	7314777.00	2100358.00	13241292.0	5975015.00	1292125.00	29923536.0	-0.99
1978	6937133.00	2002045.00	12689855.0	5780593.00	1258002.00	28667616.0	3.24
1979	6549040.00	1900556.00	12122163.0	5578839.00	1222532.00	27373104.0	7.61
1980	6130489.00	1789587.00	11498627.0	5354152.00	1182549.00	25955376.0	12.40
1981	5702357.00	1675737.00	10862166.0	5122471.00	1141318.00	24504032.0	17.30
1982	5179549.00	1536027.00	10083571.0	4835438.00	1090026.00	22724576.0	23.30
1983	4642726.00	1392197.00	9287383.00	4537817.00	1036861.06	20896960.0	29.47
1984	4090465.00	1243879.00	8472754.00	4228745.00	981636.31	19017472.0	35.81
1985	4028775.00	1228247.00	8393939.00	4200146.00	977222.81	18828320.0	36.45
1986	3966234.00	1212310.00	8313826.00	4170943.00	972695.06	18636000.0	37.10
1987	3902760.00	1196107.00	8232101.00	4141144.00	968057.94	18440160.0	37.76
1988	3838383.00	1179589.00	8148801.00	4110674.00	963318.69	18240752.0	38.44
1989	3864656.00	1187738.00	8201418.00	4132809.00	968100.50	18354704.0	38.05
1990	3884570.00	1193892.00	8241127.00	4149507.00	971703.94	18440784.0	37.76
1991	3904665.00	1200074.00	8281029.00	4166271.00	975317.50	18527344.0	37.47
1992	3924814.00	1206286.00	8321118.00	4183099.00	978941.75	18614240.0	37.18
1993	3945081.00	1212526.00	8361391.00	4199997.00	982576.19	18701568.0	36.88
1994	3965468.00	1218796.00	8401841.00	4216960.00	986221.12	18789264.0	36.58
1995	3982939.00	1224163.00	8436475.00	4231472.00	989336.19	18864368.0	36.33
1996	4000498.00	1229552.00	8471250.00	4246033.00	992458.69	18939776.0	36.08
1997	4018145.00	1234960.00	8506150.00	4260642.00	995588.62	19015472.0	35.82
1998	4035879.00	1240391.00	8541191.00	4275301.00	998725.94	19091472.0	35.56
1999	4053702.00	1245844.00	8576376.00	4290009.00	1001870.69	19167776.0	35.31
2000	4071611.00	1251318.00	8611695.00	4304766.00	1005022.87	19244384.0	35.05

Exhibit 5-I: LWP and RCI for Outdoor Speech Interference

Option 1

YEAR	SSF	SD	UR	DD	VDU	TOTAL	RCI
1976	7245359.00	2078238.00	13101522.0	5922344.00	1281447.00	29628880.0	0.0
1977	7314777.00	2100358.00	13241292.0	5975015.00	1292125.00	29923536.0	-0.99
1978	6937133.00	2002045.00	12689855.0	5780593.00	1258002.00	28667616.0	3.24
1979	6549040.00	1900556.00	12122163.0	5578839.00	1222532.00	27373104.0	7.61
1980	5948427.00	1742095.00	11092035.0	5184065.00	1137934.00	25104528.0	15.27
1981	5331439.00	1578924.00	10037516.0	4772628.00	1049239.00	22769728.0	23.15
1982	4463151.00	1347684.00	8595728.00	4202078.00	928897.94	19537536.0	34.06
1983	3560932.00	1106877.00	7110856.00	3595427.00	799747.37	16173839.0	45.41
1984	2617977.00	854630.06	5576502.00	2943295.00	659228.06	12651632.0	57.30
1985	2171539.00	736591.94	4778886.00	2577429.00	569998.94	10834443.0	63.43
1986	1710221.00	614409.81	3959396.00	2188874.00	473416.69	8946316.00	69.81
1987	1554945.00	548938.25	3586003.00	2019098.00	438519.19	8147503.00	72.50
1988	1283290.00	478494.37	3204295.00	1842273.00	401966.81	7210318.00	75.66
1989	1295350.00	482510.62	3226101.00	1852650.00	404037.06	7260648.00	75.49
1990	1304475.00	485544.94	3242564.00	1860480.00	405597.44	7298660.00	75.37
1991	1313658.00	488594.81	3259104.00	1868340.00	407162.00	7336858.00	75.24
1992	1322901.00	491659.50	3275720.00	1876230.00	408731.19	7375241.00	75.11
1993	1332203.00	494740.12	3292413.00	1884153.00	410304.87	7413813.00	74.98
1994	1341565.00	497835.94	3309182.00	1892107.00	411883.00	7452572.00	74.85
1995	1349594.00	500486.87	3323538.00	1898909.00	413231.81	7485758.00	74.73
1996	1357666.00	503149.31	3337950.00	1905736.00	414583.81	7519084.00	74.62
1997	1365782.00	505822.87	3352418.00	1912586.00	415938.94	7552546.00	74.51
1998	1373943.00	508507.50	3366944.00	1919459.00	417297.50	7586150.00	74.40
1999	1382149.00	511204.06	3381527.00	1926355.00	418659.12	7619894.00	74.28
2000	1390397.00	513911.69	3396166.00	1933274.00	420024.06	7653772.00	74.17

Exhibit 5-1: LWP and RCI for Outdoor Speech Interference

Option 3

YEAR	SSF	SD	UR	DU	[illegible]	TOTAL	RCI
1976	7245359.00	2078238.00	13101522.0	5922344.00	1281447.00	29628880.0	0.0
1977	7314777.00	2100358.00	13241292.0	5975015.00	1292125.00	29923536.0	-0.99
1978	6937133.00	2002045.00	12689855.0	5790593.00	1258002.00	28667616.0	3.24
1979	6549040.00	1900556.00	12122163.0	5578839.00	1222532.00	27373104.0	7.61
1980	6130489.00	1789587.00	11498627.0	5354152.00	1182549.00	25955376.0	12.40
1981	5702357.00	1675737.00	10862166.0	5122471.00	1141318.00	24504032.0	17.30
1982	4952738.00	1476482.00	9604978.00	4633069.00	1038423.31	21705680.0	26.74
1983	4177914.00	1270029.00	8313924.00	4117934.00	929419.44	18809200.0	36.52
1984	3374014.00	1055353.00	6985684.00	3572285.00	813049.06	15800385.0	46.67
1985	3061990.00	973662.69	6390502.00	3307793.00	747131.37	14481078.0	51.13
1986	2742582.00	889856.25	5782511.00	3032416.00	677786.31	13125151.0	55.70
1987	2415167.00	803806.69	5160741.00	2744743.00	604420.56	11728877.0	60.41
1988	2079033.00	715321.00	4524130.00	2442894.00	526190.75	10287568.0	65.28
1989	2096551.00	720790.31	4554158.00	2456383.00	528861.50	10356743.0	65.05
1990	2109797.00	724920.62	4576828.00	2466563.00	530873.81	10408981.0	64.87
1991	2123121.00	729069.87	4599607.00	2476780.00	532891.75	10461468.0	64.69
1992	2136524.00	733238.37	4622487.00	2487037.00	534915.56	10514201.0	64.51
1993	2150005.00	737426.87	4645475.00	2497337.00	536945.44	10567188.0	64.33
1994	2163566.00	741634.94	4668565.00	2507676.00	538980.94	10620421.0	64.16
1995	2175188.00	745236.75	4688333.00	2516521.00	540720.56	10665998.0	64.00
1996	2186867.00	748853.69	4708176.00	2525395.00	542464.25	10711755.0	63.85
1997	2198605.00	752484.37	4728104.00	2534300.00	544212.25	10757705.0	63.69
1998	2210402.00	756129.12	4748104.00	2543234.00	545964.44	10803833.0	63.54
1999	2222257.00	759787.94	4769183.00	2552198.00	547720.69	10850145.0	63.38
2000	2234169.00	763462.31	4788347.00	2561191.00	549481.06	10896650.0	63.22

Exhibit 5-I: LWP and RCI for Outdoor Speech Interference

Option 5

YEAR	SSF	SO	UR	DU	VDU	TOTAL	RCI
1975	7245359.00	2078238.00	13101522.0	5922344.00	1281447.00	29628880.0	0.0
1977	7314777.00	2100358.00	13241292.0	5975015.00	1292125.00	29923536.0	-0.99
1978	6937133.00	2002045.00	12689855.0	5780593.00	1258002.00	28667616.0	3.24
1979	6549040.00	1900556.00	12122163.0	5578839.00	1222532.00	27373104.0	7.61
1980	6130489.00	1769587.00	11498627.0	5354152.00	1182549.00	25955376.0	12.40
1981	5702357.00	1675737.00	10862166.0	5122471.00	1141318.00	24504032.0	17.30
1982	4844859.00	1447427.00	9436713.00	4568621.00	1026080.62	21323696.0	28.03
1983	3955550.00	1210056.00	7970635.00	3982564.00	903322.81	18022112.0	39.17
1984	3028510.00	962106.94	6458713.00	3357196.00	771223.69	14577748.0	50.80
1985	2592136.00	846755.75	5677019.00	3010375.00	688702.87	12814987.0	56.75
1986	2142316.00	727655.31	4875658.00	2645123.00	600752.69	10991504.0	62.90
1987	1677392.00	604343.81	4052462.00	2257699.00	505946.75	9097842.00	69.29
1988	1283290.00	478494.37	3204295.00	1842273.00	401966.81	7210318.00	75.66
1989	1295350.00	482510.62	3226101.00	1852650.00	404037.06	7260648.00	75.49
1990	1304475.00	485544.94	3242564.00	1860480.00	405597.44	7298660.00	75.37
1991	1313658.00	488594.81	3259104.00	1868340.00	407162.00	7336858.00	75.24
1992	1322901.00	491659.50	3275720.00	1876230.00	408731.19	7375241.00	75.11
1993	1332203.00	494740.12	3292413.00	1884153.00	410304.87	7413813.00	74.98
1994	1341565.00	497835.94	3309182.00	1892107.00	411883.00	7452572.00	74.85
1995	1349594.00	500486.87	3323538.00	1898909.00	413231.81	7485758.00	74.73
1996	1357666.00	503149.31	3337950.00	1905736.00	414583.81	7519084.00	74.62
1997	1365782.00	505822.87	3352418.00	1912586.00	415938.94	7552546.00	74.51
1998	1373943.00	508507.50	3366944.00	1919459.00	417297.50	7586150.00	74.40
1999	1382149.00	511204.06	3381527.00	1926355.00	418659.12	7619894.00	74.28
2000	1390397.00	513911.69	3396166.00	1933274.00	420024.06	7653772.00	74.17

Exhibit 5-I: LWP and RCI for Outdoor Speech Interference

Option 7

YEAR	SSF	SD	UR	DU	VBU	TOTAL	RCI
1976	7245359.00	2078238.00	13101522.0	5922344.00	1281447.00	29628880.0	0.0
1977	7314777.00	2100358.00	13241292.0	5975015.00	1292125.00	29923536.0	-0.99
1978	6937133.00	2002045.00	12689855.0	5780593.00	1258002.00	28667616.0	3.24
1979	6549040.00	1900556.00	12122163.0	5578839.00	1222532.00	27373104.0	7.61
1980	5879392.00	1723592.00	10980947.0	5142227.00	1129693.00	24855824.0	16.11
1981	5190388.00	1541042.00	9811809.00	4685853.00	1032028.94	22261104.0	24.87
1982	4317858.00	1308599.00	8365358.00	4110845.00	910669.87	19013312.0	35.83
1983	3410512.00	1066391.00	6875088.00	3498714.00	780210.81	15630915.0	47.24
1984	2461007.00	812366.62	5334090.00	2839292.00	637916.25	12084671.0	59.21
1985	2010500.00	693190.69	4531812.00	2468126.00	547226.87	10250854.0	65.40
1986	1648139.00	572546.06	3706805.00	2072843.00	448676.31	8449009.00	71.48
1987	1467609.00	526081.94	3458027.00	1959430.00	425738.37	7836885.00	73.55
1988	1283290.00	478494.37	3204295.00	1842273.00	401966.81	7210318.00	75.66
1989	1295350.00	482510.62	3226101.00	1852650.00	404037.06	7260648.00	75.49
1990	1304475.00	485544.94	3242564.00	1860480.00	405597.44	7298660.00	75.37
1991	1313658.00	488594.81	3259104.00	1868340.00	407162.00	7336858.00	75.24
1992	1322901.00	491659.50	3275720.00	1876230.00	408731.19	7375241.00	75.11
1993	1332203.00	494740.12	3292413.00	1884153.00	410304.87	7413813.00	74.98
1994	1341565.00	497835.94	3309182.00	1892107.00	411883.00	7452572.00	74.85
1995	1349594.00	500486.87	3323538.00	1898909.00	413231.81	7485758.00	74.73
1996	1357666.00	503149.31	3337950.00	1905736.00	414583.81	7519084.00	74.62
1997	1365782.00	505822.87	3352418.00	1912586.00	415938.94	7552546.00	74.51
1998	1373943.00	508507.50	3366944.00	1919459.00	417297.50	7586150.00	74.40
1999	1382149.00	511204.06	3381527.00	1926355.00	418659.12	7619894.00	74.28
2000	1390397.00	513911.69	3396166.00	1933274.00	420024.06	7653772.00	74.17

Exhibit 5-1: LWP and RCI for Outdoor Speech Interference

Silent Option

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	7245359.00	2078238.00	13101522.0	5922344.00	1281447.00	29628880.0	0.0
1977	7314777.00	2100358.00	13241292.0	5975015.00	1292125.00	29923536.0	-0.99
1978	6937133.00	2002045.00	12689855.0	5780593.00	1258002.00	28667616.0	3.24
1979	6549040.00	1900556.00	12122163.0	5578839.00	1222532.00	27373104.0	7.61
1980	5735386.00	1684836.00	10755658.0	5058072.00	1113739.00	24347664.0	17.82
1981	4894903.00	1461488.00	9353048.00	4510443.00	998548.56	21218416.0	28.39
1982	3936326.00	1205809.00	7779140.00	3879543.00	866122.19	17666928.0	40.37
1983	2934777.00	938098.69	6153705.00	3202650.00	722546.56	13951776.0	52.91
1984	1878769.00	655216.87	4466494.00	2464314.00	563739.94	10028532.0	66.15
1985	1421576.00	510527.69	3517760.00	2013087.00	455474.94	7918424.00	73.27
1986	960105.62	363299.69	2535229.00	1520742.00	334063.50	5713439.00	80.72
1987	1049648.00	352512.31	2404100.00	1457411.00	321241.37	5584912.00	81.15
1988	929914.87	325086.75	2270531.00	1392287.00	308023.37	5225842.00	82.36
1989	937232.06	327802.69	2286521.00	1400334.00	309640.00	5261529.00	82.24
1990	942773.00	329856.69	2298592.00	1406403.00	310858.31	5288482.00	82.15
1991	948353.00	331923.00	2310719.00	1412497.00	312080.00	5315572.00	82.06
1992	953972.81	334001.81	2322904.00	1418615.00	313305.31	5342798.00	81.97
1993	959633.25	336093.12	2335145.00	1424756.00	314534.06	5370161.00	81.88
1994	965333.87	338197.06	2347441.00	1430922.00	315766.56	5397659.00	81.78
1995	970225.62	340000.25	2357967.00	1436198.00	316819.69	5421209.00	81.70
1996	975146.69	341812.87	2368534.00	1441491.00	317875.50	5444859.00	81.62
1997	980097.81	343634.37	2379144.00	1446801.00	318933.56	5468610.00	81.54
1998	985079.37	345465.06	2389795.00	1452130.00	319994.31	5492463.00	81.46
1999	990090.62	347305.31	2400487.00	1457476.00	321057.56	5516415.00	81.38
2000	995131.12	349154.81	2411222.00	1462839.00	322123.25	5540469.00	81.30

Exhibit 5-J: LWP and RCI for Indoor Speech Interference

Baseline Option

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	241099.94	101117.81	260556.62	183666.87	48780.93	835222.12	0.0
1977	245340.94	102814.81	264624.31	186085.25	49220.74	848086.00	-1.54
1978	235436.31	98586.25	253871.00	180172.87	47847.48	815913.87	2.31
1979	225003.94	94142.94	242664.44	174006.62	46416.57	782234.50	6.34
1980	213028.25	89069.12	229990.37	166782.62	44800.62	743671.00	10.96
1981	200410.56	83743.12	216826.12	159285.69	43134.52	703400.00	15.78
1982	184807.06	77158.75	200515.81	149923.37	41059.31	653464.25	21.76
1983	168386.19	70250.06	183887.00	140104.25	38907.61	601535.06	27.98
1984	151337.44	63153.85	166644.44	129858.00	36673.82	547667.50	34.43
1985	150228.31	62572.57	165287.87	129115.44	36489.58	543693.75	34.90
1986	148867.37	61970.14	163892.69	128401.62	36299.95	539431.75	35.41
1987	147455.87	61348.47	162452.62	127603.87	36105.05	534965.81	35.95
1988	145994.25	60704.95	161118.50	126776.69	35905.24	530499.56	36.48
1989	147522.75	61310.99	162607.06	127753.25	36088.79	535282.75	35.91
1990	148682.37	61769.76	163732.25	128489.44	36226.52	538900.31	35.48
1991	149853.12	62231.62	164863.94	129228.06	36364.16	542540.81	35.04
1992	151030.56	62696.75	166002.06	129969.00	36501.70	546200.06	34.60
1993	152216.94	63165.01	167146.69	130712.44	36639.16	549880.19	34.16
1994	153412.31	63636.41	168297.75	131458.19	36776.50	553581.12	33.72
1995	154438.37	64040.84	169283.94	132095.81	36893.48	556752.37	33.34
1996	155471.19	64447.59	170274.87	132735.00	37010.37	559939.00	32.96
1997	156510.62	64856.63	171270.56	133375.87	37127.21	563140.87	32.58
1998	157556.81	65268.05	172271.06	134018.69	37243.94	566358.50	32.19
1999	158609.69	65681.81	173276.19	134663.00	37360.58	569591.25	31.80
2000	159669.44	66098.00	174286.12	135308.94	37477.13	572839.62	31.41

Exhibit 5-1: LWP and RCI for Indoor Speech Interference

Option 1

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	241099.94	101117.81	260556.62	183666.87	48780.93	835222.12	0.0
1977	245340.94	102814.81	264624.31	186085.25	49220.74	848086.00	-1.54
1978	235436.31	98586.25	253871.00	180172.87	47847.48	815913.87	2.31
1979	225003.94	94142.94	242664.44	174006.62	46416.57	782234.50	6.34
1980	207188.00	86709.12	221212.56	161019.31	43000.10	719129.06	13.90
1981	188477.94	78923.56	199001.94	147467.50	39415.66	653286.56	21.78
1982	151706.12	67769.94	168476.44	128411.00	34555.11	560918.56	32.84
1983	133700.50	56106.27	136974.81	108143.19	29340.45	464265.19	44.41
1984	104332.87	43872.98	104439.56	86327.06	23670.97	362643.37	56.58
1985	90737.06	38254.12	87724.81	74176.37	20074.66	310966.94	62.77
1986	76458.62	32361.86	70603.75	61283.26	16188.38	256895.31	69.24
1987	68911.69	29187.27	62808.26	55754.22	14786.67	231448.00	72.29
1988	60945.43	25845.50	55074.68	49908.59	13314.02	205038.06	75.45
1989	61587.81	26107.02	55548.97	50317.48	13390.47	206951.62	75.22
1990	62074.51	26305.03	55945.50	50625.95	13447.91	208398.81	75.05
1991	62564.96	26504.44	56344.48	50935.64	13505.32	209854.75	74.87
1992	63059.25	26705.24	56745.90	51246.60	13562.75	211319.62	74.70
1993	63557.22	26907.48	57149.77	51558.79	13620.17	212793.31	74.52
1994	64059.12	27111.16	57556.12	51872.19	13677.58	214276.06	74.35
1995	64489.89	27285.85	57904.42	52140.25	13726.51	215546.81	74.19
1996	64923.57	27461.60	58254.48	52409.28	13775.43	216824.19	74.04
1997	65360.06	27638.37	58606.43	52679.14	13824.36	218108.25	73.89
1998	65799.37	27816.24	58960.13	52949.87	13873.26	219398.75	73.73
1999	66241.62	27995.14	59315.66	53221.52	13922.16	220696.00	73.58
2000	66[illegible].75	28175.13	59673.06	53494.04	13971.04	221999.87	73.42

Exhibit 5-J: LWP and RCI for Indoor Speech Interference

Option 3

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	241099.94	101117.81	260556.62	183666.87	48780.93	835222.12	0.0
1977	245340.94	102814.81	264624.31	186085.75	49220.74	848086.00	-1.54
1978	235436.31	98586.25	253871.00	180172.87	47847.48	815913.87	2.31
1979	225003.94	94142.94	242664.44	174006.62	46416.57	782234.50	6.34
1980	213028.25	89069.12	229990.37	166782.62	44800.62	743671.00	10.96
1981	200410.56	83743.12	216826.12	159285.69	43134.52	703400.00	15.78
1982	177478.94	74185.56	190296.69	143043.31	38975.41	623979.87	25.29
1983	153361.00	64151.62	162798.69	125878.94	34571.53	540761.69	35.26
1984	128370.81	53744.96	134594.06	107576.00	29871.75	454157.56	45.62
1985	119072.19	49914.93	122163.50	98831.44	27207.18	417189.12	50.05
1986	109262.75	45887.05	109266.75	89637.44	24407.98	378461.87	54.69
1987	99149.75	41736.55	96229.62	80076.06	21449.18	338641.06	59.45
1988	88904.00	37524.57	82708.25	70036.50	18293.73	297467.00	64.38
1989	89836.75	37901.94	83487.06	70596.56	18394.37	300218.62	64.06
1990	90547.06	38187.66	84076.00	71018.87	18469.91	302299.44	63.81
1991	91260.75	38475.34	84668.44	71442.75	18545.43	304392.62	63.56
1992	91980.00	38765.04	85264.44	71868.25	18620.93	306498.56	63.30
1993	92704.62	39056.71	85864.00	72295.25	18696.39	308616.94	63.05
1994	93434.81	39350.46	86467.06	72723.87	18771.84	310748.00	62.79
1995	94061.62	39602.38	86983.94	73090.44	18836.11	312574.44	62.58
1996	94692.56	39855.85	87503.37	73458.06	18900.36	314410.12	62.36
1997	95327.56	40110.78	88025.44	73826.75	18964.59	316255.06	62.14
1998	95966.81	40367.19	88550.12	74196.69	19028.78	318109.56	61.91
1999	96610.12	40625.15	89077.37	74567.62	19092.95	319973.19	61.69
2000	97257.62	40884.57	89607.31	74939.69	19157.08	321846.25	61.47

Exhibit 5-1: LWP and RCI for Indoor Speech Interference

Option 5

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	241099.94	101117.81	260556.62	183666.87	48780.93	835222.12	0.0
1977	245340.94	102814.81	264624.31	186085.25	49220.74	848086.00	-1.54
1978	235436.31	98586.25	253871.00	180172.87	47847.48	815913.87	2.31
1979	225003.94	94142.94	242664.44	174006.62	46416.57	782234.50	6.34
1980	213028.25	89069.12	229990.37	166782.62	44800.62	743671.00	10.96
1981	200410.56	83743.12	216826.12	159285.69	43134.52	703400.00	15.78
1982	173997.94	72736.44	186653.87	140853.19	38477.03	612718.44	26.64
1983	146392.81	61235.94	155379.56	121278.12	33518.12	517804.50	38.00
1984	117467.81	49188.13	123236.75	100337.31	28184.32	418414.31	49.90
1985	103961.94	43614.86	106793.81	88742.37	24853.93	367966.81	55.94
1986	90187.31	37922.43	89946.19	76579.75	21307.62	315943.19	62.17
1987	75727.94	31955.88	72687.37	63686.24	17490.23	261547.56	68.69
1988	60945.43	25845.50	55024.68	49908.59	13314.02	205038.06	75.45
1989	61587.81	26107.02	55548.97	50317.48	13390.47	206951.62	75.22
1990	62074.51	26305.03	55945.50	50625.95	13447.91	208398.81	75.05
1991	62564.96	26504.44	56344.48	50935.64	13505.32	209854.75	74.87
1992	63059.25	26705.24	56745.90	51246.60	13562.75	211319.62	74.70
1993	63557.22	26907.48	57149.77	51558.79	13620.17	212793.31	74.52
1994	64059.12	27111.16	57556.12	51872.19	13677.58	214276.06	74.35
1995	64489.89	27285.85	57904.42	52140.25	13726.51	215546.81	74.19
1996	64923.57	27461.60	58254.48	52409.28	13775.43	216824.19	74.04
1997	65360.06	27638.37	58606.43	52679.14	13824.36	218108.25	73.89
1998	65799.37	27816.24	58960.13	52949.87	13873.26	219398.75	73.73
1999	66241.62	27995.14	59315.66	53221.52	13922.16	220696.00	73.58
2000	66686.75	28175.13	59673.06	53494.04	13971.04	221999.87	73.42

Exhibit 5-J: LWP and RCI for Indoor Speech Interference

Option 7

YEAR	SSF	SD	UR	DU	VOU	TOTAL	RCI
1976	241099.94	101117.81	260556.62	183666.87	48780.93	835222.12	0.0
1977	245340.94	102814.81	264674.31	186085.25	49220.74	848086.00	-1.54
1978	235436.31	98686.25	253871.00	180172.87	47847.48	815913.87	2.31
1979	225003.94	94142.94	242664.44	174006.62	46416.57	782234.50	6.34
1980	204975.06	85790.31	218815.50	159602.12	42667.20	711850.19	14.77
1981	183947.69	77111.25	194129.62	144524.25	38720.71	638433.50	23.56
1982	157038.12	65827.44	163506.12	125317.62	33819.20	545508.50	34.69
1983	128878.56	54099.23	131900.44	104867.44	28552.21	448297.81	46.33
1984	99336.50	41792.05	99255.62	82881.75	22812.03	346077.87	58.56
1985	85623.37	36122.65	82462.69	70496.75	19157.96	293863.37	64.82
1986	71421.81	30252.20	65264.93	57397.39	15194.66	239530.87	71.32
1987	66252.56	28077.79	60114.33	53756.60	14273.63	222474.81	73.36
1988	60945.43	25845.50	55024.68	49909.59	13314.02	205038.06	75.45
1989	61587.81	26107.02	55548.97	50317.48	13390.47	206951.62	75.22
1990	62074.51	26305.03	55945.50	50625.95	13447.91	208398.81	75.05
1991	62564.96	26504.44	56344.48	50935.64	13505.32	209854.75	74.87
1992	63059.25	26705.24	56745.90	51246.60	13562.75	211319.62	74.70
1993	63557.22	26907.48	57149.77	51558.79	13620.17	212793.31	74.52
1994	64059.12	27111.16	57556.12	51872.19	13677.58	214276.06	74.35
1995	64489.89	27285.85	57904.42	52140.25	13726.51	215546.81	74.19
1996	64923.57	27461.60	58254.48	52409.28	13775.43	216824.19	74.04
1997	65360.06	27638.37	58606.43	52679.14	13824.36	218108.25	73.89
1998	65799.37	27816.24	58960.13	52949.87	13873.26	219398.75	73.73
1999	66241.62	27995.14	59315.66	53221.52	13922.16	220696.00	73.58
2000	66686.75	28175.13	59673.06	53494.04	13971.04	221999.87	73.42

Exhibit 5-J: LWP and RCI for Indoor Speech Interference
Silent Option

YEAR	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	241099.94	101117.81	260556.62	183666.87	48780.93	835222.12	0.0
1977	245340.94	102814.81	264624.31	186085.25	49220.74	848086.00	-1.5
1978	235436.31	98586.25	253871.00	180172.87	47847.48	815913.87	2.3
1979	225003.94	94142.94	242664.44	174006.62	46416.57	782234.50	6.3
1980	200361.94	83966.62	213956.44	156752.19	42022.86	696960.00	16.5
1981	174661.75	73156.87	184372.25	138578.19	37368.79	608137.81	27.1
1982	145005.56	60799.03	151024.75	117535.31	32021.12	506385.69	39.3
1983	113881.56	47830.73	116565.19	94912.25	26226.21	399415.87	52.1
1984	81117.75	34169.09	80938.94	70258.31	19827.76	286311.81	65.7
1985	64256.11	27178.04	61203.12	55323.49	15473.11	223433.69	73.2
1986	46757.07	19915.91	41218.70	39237.11	10616.46	157745.12	81.11
1987	44227.80	18837.98	38564.14	37199.46	10098.96	148928.25	82.1
1988	41432.28	17655.14	35864.56	35190.79	9574.64	139717.31	83.27
1989	41869.94	17834.83	36211.05	35486.09	9632.37	141034.25	83.11
1990	42201.56	17970.89	36473.19	35708.95	9675.75	142030.25	82.99
1991	42535.75	18107.92	36736.98	35932.77	9719.14	143032.50	82.87
1992	42872.56	18245.94	37002.44	36157.55	9762.55	144040.94	82.75
1993	43211.90	18384.93	37269.59	36383.30	9805.98	145055.56	82.63
1994	43553.91	18524.92	37538.41	36610.00	9849.43	146076.56	82.51
1995	43847.47	18645.03	37768.90	36804.00	9886.46	146951.81	82.41
1996	44143.04	18765.86	38000.59	36998.68	9923.51	147831.56	82.30
1997	44440.52	18887.42	38233.55	37194.06	9960.56	148715.94	82.19
1998	44739.97	19009.70	38467.75	37390.12	9997.62	149605.00	82.09
1999	45041.36	19132.73	38703.18	37586.87	10034.68	150498.75	81.98
2000	45344.70	19256.51	38939.89	37784.31	10071.74	151397.06	81.87

SECTION 6

NOISE CONTROL TECHNOLOGY

INTRODUCTION

There are four main sources of noise on a truck-mounted solid waste compactor. These are:

1. Truck chassis,
2. Power take-off (PTO),
3. Hydraulic pump,
4. Impact between components.

The control of truck chassis noise is not addressed by this study, but the garbage truck manufacturer has control over chassis noise in the compaction cycle by his specification of the engine speed during compaction. A significant reduction in noise can be achieved by restricting the maximum engine speed during the compaction cycle.

The transmission power take-off currently used on most compactor trucks produces an obtrusive whine. Alternative designs and types of PTO will be discussed that greatly reduce or eliminate this whine. The hydraulic pump can also make a measurable amount of noise and on some trucks a noise reduction can be achieved by employing a quiet pump. Methods for reducing the noise from impacts between components by means of cushioning these impacts will be discussed.

It has been found that the hydraulic lines and valves on a garbage truck generally make very little noise. In a properly designed system, there is some very slight flow noise from control valves and that is all. Sometimes a valve or very sharp bend may produce flow cavitation and hence noise. However, this is easily cured with a large valve or bend radius. Measurements have been made of the hydraulic system noise of a truck body on which no special precautions had been taken to reduce the hydraulic system noise. The lines were hard bolted to the body and there was no hydraulic accumulator. In spite of this, the noise was very difficult to measure and insignificant (less than 60 dBA at 7 m) when compared with the noise from the rest of the truck. Thus, it appears unnecessary to address further the matter of quieting hydraulic lines and valves.

Three stages of noise control treatment will be discussed for the steady noise levels. These are:

Stage 1 - Reduction of engine speed to 1200 rpm maximum.

Stage 2 - Elimination or redesign of transmission power take-offs in conjunction with reduced engine speed.

Stage 3 - Quieting the hydraulic pump in addition to the above.

These noise control treatments will be considered in conjunction with a chassis noise control program and the combined noise levels presented. Reduction of impact noise by hydraulic and rubber cushions will also be discussed.

STAGE 1 - ENGINE SPEED REDUCTION TO 1200 RPM

The speed at which the engine is operated during the compaction cycle is currently determined by the cycle time desired and the size of the hydraulic pump. Typically, truck engines run between 1200 and 1800 rpm and employ a pump of about 5 cubic inches/revolution displacement (about 20 gallons per minute (gpm) at 1,000 rpm). The speed of the engine while the truck is compacting is set to a nominal value by the manufacturer, but the operator can, and sometimes does, reset the cycle speed to any value he desires. Thus, the manufacturer's speed may not have any particular meaning.

Speed controls

There are a number of different types of engine speed controls available. The simplest is a solenoid or an electropneumatic cylinder which advances the throttle linkage by a preset amount when the "compactor cycle" button is pressed. Other speed controls are pneumatic governors and electronic governors. However, none of these governors are tamper-proof and all can be reset by the operator. Further, most front loading garbage trucks do not have any form of automatic speed control. The engine speed during cycling is controlled only by the operator's foot. Therefore, the hardware required for this level of noise reduction consists of two items:

1. An electro-pneumatic throttle control or some other form of governor. Since governors are usually installed on most compactor trucks, except for the front loaders, this requirement will relate primarily to front loaders. Governors are not usually installed on front loaders since the cab operator is able to control both the loading cycle and engine speed.
2. A larger hydraulic pump is needed if the same cycle time is to be achieved with a lower engine speed. For example, if a 20 gpm at 1,000 rpm pump is currently used at an engine speed of 1800 rpm, then a 30 gpm at 1,000 rpm pump will be required for an engine speed of 1200 rpm to achieve the same volume flow rate.

An engine speed of 1200 rpm was chosen since this is typically the slowest idle speed to which a gasoline engine can be set and yet not have the engine stall during the compaction cycle. An engine which is set to a no-load speed of 1200 rpm will lose speed to about 1,000 rpm when it comes under load. Typically, an engine is required to produce 20 hp, but in some cases 40 hp may be required. Most truck engines rated at 200 hp or more are capable of delivering 40 hp at 1,000 rpm.

The simplest types of governors allow a substantial speed drop, as mentioned above. More sophisticated governors, such as some of the electronic governors, permit much smaller speed losses. However, diagnostic measurements show that there is no noise difference between the case when the engine is closely regulated to 1050 rpm with or without load, and the case when the engine is set to 1200 rpm under no load and its speed allowed to drop under load. Accordingly, there is little to be gained in noise control by installing the better governor. However, it can help in preventing the engine from stalling under load.

Noise levels

Table 3-3 in Section 3 presented the mean sound levels of 45 truck-mounted solid waste compactors. The noise generated by a power take-off driven from an automatic transmission has been analyzed. The noise level at 1200 rpm was 74 dBA at 7 m (as compared to 79 dBA at an engine speed of 1800 rpm). Table 6-1 predicts the overall levels to be expected for 7 trucks which were considered. The chassis noise level, as a function of any noise regulation, has been combined with an assumed transmission power take-off noise level of 74 dBA at 7 m to give the overall noise level of the truck while cycling. An engine speed of 1200 rpm has been assumed for most trucks. However, on some of the larger diesel powered trucks, it has been supposed that the engine can be slowed down to 1,000 rpm. With no chassis noise regulated, no truck can be quieter than 78 dBA at 7 m. However, with an 80 dBA chassis regulation, all trucks can

TABLE 6-1

OVERALL NOISE LEVELS UNDER STAGE 1 of NOISE CONTROL (TRANSMISSION PTO = 74 dBA at 7m)

				Overall Noise Levels at 7 m Chassis Regulation dBA			
Truck	Fuel	RPM	Unreg.	83*	80	78	75
1	Diesel	1200	82	77	76	75	75
2	Diesel	1000	82	77.5	76	75.5	74.5
3	Diesel	1200	80	76.5	75	75	74.5
4	Diesel	1000	81	77.5	76	75.5	74.5
5	Diesel	1000	79.5	77.5	76	75.5	74.5
6	Diesel	1200	80	77	75.5	75	74.5
7	Gasoline	1200	78	78	74.5	74.5	74

*This assumes actual truck-noise level 2.5 dB below regulatory level

Source: Reference 6-1.

meet a 76 dBA noise level at 7 m. Figure 6-1 illustrates further these quieted noise levels based on different chassis regulations. More recent information submitted by chassis manufacturers essentially corroborates these data (Ref. 6-3 and 6-4).

Four trucks were measured which incorporated this noise control method. They all met a noise level of 76 dBA at 7 m. Three of the trucks were gasoline powered and operated with engine speeds of 1200 rpm or less. These three were all rear loaders. One diesel-powered side loader also met this noise level, but it employed a front power take-off instead of the noisier transmission power take-off. In addition, this engine was only operated at 900 rpm during its compaction cycle.

Fuel savings

One consequence of the lower engine speed during cycling is that the truck engine will consume less fuel. These savings come about because the engine has to do less work overcoming internal friction, even though it develops the same power externally. Estimates have been made for the fuel savings to be expected for both diesel and gasoline engines, which are rated at 200 hp yet are only developing 20 to 40 hp during cycling.

TABLE 6-2

FUEL SAVINGS DUE TO REDUCED ENGINE rpm

Engine	Rated hp	Utilized hp	Standard rpm	Reduced rpm	Fuel Savings gal/hr
Gasoline	200	20	1800	1200	0.33
Diesel	200	20	1500	1000	0.55

Source: Reference 6-1.

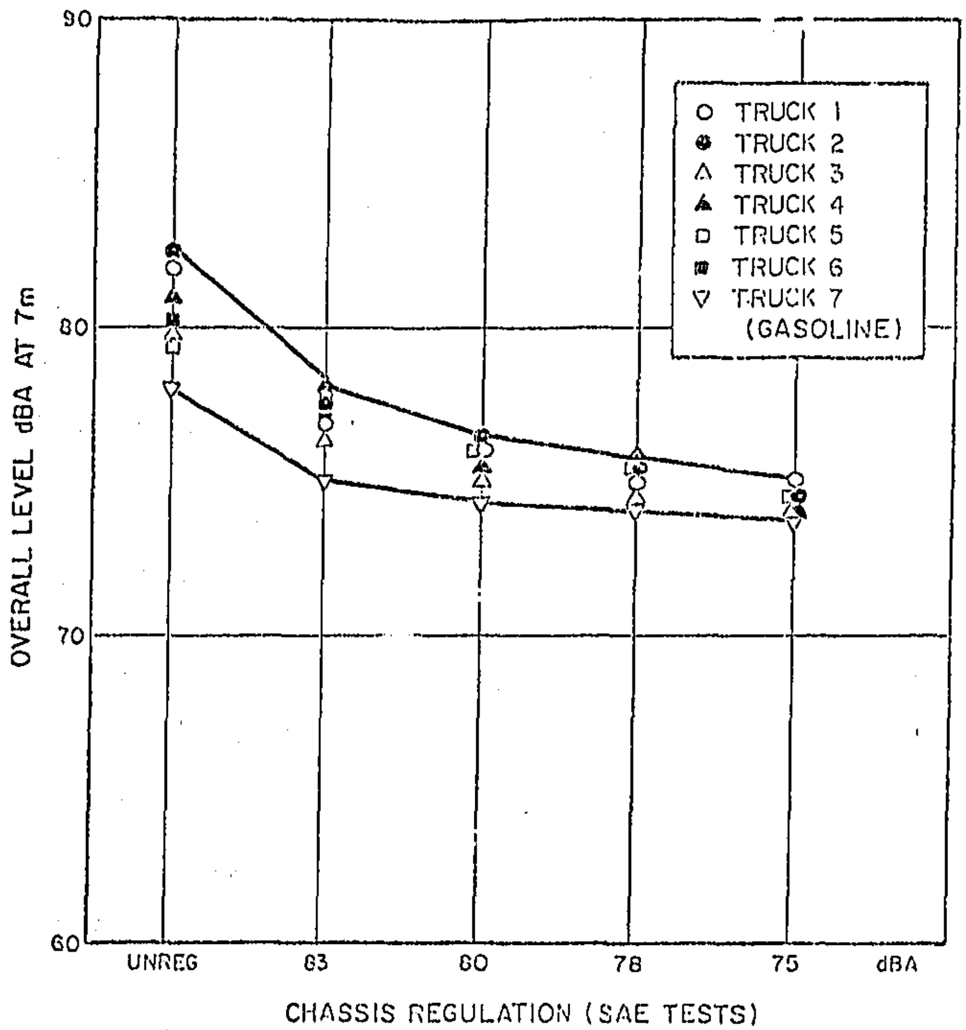


FIGURE 6-1

OVERALL NOISE LEVEL UNDER STAGE 1 OF NOISE CONTROL

Source: Reference 6-1.

The fuel savings are larger on diesel engines than on gasoline engines because the former have more internal friction. If we suppose that the trucks are cycling 25 percent of the time for an 8-hour day, then the fuel savings are 2/3 gallon/day on a gasoline powered truck and 1 gallon/day on a diesel powered truck.

Conclusions

A noise level of 76 dBA at 7 m can be achieved for a refuse collection vehicle primarily by slowing the engine down to 1200 rpm or less. This requires an automatic engine throttle control which exists on most compactor trucks at present, except for front loaders. In these cases, an automatic throttle limit will be required. In order to retain the productivity of the truck, a larger hydraulic pump is needed for these lower engine speeds. An overall noise level of 76 dBA at 7 m can be achieved during the compaction cycle only when this noise reduction measure is used on a chassis which has been quieted to some extent.

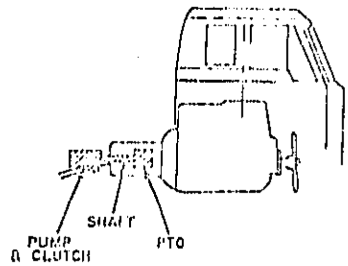
STAGE 2 - ENGINE SPEED REDUCTION AND REDESIGN OR ELIMINATION OF THE TRANSMISSION PTO

In order to reduce the noise of compacting garbage trucks below that of Stage 1, the power take-off noise must be reduced in addition to reducing the speed of the engine. Under Stage 1, the overall noise was dominated by the transmission power take-off gear at 74 dBA. There does not appear to be any simple way to reduce this noise, which is the source of the whine heard from compacting garbage trucks. Previously, it was found that vibrations from the gears were transmitted quite extensively throughout the truck chassis. Thus, large areas of the chassis and transmission as well as the PTO would have to be wrapped with sound deadening material if this were to be selected as a means of reducing the noise. Therefore, enclosing it in a sound absorbing enclosure is not considered to be a practical means of reducing PTO noise.

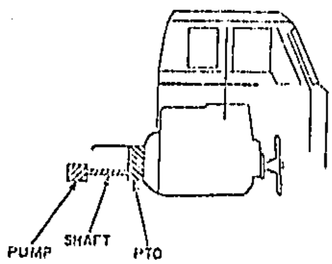
One manufacturer of automatic transmissions for trucks is currently researching the source and means of reducing the noise from transmission PTOs. Since the tooth design of the PTO goes back over 40 years and is very stubby by modern standards, they are considering a finer tooth design or helical gear teeth with the prospect of generating less noise. However, at this time it is not known what the outcome of this study will be, nor how much noise reduction is possible by redesign of the PTO gears. Other types of PTO which do not make as much noise as the conventional transmission PTO are discussed below and are illustrated in Figure 6-2.

Front Power Take-off

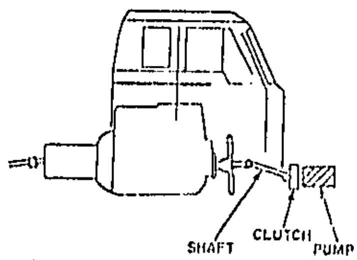
One such quieter power take-off which has been tried by a number of manufacturers is the "Front Power Take-off." This takes the power from the front end of the engine crankshaft. A double-jointed shaft couples the crankshaft with the hydraulic pump which is installed on the front bumper of the truck. This arrangement is similar to that employed on cement mixer trucks. On diesel engines, the drive can be direct, but on gasoline engines, which can rotate at up to 4,000 rpm, a clutch must be installed between the engine and pump in order to prevent the pump from overspeeding. Most hydraulic pumps cannot be driven above approximately 2,800 rpm.



(a) Transmission-Mounted PTO



(b) Flywheel PTO



(c) Front PTO

FIGURE 6-2

ARRANGEMENTS FOR POWER TAKE-OFF

Source: Reference 6-1.

Company E reported that they had reliability problems with an electric clutch on a front power take-off when installed on trucks. This was also confirmed by Company F. However, Company G claims very good reliability for their pneumatic-hydraulic clutch (Figure 6-3). This clutch comes in several gear ratios: 0.5, 0.75, 1.0 and 1.25. One compactor truck manufacturer says that he prefers the 0.75:1 ratio with the pump running at only 75 percent of engine speed. This would still prevent the pump from overspeeding should the clutch be engaged with the engine at all but the highest rpm. Electric interlocks can be installed to prevent pump overspeeding and are supplied by Company H. This will disconnect the pump should the engine exceed a certain preset rpm.

Front power take-offs have been used on front, rear, and side loaders. There do not appear to be any inherent problems in the use of front PTOs. Even the clearance problems on front loaders due to the mounting of the pump on the front bumper can be overcome by lengthening the loading arms. One major manufacturer, Company I, offered front power take-offs on their "quieted" trucks.

A problem with a front power take-off is that the drive shaft has to pass through the radiator. This generally requires either the raising of the radiator for clearance, or cutting a hole in the radiator for the drive shaft. Some truck manufacturers do offer front-mounted PTO options on their medium trucks. Company J offers a front PTO option on two of its lines of trucks. However, it is called a "Limited Production Option" which requires a long lead time and special tooling charges. Company E and Company K (private communication) are also planning to offer a front PTO option on some of their medium trucks.

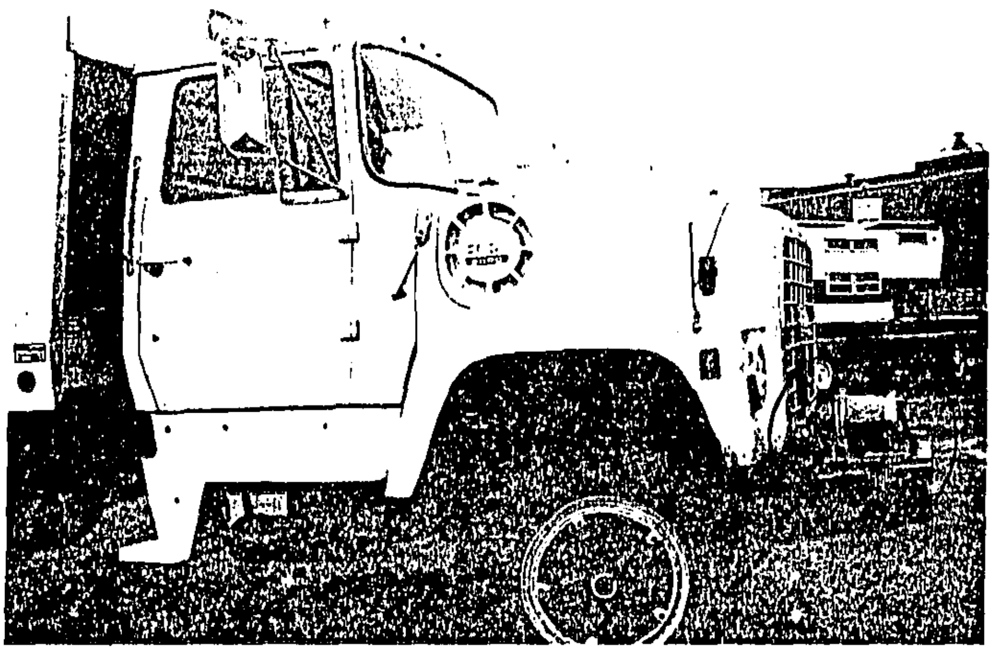


FIGURE 6-3

FRONT POWER TAKE-OFF

Source: Reference 6-1.

Flywheel Power Take-off

An alternative type of power take-off which has been used successfully is the "Flywheel Power Take-off" (Figure 6-4). This is a PTO inserted between the engine crankcase and transmission. It is about 8-1/2 inches long and weighs 180 lbs. It is currently available only on Company L engines. This PTO did not make any noise that could be discerned from the chassis noise on the trucks that were measured. There was no whine of the PTO gears as with transmission PTOs. This is presumably because the gears are all mounted in one integral housing and are correctly aligned. Thus, a compactor truck manufacturer who employs a Company L chassis need not employ any special hardware to achieve Stage 2 quieting other than to employ a quieted version of the chassis and regulate the engine speed, during compaction, by the engine's own governor.

Company K has also supplied a flywheel power take-off on a number of their chassis. It is not currently available, but they have supplied it on Company M gasoline engines and Company N diesel engines. They have used a toothed belt, driven off the engine flywheel, to drive the hydraulic pump. This appears to be a very reliable system and has been in service in San Francisco for over eighteen months.

Noise Levels

A direct drive PTO does not, of itself, make any significant noise. If the PTO is geared, then it may make some noise; but since the gears are a modern design and are incorporated in an integral housing, they are not expected to make any significant noise. The main source of

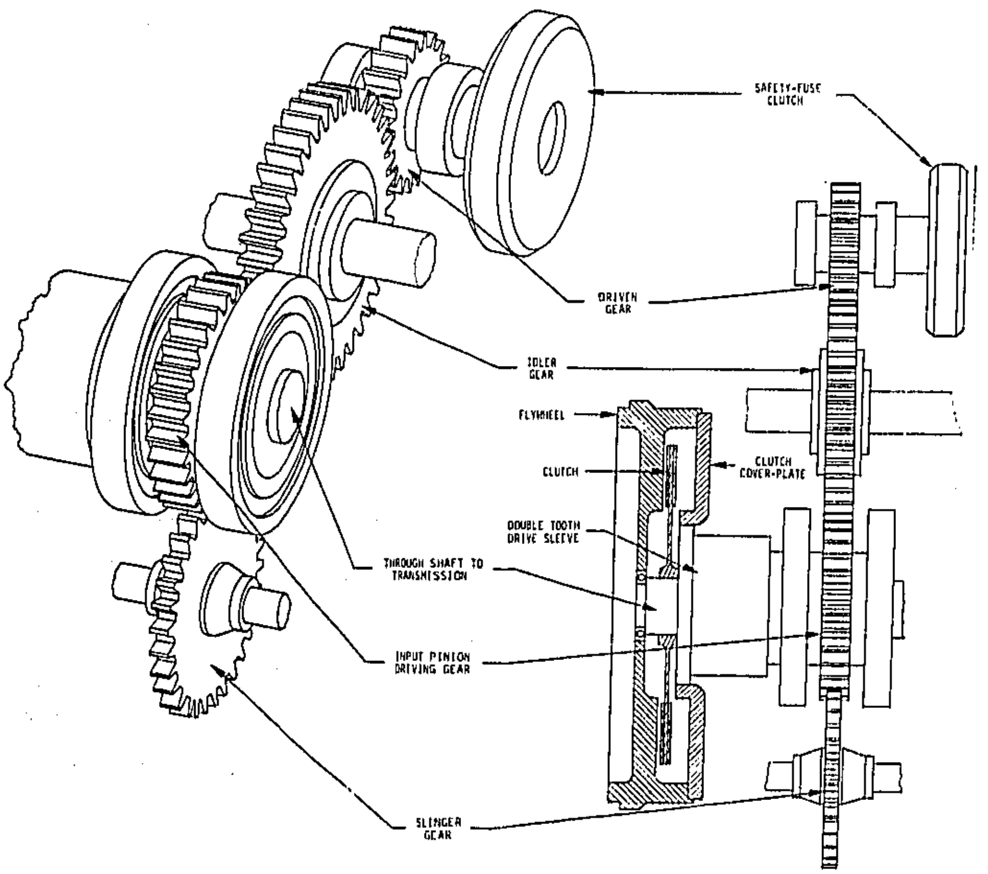


FIGURE 6-4

FLYWHEEL POWER TAKE-OFF

Source: Reference 6-1.

noise comes from the chassis, with some from the hydraulic pump. In the diagnostic study, the noise level of a Company O pump at 1,000 rpm was 64 dBA at 7 m.

Table 6-3 shows the predicted overall noise levels of vehicles with unregulated and regulated chassis. The unregulated vehicles are all well over 75 dBA at 7 m, but under an 80 dBA chassis noise regulation, all vehicles generate less than 72 dBA at 7 m, with the gasoline-powered vehicles generating 67.5 dBA. The largest diesel engines have sufficient power that they can be slowed down to 1,000 rpm, as was done on a Company D side loader with a Company N diesel engine. The levels are also illustrated in Figure 6-5.

The fuel savings with a front PTO and reduced engine speed are expected to be the same as for reduced engine speed (Stage 1) alone.

One truck has already been measured with this Stage 2 noise control treatment. This was a Company I truck with the quieted option and a Company J gasoline engine. The noise level measured was 69 dBA at 7 m.

Conclusions

By combining a reduction of engine speed to 1200 rpm or below, and elimination or redesign of the transmission power take-off, the sound level of compactor trucks can be reduced to 72 dBA at 7 m.

STAGE 3 - STAGE 2 PLUS A QUIET PUMP AND 75 dBA CHASSIS

Under Stage 2 of noise control, the main noise sources are the hydraulic pump, which generates 64 dBA of noise at 7 m, and the chassis. When regulated for 80 dBA under the SAE J366b test, the chassis gives a noise level of less than 70 dBA at 7 m during the compaction cycle.

TABLE 6-3

OVERALL NOISE LEVELS UNDER STAGE 2 OF NOISE CONTROL (HYDRAULIC PUMP = 64 dBA at 7 m)

				Overall Noise Levels at 7 m Chassis Regulation (dBA)			
Truck	Fuel	RPM	Unreg.	83	80	78	75
1	Diesel	1200	81	74.5	71	70	68
2	Diesel	1000	81	75.5	72	71	68
3	Diesel	1200	80	73	70	69	67
4	Diesel	1000	80	75.5	72	70.5	68
5	Diesel	1000	78	75.5	72	71	69
6	Diesel	1200	78	74.5	71	70	67.5
7	Gasoline	1200	76	70	67.5	67.5	66

Source: Reference 6-1.

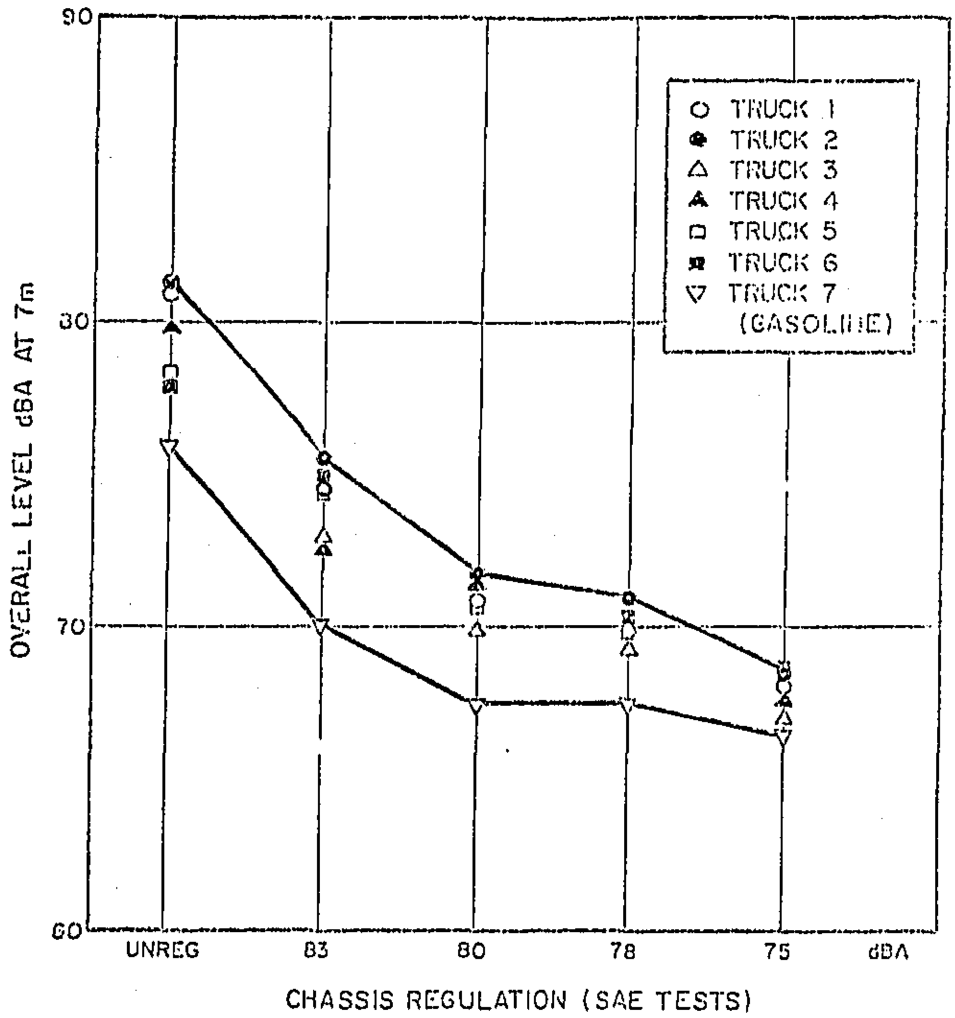


FIGURE 6-5

OVERALL NOISE LEVEL UNDER STAGE 2 OF NOISE CONTROL

Source: Reference 6-1

If the truck chassis were regulated for 75 dBA under the SAE J366b test, then the noise level would be 65 dBA or less during the compaction cycle. At this level, the truck chassis and hydraulic pump would generate very similar noise levels (65 and 64 dBA at 7 m, respectively). Further noise reduction can now be achieved by using a quiet pump.

Quiet Pumps

There are a number of proprietary quiet pumps on the market. One very successful design is a German patent being marketed by Company P (Figure 6-6). This design uses an outer gear and a smaller eccentric gear inside. The two are spaced by a cam. This type of gear pump is particularly quiet. Noise levels of less than 55 dBA at 1,000 rpm and 7 m can be obtained. Company Q has also developed quiet versions of their vane pumps.

An alternative means of quieting the pump is to enclose it. This would require building a sheet steel box around the pump with seals around the holes of the drive shaft and hydraulic lines. The box would be lined on the inside with acoustic foam and would be mounted on the chassis frame and not the pump. The pump would be isolated from the chassis frame to reduce vibrations. This technique should give at least a 10 dBA reduction in noise from a standard pump.

Noise Levels

Table 6-4 predicts the expected overall noise levels of the solid waste compactor trucks with Stage 3 noise control treatment. Significant differences from Stage 2 only occur when the Stage 3 treatment is

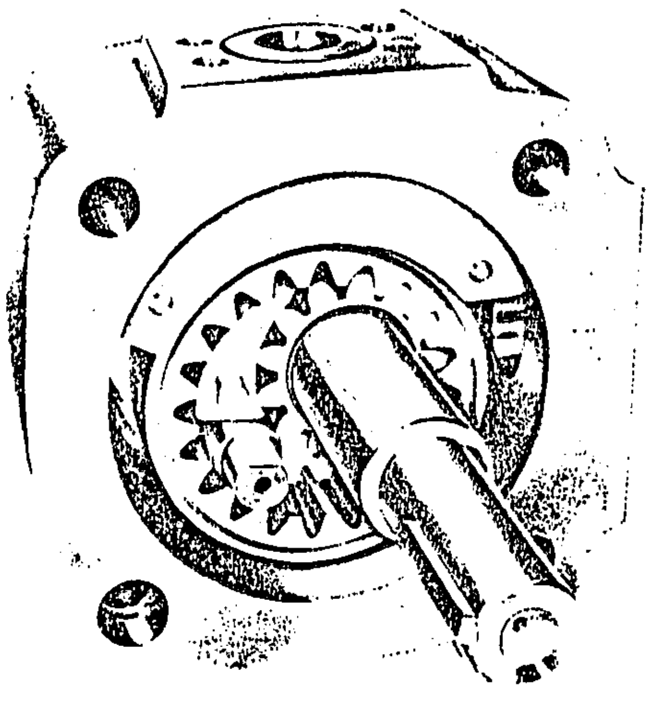


FIGURE 6-5

A QUIET HYDRAULIC PUMP DESIGN

Source: Reference 6-1.

TABLE 6-4

OVERALL NOISE LEVELS UNDER STAGE 3 OF NOISE CONTROL (HYDRAULIC PUMP = 55 dBA at 7 m)

Truck	Fuel	RPM	Unreg.	Overall Noise Levels at 7 m Chassis Regulation (dBA) 83	80	78	75
1	Diesel	1200	81	74	70	69	66.5
2	Diesel	1000	81	75	71	71	67
3	Diesel	1200	80	72.5	69	68	64.5
4	Diesel	1000	80	75	71	69.5	65
5	Diesel	1000	78	75	71	70	66.5
6	Diesel	1200	78	74	70	69.5	65.5
7	Gasoline	1200	76	69	65.5	65.5	62

Source: Reference 6-1.

combined with a 75 dBA chassis regulation. Then all trucks are quieter than 67 dBA at 7 m and the gasoline powered truck is 62 dBA at 7 m. These data are illustrated in Figure 6-7.

Auxiliary Engines

A number of compactor trucks drive their hydraulic systems from auxiliary gasoline engines mounted on the truck body, rather than using the main truck engine. These engines are typically water cooled, four cylinder engines that run on the same fuel as the main truck engine. They usually displace between 100 and 172 cubic inches and are considerably underrated for this application. Air-cooled diesel engines have also been used as auxiliary engines on garbage trucks.

Only one truck with an auxiliary engine was measured. It had a Company R gasoline engine and generated 81 dBA at 7 m. These engines are also used to drive the larger engine generator sets used in recreational vehicles and boats. Some manufacturers produce specially enclosed, low noise engines. This is a very important selling point in the recreation industry. Noise levels as low as 66 dBA at 1 m (equivalent to 50 dBA at 7 m) have been quoted verbally by the manufacturer. This is a very low level, and well below any noise level to which chassis powered equipment can be quieted. Thus, it appears to be well within the state-of-the-art to build an acoustic enclosure around a water cooled auxiliary engine which will make it at least as quiet as any chassis powered equipment. Air-cooled engines may be more difficult to quiet, however.

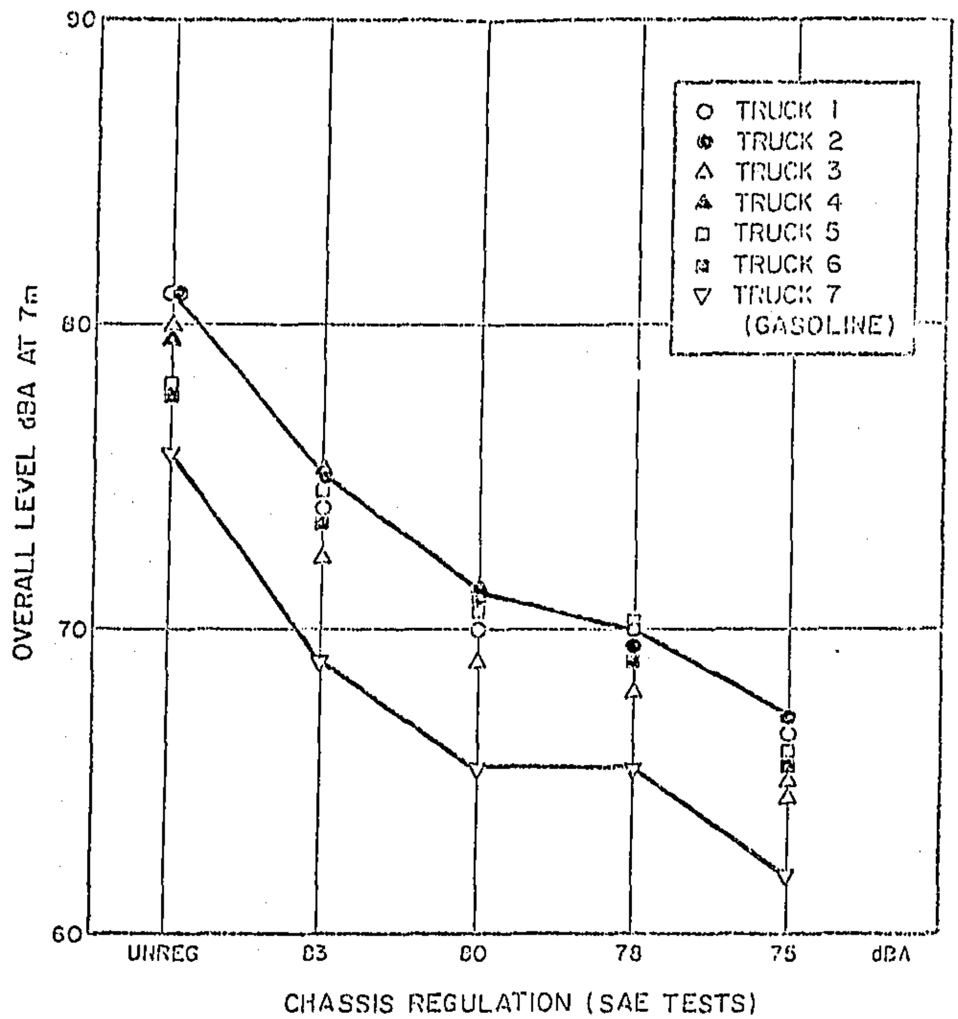


FIGURE 6-7

OVERALL NOISE LEVEL UNDER STAGE 3 OF NOISE CONTROL

Source: Reference 6-1.

Quieting of Impact Noise

There are a number of sources of impact noises which occur during the loading and compacting cycles. Garbage cans hit against the loading hopper; hydraulic cylinders bottom while performing the compaction; the container and forks of a front loader bang; and container covers bang. Although the quieting of the containers is not strictly within the scope of a compactor noise regulation, it is pertinent here to comment briefly on techniques that are expected to provide some reduction in impact noise.

- o Garbage can impacts on rear and side loaders can be minimized by covering the edge of the loading hopper with a 1/2 inch thick rubber strip, or by use of plastic garbage cans.
- o On rear loading compactor trucks, one significant source of noise is the impact of the hydraulic cylinders as they "bottom" at the end of their stroke. Typically, the piston is driven to the end of the cylinder which it strikes and a peak noise level of approximately 90-100 dBA may be observed. A commonly used technique to lessen the impact is to install "cushions" inside the cylinders at the end of the stroke. Inexpensive cushions are made of rubber, but are not very durable. A more durable mechanism is a pin on each side of the piston, which engages the hydraulic oil exit port as the piston nears the end of its stroke. This gradually shuts off the flow of oil and slows down the piston. Figure 6-8 shows a cutaway view of a hydraulic cylinder with these cushions installed. The cushions are standard items and

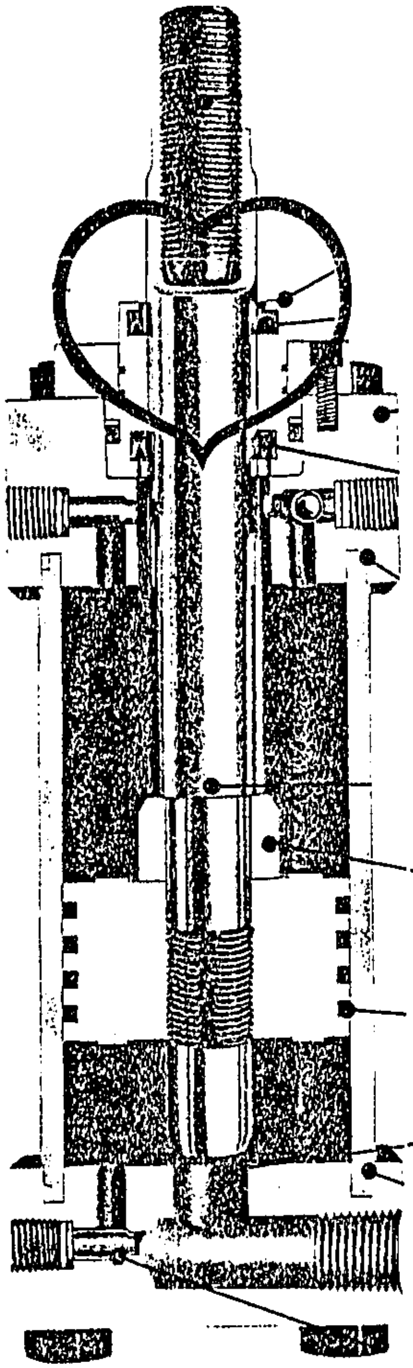


FIGURE 6-8

HYDRAULIC CYLINDER WITH CUSHIONS

Source: Reference 6-1.

are recommended by the manufacturer for all applications with piston speeds in excess of 20-25 ft/min (manufacturer's literature). Company C rear loaders do not require cushions since their cylinders do not bottom; rather, the stroke is reversed electrically before it has bottomed. There is no evidence that cylinder bottoming is a significant source of noise in side and front loaders and therefore, these do not require cushions. Hydraulic cushions may be required on rear loading compactor trucks. There are two compacting cylinders on each truck, requiring a cushion at each end. Thus four cushions would be required on each truck. The hydraulic cylinders are between 3 inches and 5-1/2 inches bore, depending on the truck model.

- Banging of a container takes place while it is being lifted and dumped on the arms of the front loader. One of the best ways of reducing this noise is to coat the container with a damping material in order to damp its noise. In addition, some noise reduction might be obtained by coating the front loader arms with an epoxy damping material. Although this does not produce much damping, it may lessen the impacts themselves. It is not clear, however, how durable such an epoxy compound would be under such severe service.
- At the end of a front loader cycle, the lid covering the hopper is allowed to drop fairly rapidly and creates a large impact. This impact can be minimized by riveting a 1/2-inch rubber seal around the hopper mouth in order to cushion the impact. Damping of the container lid also would help to reduce impact noise.

In summary, there is a great deal which can be applied to lessen impact noise on garbage trucks: hydraulic cushions, rubber edgings or stops, and epoxy or other damping compounds.

CONCLUSIONS

There are three stages, or levels, of noise control which can be applied to compacting garbage truck bodies. The first stage is to restrict the engine speed during cycling to 1200 rpm or less. This reduces both engine and power take-off noise. Many rear and side loading trucks already have automatic engine speed controls, but front loaders do not. These will require the installation of an engine speed control.

The second stage of noise control is the quieting of the power take-off. Either the transmission power take-off can be redesigned (although this is not widely available now) or different types of power take-offs can be used. A "front power take-off" is connected to the front of the engine crankshaft. This type is quiet but requires extending the front bumper and a special radiator with a hole for the drive shaft. This radiator (with associated fan modifications) is available from some truck chassis manufacturers with some engine combinations. A "flywheel power take-off" is available on all Company L diesel engines, and Company K has engineered a design for Company M gasoline and Company N diesel engines that can also be adapted to other engines. In addition, at least one manufacturer of power take-offs is reported to be developing a new flywheel PTO (Ref. 6-2).

The final stage of noise control is to use a quiet hydraulic pump. There are a number of proprietary designs available.

The use of truck compactor noise control levels must be coordinated with truck chassis noise regulations. The noise control measures will not be very effective by themselves unless the chassis are also quieted. The resulting overall noise level will then be a function of the level of noise control for both the compactor body and the chassis.

Impact sounds can be reduced by a variety of techniques which vary with the source. The bottoming of the hydraulic cylinders can be quieted by installing hydraulic cushions. Areas where impacts occur with garbage cans or container lids can be covered with rubber edgings and the noise appropriately reduced.

REFERENCES
Section 6

6-1. "Noise Control/Technology for Specialty Trucks (Solid Waste Compactors)", Bolt, Beranek and Newman, Inc., BBN Draft Report 3249, February 1976.

6-2. Letter from D.F. Thomas, Waterous Company, to Fred Mintz, EPA, dated December 15, 1976.

6-3. Letter from E.G. Ratering, General Motors Corporation, to Henry E. Thomas, EPA, dated February 20, 1978.

6-4. Letter from W.E. Schwieder, Ford Motor Company, to Henry E. Thomas, EPA, dated May 18, 1978.

SECTION 7

ECONOMIC ANALYSIS

The three different noise emission standards for truck mounted compactor bodies are analyzed in this section from two points of view: first, the additional costs associated with achieving each specified stage of quieting are examined, and second, the various economic impacts expected to result from achieving each stage are pointed out. The various stages of quieting relate to specific options which have been considered by EPA.

COST ANALYSIS*

Estimates of the costs incurred in achieving three different stages of quieting for compactor bodies are presented in this section. The categories of costs considered include: direct material and labor costs; overhead costs; and, maintenance and operating costs.

Direct Material and Labor Cost Estimates

Stage 1. Cost Estimates

The Stage 1 quieting technology consists of governing the engine speed to a maximum of 1,200 revolutions per minute during the compaction cycle. To estimate the cost of this treatment, the following assumptions have been made:

1. The general design and capacity of side and rear loading compactors are similar and it is not necessary to distinguish between the two for costing purposes. A review of component systems (i.e.,

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* The methodology used in developing the costs in this section is presented in Section 7 Exhibit.

hydraulics) and discussions with manufacturers of both types of vehicles validated this assumption.

2. The existing governors on side and rear loading vehicles can be adjusted to achieve the desired engine speed.

3. A speed control device will have to be installed on front loading vehicles.

4. The size of the hydraulic pump or the gear ratio of the power take-off unit on all three vehicle configurations will be increased to preserve the existing flow rates and compaction cycle times.

5. Special treatment will not be required to prevent tampering with speed control components.

The side and rear loading vehicle configurations will require only minimal modifications to achieve Stage 1 treatment. Engine speed controls are already standard equipment on these vehicles since they are necessary to operate the compaction cycle from the side or rear of the vehicle. It is assumed that these governors can be calibrated to 1,200 rpm and are sufficiently sensitive to prevent engine stalling. Therefore, no appreciable material cost is estimated for the speed control aspects of Stage 1.

Slowing the engine speed will reduce the hydraulic flow rate and thus slow the compaction cycle on these vehicles. To sustain productivity, a larger hydraulic pump or a higher ratio PTO will be required. The additional capacity needed will vary with the size of the compactor unit, but the incremental material cost for the average vehicle is estimated to range between $200 and $300.

The additional labor cost for Stage 1 treatment of side and rear loaders is estimated to be approximately $70. This amount represents roughly nine direct labor hours, which should be adequate allowance for the minor modifications involved.

Stage 1 treatment for front loading vehicles is more extensive than that for the other two configurations. Existing models do not have engine governors since the speed of the engine is regulated by the driver. Thus, it will be necessary to install a speed control device along with necessary instrumentation and hardware components. The system must maintain an engine speed of 1,200 rpm and lock out the engine accelerator in the cab. The cost for the governor and associated hardware will range between $300 and $500 depending upon the type of chassis and engine.

As with the other two vehicle categories, the hydraulic pump capacity or PTO gear ratio must be increased to preserve compaction cycle times. Again, depending upon the size of the pump, the additional cost will range between $250 and $300 per unit.

The additional labor cost will vary depending on whether the engine governor is ordered with the chassis or must be installed by the compactor manufacturer, but it is estimated to range between $100 and $200.

Stage 2. Cost Estimates

The Stage 2 quieting technology consists of employing alternate methods of power take-off (PTO) from the engine. An EPA sponsored study has indicated that the design of the transmission PTO is unsuitable for effective noise control. Two alternatives are: the flywheel PTO and the direct drive, crankshaft PTO.

The flywheel PTO option is effective in noise reduction but, at the present time, is limited in availability from chassis manufacturers. Company L is the only manufacturer which offers the flywheel PTO as a standard option. Some other chassis manufacturers offer the flywheel PTO as a special option. An independent component manufacturer was also identified which manufactures a flywheel PTO which can be applied to other makes of medium and heavy duty truck chassis.

The front mounted, direct drive, crankshaft PTO is effective in noise reduction but is also limited in availability. Only a few truck chassis are on the market which are designed to accommodate a front mounted power take-off unit and, because these have been designed primarily for the cement mixer market, they are much bigger and heavier than the chassis normally used for solid waste compactors. Chassis which are not designed for the front PTO must undergo extensive modification to extend the frame in front and to provide clearance for the pump to crankshaft coupling.

This makes the front PTO an impractical alternative for front loading trucks. Not only is the required frame extension on the front of the vehicle too long to allow safe clearance between the container forks and the frame extension of the front loading truck, but the cab, frame and radiator modifications required on the cab over engine used with front loaders are so extensive as to be impractical.

The cost estimates for Stage 2 treatment are based on the following assumptions:

1. Stage 1 noise control treatment has been implemented.

2. Side and rear loading vehicles are again assumed to be the same for costing purposes.

3. The most cost effective treatment for side and rear loading vehicles is the front mounted, crankshaft power take-off. (Some end users may elect to purchase Company L chassis with the flywheel PTO option but this would generally be a more expensive alternative and not really indicative of actual quieting costs.)

4. The most cost effective treatment for quieting front loading vehicles appears to be the flywheel PTO option.

The cost associated with Stage 2 treatment for side and rear loading vehicles consists of three major elements: radiator modification, frame extension, and hydraulic system components. Each of these cost elements is described in the following paragraphs.

The radiator modification consists of cutting a hole in the radiator to provide clearance for the driveshaft connecting the crankshaft to the hydraulic pump assembly. Most chassis manufacturers do not currently make modifications of this nature. Therefore, the compactor body manufacturers must assume responsibility for this modification. Since radiator work is a specialized process which most compactor manufacturers are not equipped to handle, it is assumed that the radiator will be removed from the truck chassis and sent to a subcontractor for modification. The additional cost incurred in this operation will range between $150 and $250 per vehicle.

The frame extension consists of extending the basic frame of the chassis by 18 inches to 24 inches to provide a front mount location for the hydraulic pump assembly. It is assumed that most compactor body manufacturers will fabricate the necessary structural components in-house. The basic materials required are steel channel, steel sheet and miscellaneous hardware. The cost of material required will vary according to chassis type and size, but should not exceed $100 to $150 per unit.

The hydraulic system components consist of the hydraulic pump, clutch, and additional hardware. A clutch is required with most direct drive configurations to isolate the pump from the engine and prevent overspeeding. A number of different clutches can be purchased for this application, including electrically, centrifugally, and pneumatically operated models. The cost of the clutch and associated hardware will vary between $400 and $600 per unit.

It is possible that a special tandem pump could be used which would eliminate the need for the clutch.

Additional hydraulic components such as tubing, check valves, fittings, etc., will be required since the hydraulic pump will be located in front of the cab and hence further away from the compactor body. These components are expensive and the added cost may be as high as $75 to $125 per unit.

The total incremental cost of materials and subcontract work for side and rear loading vehicles ranges between $725 and $1,125 per unit. However, an estimated $100* of this cost is offset by the fact that a power take-off unit is no longer required. The net incremental material cost is therefore estimated to range from $625 to $1,025 per vehicle.

The incremental labor is estimated to be 25 to 35 man-hours per unit for production, assembly and checking. This is equivalent to an additional cost of $200 to $280 per unit.

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* The cost of the power take-off unit can vary from $75 to as high as $600 depending upon the type of transmission and the PTO features desired. This estimate reflects the labor and component cost for installation of the most commonly used PTO.

Front loading vehicles are assumed to employ the flywheel PTO alternative. The incremental cost of this option from Company L is approximately $915 per vehicle. This estimated cost should be representative of the cost of other alternatives which are applicable to the front loading configuration.

The additional labor cost associated with the flywheel PTO option should be minimal. An additional cost of $50 to $100 has been estimated to account for possible increases in installation and checking time.

Stage 3. Cost Estimates

The Stage 3 technology consists of quieting the hydraulic pump. Two alternative treatments are considered: a pump sound enclosure and a quiet hydraulic pump.

The cost of labor and material for a pump sound enclosure is estimated to range between $30 and $50 per unit and has the disadvantage of being subject to contamination from leaking hydraulic fluid and being costly to maintain. However, the quiet pump has the disadvantage of costing between $200 and $300 depending on the size and type of pump used.

The estimated cost for Stage 3 treatment for all three vehicle types, therefore, ranges between $30 and $300 assuming no additional labor for installation of the quiet pump.

Impact Noise Cost Estimates

The technology to reduce impact noise consists primarily of lining the rim of the loading hopper of each vehicle type with an impact absorbing rubber strip. An additional treatment is needed for rear loaders to reduce the impact noise associated with the bottoming and reversal of the compaction ram cylinders.

The application of a two-inch rubber strip to the loading hopper does not present any significant manufacturing problems. It is assumed that manufacturers will glue or rivet the rubber to the hopper rim at a final assembly station without any major impact on present operations.

The cost of this treatment will vary with each type of vehicle as a function of the hopper size. Assuming an average vehicle size, it is estimated that labor and material cost for front loaders will range between $35 and $50 per unit. The estimated cost for side and rear loaders ranges between $10 and $20.

The reduction of impact noise associated with the hydraulic cylinders of rear loaders poses a more significant problem to manufacturers. Since most manufacturers produce their own cylinders, the need for cushioned cylinders requires a major redesign of the component and major changes in the production of the cylinder assembly. It is difficult to determine at present whether manufacturers will redesign the present cylinders and production processes, purchase the cushioned cylinders from other manufacturers, use rubber cushions, or seek out other means of eliminating the impact (i.e., using electrical limit switches).

Assuming that manufacturers elect to redesign their present cylinders, the estimated cost will vary with the size of the cylinders and the ability of the producer to modify the design and production process. However, once the initial design and implementation costs are amortized, it is estimated that the additional labor and material cost for the modified cylinders should not exceed $150 to $200 per compactor unit.

Auxiliary Engine Cost Estimates

The technology proposed for quieting auxiliary engines on all types of vehicles is to install an engine enclosure to muffle noise emissions. Two types of auxiliary engines are used on compactors: air cooled and water cooled.

Application of the technology to the water cooled engine presents no major problems, assuming that the enclosure is properly designed and provides adequate venting for dissipation of engine heat. However, the proposed technology is not applicable to air cooled engines since the enclosure would interfere with cooling of the engine. As a result, the application of the proposed quieting technology will probably preclude the use of air cooled engines on future compactors.

The labor and material cost of enclosing the water cooled auxiliary engine is estimated to be $165 to $260 per unit. The cost should be approximately the same for all three vehicle types since all generally use the same type and size of engine.

Overhead Cost Estimates

Manufacturing overhead costs are expected to increase in some cost categories such as additional indirect materials (adhesives, assembly hardware, etc.), supervision, inspection, and manufacturing technical support (methods, standards, production scheduling and control, etc.) as a result of quieting.

These additional overhead costs should not exceed 100 to 125 percent of the incremental direct labor associated with quieting. (The existing manufacturing overhead rate is estimated to be 200 percent of direct labor cost.)

General, Sales, and Administrative (GS&A) costs will also increase slightly as a result of noise emission standards. These costs will arise from two sources: the cost of planning and implementing the noise control technology, and the cost of ongoing compliance with the noise standard.

The necessary planning and implementation efforts will result in additional costs amounting to 20 to 30 percent of incremental direct labor.

The compliance costs result primarily from product testing and record-keeping costs. It is assumed that two types of product testing will be required. The first type would be product verification (PV) testing by the manufacturer to insure that initial production runs of each type of vehicle meet noise standards. It is estimated that between 2 and 15 percent of the units produced annually will require testing. The second type of test would be the selective enforcement audit (SEA) which would be conducted by EPA officials. It is expected that 50 such requests will be made within the industry each year and that this will average out in a way that requires each company to test an additional two percent of the units produced annually.

The cost per vehicle tested is estimated to range between $350 and $600 and the annual testing costs are assumed to be allocated over the total number of units produced each year.

Manufacturers will also be required to maintain complete records of test results as well as records of product sales (for the purpose of recall).

The total estimated cost of both these compliance activities ranges between 35 and 180 percent of incremental direct labor cost depending upon the equipment category and level of quieting treatment. This variability is reflected in the estimates of incremental GS&A overhead cost for each treatment level and vehicle configuration.

Maintenance and Operating Cost Estimates

Maintenance Costs

* Stage 1

The Stage 1 technology for side, rear, and front loaders requires the adjustment or addition of a speed control device and installation of a larger hydraulic pump. Both of these components are relatively low maintenance items. For example, a fleet of 60 trucks, representing a mix of front, side, and rear loaders, showed no maintenance charges over a ten-month period associated with the engine governor and only minimal expenses for the hydraulic pump. Based on this historical data and an evaluation of the quieting technology, it is estimated that no increases will occur in maintenance costs for Stage 1 treatment of side, rear, and front loading vehicles.

* Stage 2

The installation of a front mounted, direct drive hydraulic pump on side and rear loaders will result in additional maintenance costs. It is estimated that the clutch, which is required on the hydraulic pump to prevent overspeeding, will require replacement every four years. The annualized labor and material cost for this maintenance is estimated to be $100 to $150 per vehicle. Some additional maintenance will also be required on the hydraulic system (typically a high maintenance area) due to the increased number of components. This added cost is estimated to be $30 to $40 per year per vehicle.

Offsetting these costs will be savings in power take-off (PTO) maintenance. The standard PTO unit presently used on compactors has an expected life of approximately three years. By eliminating this unit, the annualized maintenance savings are estimated to be $75 to $125.

The net increase in maintenance costs for side and rear loaders is therefore estimated to be approximately $60 per year per vehicle.

Front loaders are assumed to employ the flywheel PTO option which will require no significant increase in maintenance costs.

*Stage 3

Industry experience does not now exist for the life expectancy of the quiet pump, but it appears to perform as well as standard, conventional units. It may, however, be more susceptible to damage from dirt within the hydraulic system. Thus, it is conceivable that maintenance costs could rise, but it is not possible at this time to quantify the potential increase.

The sound enclosure alternative will increase maintenance costs slightly since the life expectancy of the sound absorbing material is limited. The film coated fiberglass, used to line the pump enclosure, is susceptible to accumulations of dirt and grease as well as damage from routine maintenance. It is, therefore, assumed that this lining will be replaced every other year at a cost of $10 to $15 per year.

*Impact

The rubber material used to line the loading hopper will be subject to a high level of wear and damage and will probably require replacement each year. The annual cost of this operation is estimated to be $40 to $50 for front loaders and $15 to $20 for side and rear loaders.

The use of cushioned cylinders on the rear loading vehicles is expected to have offsetting impacts on maintenance costs. The effect of the cushioning action should reduce the amount of wear on the cylinder and thus, to some extent, prolong the life of the component. However, the added complexity of the cylinder design will lead to increased costs when the cylinders are rebuilt. It is difficult to assess the net tradeoffs between these two factors since there is little experience in the compactor industry with cushioned cylinders, but the net impact is not expected to be significant.

*Auxiliary Engines

The maintenance cost of the auxiliary engine is not expected to change as a result of quieting, but some additional maintenance costs are anticipated for replacement of the sound enclosure lining which has a limited life expectancy. The resulting annual increase in maintenance cost for replacing this lining is estimated to be $15 to $20 per vehicle.

Operating Costs

The only operating cost significantly impacted by the quieting technology is fuel cost. Fuel savings are projected for all vehicles due to the Stage 1 reduction in engine speed. Assuming that trucks are cycling 25 percent of the time, the fuel savings will amount to 0.08 gallons per hour for gasoline engines and 0.13 gallons per hour for diesel engines.

The estimates reflected in Table 7-1 assume that:

1. The average compactor is operated 2,200 hours per year.
2. Fuel prices are $.50 for gasoline and $.40 for diesel.
3. All front loaders are diesel engine powered.
4. Sixty percent of all side and rear loaders are gasoline-powered engines and 40 percent are diesel-powered.

TABLE 7-1

ESTIMATED ANNUAL UNIT OPERATING
COST REDUCTION DUE TO FUEL ECONOMIES

BODY TYPE	ANNUAL SAVINGS
Front Loader	$114
Side Loader	99
Rear Loader	99

In view of the increases in fuel prices since this analysis was performed, it is apparent that the dollar savings in fuel will be greater than that used in the analysis and consequently will provide more of an offset in operating costs than was concluded in the analysis. For example, assuming current gasoline prices of $1.00 per gallon and diesel fuel prices of $.90 per gallon, the annualized cost (the stream of fixed annual payments needed to cover the discounted sum of future capital, operating and maintenance costs over a pre-specified period of time) of one of the regulatory options considered is $13.4 million. This may be compared with the $21.5 million annualized cost estimated for that option given the original assumed fuel prices of $.50 for gasoline and $.40 for diesel. Similar decreases in annualized costs are found for other options. This result indicates that the analysis is conservative and that the actual increase in operating costs is likely to be lower than the estimates presented in this report.

Summary of Cost Estimates

The range of estimated costs for direct labor and material is summarized in Table 7-2 and the estimated increases in overhead expenses are summarized in Table 7-3.

The overhead increases shown for Stage 1 treatment include the estimated costs of compliance (i.e., testing and recordkeeping). These costs are not included in the estimates of treatment beyond Stage 1 since it is assumed that these costs will remain essentially constant in that the

TABLE 7-2

SUMMARY OF ESTIMATED
INCREMENTAL DIRECT LABOR AND MATERIAL COST
FOR NOISE ABATEMENT*
(COST PER UNIT)

Treatment	Front Loader			Side Loader			Rear Loader		
	High	Low	Expected	High	Low	Expected	High	Low	Expected
Stage 1	$1,000	$650	$825	$ 370	$270	$ 320	$ 370	$270	$ 320
Stage 2	1,015	965	990	1,305	825	1,065	1,305	825	1,065
Stage 3	300	30	165	300	30	165	300	30	165
Impact	50	35	45	20	10	15	220	160	190
Auxiliary Engine	260	165	215	260	165	215	260	165	215

TABLE 7-3

SUMMARY OF ESTIMATED
INCREMENTAL OVERHEAD COSTS FOR
NOISE ABATEMENT*
(COST PER UNIT)

Treatment	Front Loader			Side Loader			Rear Loader		
	High	Low	Expected	High	Low	Expected	High	Low	Expected
Stage 1	$ 690	$285	$390	$ 335	$190	$ 215	$ 320	$175	$ 200
Stage 2	230	70	105	740	275	330	740	275	330
Stage 3	60	20	25	60	20	25	60	20	25
Impact	70	25	30	20	5	10	330	75	150
Auxiliary Engine	150	50	65	150	50	65	150	50	65

*The total cost for Stages 2 and 3 are the sum of the preceding Stages and the Impact Noise costs.

Source: Reference 7-1.

number of vehicles to be tested and the necessary documentation and procedures will remain the same as the stage of quieting increases.

The total estimated cost increases associated with increasing stages of quieting are shown in Table 7-4 and summarized in Table 7-5. The costs shown in the table are based on the expected cost estimates for direct labor and materials and incremental overhead expenses. The cost for each level is cumulative over the preceding levels with the exception of impact and auxiliary engine treatments, which have not been associated with a particular treatment level.

TABLE 7-4

SUMMARY OF TOTAL ESTIMATED COST FOR NOISE ABATEMENT*

	Front Loader			Side Loader			Rear Loader		
Treatment	High	Low	Expected	High	Low	Expected	High	Low	Expected
Stage 1	$1,690	$ 935	$1,215	$ 705	$ 460	$ 535	$ 690	$ 445	$ 520
Stage 2	2,935	1,970	2,310	2,750	1,560	1,930	2,735	1,545	1,915
Stage 3	3,295	2,020	2,500	3,110	1,610	2,120	3,095	1,595	2,105
Impact	120	60	75	40	15	25	550	235	340
Auxiliary Engine	410	215	280	410	215	280	410	215	280

*These estimates do not reflect estimated maintenance and operating cost changes. The total cost for each Treatment Stage is the sum of the dollar value shown for that Stage and the cost of Impact Noise Abatement.

Source: Reference 7-1.

TABLE 7-5

SUMMARY OF TOTAL ESTIMATED COST INCREASES FOR NOISE ABATEMENT

Treatment	Front Loader	Side Loader	Rear Loader
Stage 1	$1,215	$ 535	$ 520
Stage 2	2,310	1,930	1,915
Stage 3	2,500	2,120	2,105
Impact	75	25	340
Auxiliary Engine	280	280	280

Source: Table 7-4.

The EPA cost estimates shown in Table 7-5 are compared with estimates supplied by specific compactor body manufacturers in Table 7-6.

TABLE 7-6

MANUFACTURERS INPUT AND EPA ESTIMATES

Front Loaders	Stage 1	Stage 2*	Stage 3
Manufacturer #1 Estimate	$1,085	$2,600	$2,870
Manufacturer #2 Estimate	840	1,100	3,520
EPA Estimates:			
- Expected	1,215	2,310	2,500
- High	1,690	2,935	3,295
- Low	935	1,970	2,020

Rear Loaders	Stage 1**	Stage 2	Stage 3
Manufacturer #1 Estimates:			
- RL (A)	$ 775	$1,765	$1,935
- RL (B)	780	1,785	1,965
- RL (C)	835	1,925	2,110
Manufacturer #2 Estimate	840	1,100	3,520
EPA Estimates:			
- Expected	520	1,915	2,105
- High	690	2,735	3,095
- Low	445	1,545	1,595

NOTE: - Manufacturers not identified due to the confidential nature of the information.
- No response received from side loader manufacturers.

Source: Table 7-4 and Reference 7-1.

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*Manufacturer #1 estimate is based on a front mount, direct drive pump. The EPA estimate assumes the flywheel PTO option on a Company L chassis.

**Stage 1: Manufacturer #1 estimates include the cost of an improved speed control device. The EPA estimates assume that the existing engine governor is adequate.

The impact of noise control treatments on maintenance and operating costs are summarized in the following table:

TABLE 7-7

SUMMARY OF INCREMENTAL MAINTENANCE AND OPERATING COSTS DUE TO QUIETING (DOLLARS PER VEHICLE PER YEAR)

	Maintenance			Operating		
Treatment	Front Loader	Side Loader	Rear Loader	Front Loader	Side Loader	Rear Loader
Stage 1	$ 0	$ 0	$ 0	$ -114	$ -99	$ -99
Stage 2	0	60	60	-114	-99	-99
Stage 3	10-15	10-15	10-15	-114	-99	-99
Impact	40-50	15-20	15-20			
Auxiliary	15-20	15-20	15-20			

Source: Reference 7-1.

Lead Time for Implementation

The lead time associated with implementation of quieting technology for compactor bodies is conservatively estimated at 12 to 18 months. With a few minor exceptions, the compactor technology affects only the mounting operation of the compactor assembly on the chassis. The impact on the production and assembly operations is negligible. In addition, the components affected by the technology are primarily purchased items which are readily available from suppliers. Therefore, 12 to 18 months should be sufficient for the required engineering and marketing efforts and for depleting present inventories and building new ones.

ECONOMIC IMPACT

Introduction

This section describes the estimated economic impacts of the adoption of three different noise treatment stages.

Market and total industry impacts are considered first, then the implications of these impacts are correlated with other factors and analyzed to identify specific impacts regarding individual firms or groups of firms.

Impact Framework

Analysis of information obtained from manufacturers, raw material and component suppliers, distributors, and end users has established a probable overall framework for solid waste compactor industry/market reaction to adoption of the noise emission standards suggested for study. The elements of this framework are:

1. The total costs to manufacture the equipment will increase.

2. The manufacturers, within their competitive framework, will pass this cost on in the form of an increase in the distributor price (list price).

3. The distributor will pass its cost increase on in the form of an increase in the negotiated price to the end user.

4. The truck-mounted solid waste compactor end user will pass the increase in his equipment purchase costs on to his customers as an increase in the price of collection services provided. End users will also pass on increased costs in operations and maintenance, if any. In the case of municipalities, increased costs will be reflected in increased costs for the taxpayer.

5. Final changes in industry prices and volumes will reflect the changes in solid waste compactor purchase prices and operating costs.

6. Ultimately, the consumer will pay a higher price for collection services due to the increased cost resulting from reduced noise. This will be reflected in higher prices paid for the services which utilize solid waste compactors. If there are over-all cost reductions as opposed to cost increases from the adoption of noise control technology, competitive pressures will cause cost decreases to be passed on down the economic chain to the consumer in the form of lower prices.

7. It is assumed that the technology and resulting costs used in the study would be the actual future technology adopted and costs incurred. This approach is conservative because, with the passage of time, new technology at lower costs is likely to be developed. Thus, the current costs used in this study (which are based on an assessment of on-the-shelf technology) are essentially an upper bound estimate.

There are several special characteristics of the compactor body industry which should be noted in conjunction with the above overall impact framework. First, most of the larger solid waste compactor manufacturers have a noise engineering staff and are currently manufacturing quieted products (on a special order basis at a higher price) while other manufacturers have no quieting experience. The former companies should be better prepared to meet the noise emission standards when they are set. Their initial costs under the standards will probably be lower than for those firms which have little or no experience in quieting their products, if they maintain their current advantage. And, in that the compactor body market is extremely price-competitive, the prices of these larger firms with quieting experience will tend to become industry prices. Firms without quieting experience will have to meet the established market price level and can be expected to absorb costs in the form of lower profit margins until their costs are in line.

Second, a truck-mounted solid waste compactor is a capital good which provides a flow of productive service over a period of years. Thus, first year cost/price increases are reflected only in the portion of compactor bodies manufactured and put in service that year. End user costs will continue to rise until all the equipment in service is quieted.

Another factor to note is that, given the competition in the industry, price increases for services in the end user markets depend on the level of cost increases. These costs include the increased price of equipment, expenditures for maintenance and operations, and costs associated with decreases, if any, in productivity from changed performance characteristics.

Fourth, another important consideration is that the purchaser views the price of a solid waste compactor body as only a portion of the total price of an operational unit. The cost of the truck chassis and additional accessories necessary to make a complete unit can amount to 60 percent of the total price. Thus, price increases developed for the compactor body alone, when viewed from the buyer's perspective, represent an overestimate of the percent price increase.

Finally, compliance enforcement will focus on the final assembler or mounter of the compactor body onto the truck chassis. This is a function now performed by distributors for approximately 30 percent of the compactor bodies sold. Many of these distributors may not be capable of adequate installation testing and compliance verification when new noise standards are promulgated. This may place smaller distributors at a competitive disadvantage with larger and more capable distributors in the same market area and/or shift the installation function upward to the body manufacturer. In order to avoid placing an excessive testing burden on distributors who assemble compactor vehicles, the distributors will be permitted to rely on the production verification tests of the compactor body manufacturer if the distributor faithfully follows the assembly instructions provided by the compactor body manufacturer.

Dynamics

*Adjusting to a Known Future

The dynamics associated with the adoption of noise emission standards reflect economic conditions which are somewhat unique. In effect, the truck-mounted solid waste compactor end user is not responding to short-term or unexpected phenomena, but rather to changes mandated for some point in the future--two or three or possibly even eight or ten years away. Thus, the requirements for adjustment are neither unexpected nor the result of a gradual long-term trend. They are definite and scheduled, and the adjustment response will reflect this.

The economic impact assessment specifically considers this time range of adjustments. Due to the planning horizon of two years or more from the date of promulgation and the state of expectations today, it is estimated that the major adjustments required will be made in the first year of enforcement. The adjustment period is expected to extend beyond the first year, but to be of second order significance.

*Extending the Life of Unquieted Equipment

During the first year of enforcement, it is anticipated that old solid waste compactors not subject to regulation may very well be extended in life due to the economic advantages which they have over the more costly compactors with noise control. These solid waste compactors will be phased out of the population in future years due to increased maintenance costs as they age physically and accumulate more hours of operation. Also, the impact of local noise ordinances will narrow the range of applications for the unquieted units. Further adjustments will occur in the period beyond one year due to adoption of practices which conserve the use of solid waste compactors in response to the increased costs.

*Prebuying Unquieted Equipment

There is also a dynamic problem in reflecting the adjustments which may occur because of rearranging the timing of purchases to avoid buying more expensive solid waste compactors as long as possible. The strength of economic incentives for rearranging the timing of purchases will depend on a number of factors. It will be a function of the size of the cost penalty, constraints on sales set by manufacturing capacity, the availability of capital funds and negative incentives caused by the possible application of local noise ordinances. The latter two factors restrict the amount of prebuying in relation to what end users may desire solely on the basis of the expected cost increases.

Some end users may replace equipment ahead of the normal cycle in order to purchase at lower prices before the regulation takes effect. In this case, the stock of solid waste compactors will be higher before the regulation becomes effective. This will lead to a short-term drop in sales of the more expensive quieted solid waste compactors until this extra stock is worn out.

Manufacturers of solid waste compactors are not operating near their production capacity at the present time, and industry projections indicate a fairly constant growth in unit volume over the next several years. Consequently, existing plant capacity should be adequate to absorb a substantial surge of prebuying.

Extension of the life of current compactor bodies and prebuying both indicate the period of adjustment is likely to last longer than one year. The amount of activity in each case is directly related to the size of the cost penalty incurred.

Regulatory Sequence

The magnitude of changes caused by the enforcement of the regulation in any one given year will tend to directly affect the impact occurring in that year. For example, EPA's model predicts that a move from current prices and noise levels directly to a Stage 2 cost for truck-mounted solid waste compactors will result in a sharper economic impact and create more incentives for prebuying and other rearrangements to avoid the consequences of the regulation, rather than a stair-step type of sequence in which Stage 2 is reached after a number of years at Stage 1.

A chronological sequence of three stages was used in this section for initial assessment of economic impacts: Stage 1 was assumed to be effective on July 1, 1980; Stage 2 on July 1, 1982; and Stage 3 on July 1, 1985. As the effective dates have shifted, the whole chronology of cumulative effects has also shifted.

IMPACT ASSESSMENT

Volume Impact

1. Purpose

The purpose of this section is to analyze the impact of the noise standards suggested for study on the volume of truck mounted solid waste compactor production. Volume change is a critical occurrence since it is reflected in other changes such as production employment, activity in downstream channels of distribution and effects transmitted to upstream component suppliers.

2. Baseline Forecast

The baseline forecast provides a pre-regulation base of estimated future industry activity levels, which is then related to estimated post-regulation activity levels to determine the economic impacts of the regulations.

The baseline forecast through 1993 and 1995 is presented in Tables 7-8 and 7-9. The forecast is a composite projection of unit shipments that is based on manufacturers' forecasts.

It can be seen that side loader and front loader shipments are expected to grow fastest between 1975 and 1985. Rear loader shipments are expected to decline by one percent per year over the period 1975-1985. The growth of all three body types is expected to be 2 percent over the period 1985-1995.

The projections are in marked contrast to the actual shipment growth of ten percent per year between 1964 and 1974. This rapid growth rate resulted, first from increasing market penetration by compactor bodies during this period (open body collection trucks were being phased out) and second, from the substantial increase in total solid wastes being collected between 1964-1974. The latter resulted from higher consumer disposable incomes and related purchases of more products with a larger quantity of disposable packaging per product, the migration of higher income families to houses with larger yards and increases in the quantity of yard waste in the suburbs, and more local ordinances restricting open burning.

However, a number of other factors are expected to interact to reduce the shipment growth rates and to change the loader type mix between 1975 and 1995. Front loader units are expected to increase during the first decade (1975-1985) and level off during the second (1985-1995), due to increased use in the commercial and multi-unit dwelling market. Side loaders are projected to increase significantly to about a 9-percent annual growth rate during the first decade and stabilize during the second period. There will probably be an increased replacement of rear loaders by side

TABLE 7-8

BASELINE FORECAST BY YEAR AND COMPACTOR BODY TYPE
1980-1993

	BASELINE FORECAST(1)					
	Total	Front	Side	Rear Loader		
Year	Units	Loader	Loader	Total	Quieted(2)	Standard
1980	13,700	1,600	4,100	8,000	800	7,200
1981	13,985	1,680	4,305	8,000	800	7,200
1982	14,284	1,764	4,520	8,000	800	7,200
1983	14,598	1,852	4,746	8,000	800	7,200
1984	14,928	1,945	4,983	8,000	800	7,200
1985	15,275	2,042	5,233	8,000	800	7,200
1986	15,581	2,083	5,338	8,160	816	7,344
1987	15,893	2,125	5,445	8,323	832	7,491
1988	16,211	2,167	5,554	8,490	849	7,641
1989	16,535	2,210	5,665	8,660	866	7,794
1990	16,866	2,255	5,778	8,833	883	7,950
1991	17,204	2,300	5,894	9,010	901	8,109
1992	17,547	2,346	6,011	9,190	919	8,271
1993	17,899	2,393	6,132	9,374	937	8,437

Source: Exhibit IV-2 (Reference 7-1).

Notes: (1) This table is the detailed breakdown of Exhibit IV-2 of Ref. 7-1 showing the projected estimates of units for each compactor body type.

(2) Quieted units are produced for rear loaders only, and are estimated at 10% of total rear loader units.

TABLE 7-9

COMPOSITE MANUFACTURERS' PROJECTION
OF UNIT SHIPMENTS, 1975-1985

	Average Annual Growth Rates		
Body Type	1975-1980	1980-1985	1985-1995
Front Loader	5%	5%	2%
Side Loader	12	5	2
Rear Loader	-2	0	2
Total	2%	2%	2%

Source: Reference 7-1.

loaders, which offer greater labor efficiency and lower operating costs. Finally the use of rear loaders is expected to decline during the period 1975-1985 and stabilize during the second ten year period. These factors include the fact that the packer body market has been fully penetrated so that future new unit sales will result from growth in solid waste generation and replacement of units being retired.

Also, as indicated in Section 2 of Reference 7-1, the growth of total solid wastes requiring collection is expected to be at a lower rate. This will be coupled with some technological changes in packer bodies that will result in shipments growing even slower than increases in solid wastes generated. These changes include larger packer body capacity and compaction density, particularly for municipal fleets, and the use of transfer stations, combined with satellite units, to make waste transport collection and disposal more efficient. Highway load restrictions place an upper limit on packer body capacity and compacting density. Also, the mix of packer bodies by type will shift toward more productive equipment. Front loaders may be substituted for rear loaders for non-residential applications and side loaders may be substituted for rear loaders for residential applications.

The latter is supported by data presented in a recent study which are summarized in Table 7-10.

TABLE 7-10

ON-ROUTE PRODUCTIVITY AND COLLECTION COSTS

System Number	Vehicle Loader Type	Crew Size	Productivity/Collection Hours: Homes/ Crewman	Tons/ Crewman	Homes/ Crew	Tons/ Crew	Costs: Homes/ Year	Ton
1	Side	1	107	2.5	107	2.5	$ 9.88	$ 8.29
2	Side	1	56	2.0	56	2.0	15.60	8.48
3	Rear	2	53	1.3	107	2.6	11.96	9.53
4	Rear	2	58	1.5	123	3.1	11.44	8.72
5	Rear	3	35	1.1	104	3.3	20.28	12.82
6	Rear	3	21	.7	63	2.0	28.80	17.13
7	Side	1	84	1.2	84	1.2	19.24	13.48
8	Detachable Contnr.	2	67	.8	138	1.7	28.52	21.15
9	Rear	3	66	1.1	200	3.3	24.96	14.67
10	Rear	2	35	.6	72	1.2	16.64	19.26
11	Rear	2	22	.6	44	1.1	24.44	18.41

Source: "Eleven Residential Pickup Systems Compared for Cost and Productivity," Kenneth A. Shuster, Solid Waste Management, May 1975. (Reference 7-2).

Even though the above systems varied considerably, (i.e., point of collection, frequency of collection, incentive system, loading method, and vehicle size and type, etc.), it appears that generally, one-man crews with side loaders are more efficient than other collection systems. This is further demonstrated in Table 7-11. The importance of these efficiency factors for side loaders is further enhanced when it is recognized that side loaders are most effectively applied to curbside collection systems, which presently account for 60 percent of the collection systems in the U.S. and which are expected to further increase in importance in future years.

It is believed that the value of shipments will increase somewhat faster than unit shipments due to increased body size, product improvements to achieve greater compaction density, and other product modifications.

TABLE 7-11

PERCENT OF TOTAL TIME UTILIZATION

System Number	Crew Size	Loader Type	Crew Productive Time	Crew Non-Productive Time	Total
1	1	Side	98.5%	1.5%	100%
2	1	Side	97.2	2.8	100
3	1	Side	97.6	2.4	100
4	2	Rear	63.0	37.0	100
5	2	Rear	58.3	41.7	100
6	2	Detach. Contnr.	69.5	30.5	100
7	3	Rear	61.3	38.7	100
8	3	Rear	58.7	41.3	100
9	3	Rear	61.0	39.0	100

Source: Residential Collection Systems, U.S. Environmental Protection Agency, (530/SW-97c.1), March, 1975, Page 24. (Reference 7-3).

Consequently, it is estimated that the average annual real growth in value of shipments (constant 1974 dollars) will be three percent per year between 1974 and 1985, and that unit shipments will increase at two percent per year.

Industry shipment levels, which reflect these growth rates, are shown in Table 7-12. In 1985, unit shipments are expected to be 15,000, and the value of shipments is expected to be $173 million.

Projected unit shipments for the time frame up to 1995 are needed to evaluate the economic impact of a totally quieted population of solid waste compactor bodies.

TABLE 7-12

ESTIMATED AND PROJECTED UNIT AND DOLLAR VOLUMES OF TRUCK-MOUNTED SOLID WASTE COMPACTOR BODIES, 1974-85*
$(MILLIONS) - UNITS (000s)

Unit Shipments	Estimated 1974	Projected 1980	Projected 1985	Average Annual Growth Rate 1974-1985
Front Loader	1.2	1.6	2.0	5%
Side Loader	2.1	4.1	5.2	9
Rear Loader	9.0	8.0	8.0	-1
TOTAL	12.3	13.7	15.2	2%
Value of Shipments	$125	$149	$173	3%

Source: Manufacturers' interviews and projections.

* Dollar forecasts are in 1974 constant dollars.

It is shown in Section 2 of Reference 7-1 that total gross discards of solid wastes are expected to increase 2.5 percent annually between 1980-1990. No forecast is currently available beyond that time frame. Consequently, the 2.5 percent has been utilized as the best measure available. It is reasonable to assume, however, that technology advances will increase the capacity per unit and offset the 2.5 percent average annual growth estimate. Further, it is not known whether the trade-offs between side and rear loaders will persist over this time frame. Consequently, the projections reflected in Table 7-13 assume that the average annual growth rates for each body type equal two percent per year.

TABLE 7-13

PROJECTED UNIT SHIPMENTS OF
SOLID WASTE COMPACTOR BODIES,
1985-1995
(thousands)

Body Type	1985	1990	1995	Average Annual Growth Rate 1985-1995
Front Loader	2.0	2.2	2.4	2%
Side Loader	5.2	5.7	6.3	2%
Rear Loader	8.0	8.8	9.7	2%
Total	15.2	16.7	18.4	2%

Source: Table 7-12 and Manufacturers' interviews and projections.

3a. Pricing and Price Elasticity

Assuming a full incremental cost pass-along, purchasers of quieted solid waste compactors will be presented with price increases attributable to the costs of sound attenuation, compliance, and enforcement. Estimates of the price increases that would result from these costs are summarized in Table 7-14. Costs related to the treatment of auxiliary engines are considered separately, since these treatments have not been associated with a particular level. The estimated cost related to impact noise control has been included with each of the levels.

Quieted units produced on a special order basis are also indicated in Table 7-14. It is estimated that in 1975 ten percent of rear loaders were shipped with quieting equipment and that the unit price increase resulting from the quieting treatment was approximately ten percent. In that it was not possible to relate the quieted units to a specific noise standard, the incremental price of these units is treated as a reduction in the cost to attain the EPA specified technology levels. Quieted side or front loaders are not produced.

TABLE 7-14

ESTIMATED AVERAGE LIST PRICE
PERCENTAGE INCREASE BY
NOISE LEVEL AND CATEGORY

Compactor Body Type	Stage 1 Standard	Stage 1 Quieted	Stage 2 Standard	Stage 2 Quieted	Stage 3 Standard	Stage 3 Quieted
Front Loaders	6.9%	--	12.7%	--	13.7%	--
Side Loaders	7.3	--	25.6	--	28.0	--
Rear Loaders	7.4	--	19.5	9.5%	21.1	11.1%

Source: Reference 7-1.

Consideraton was also given to the costs of quieting auxiliary engine usage on side and rear loaders, but analysis indicated that there was no significant difference between the costs of quieting auxiliary engines and the costs of quieting standard units.

The expected price increases between noise control stages for each type of compactor body are presented in detail in Table 7-15 and summarized in Table 7-16.

The dynamics of demand volume reaction to increased solid waste compactor prices can be expected to vary depending upon:

A. The extent of price increases.

B. The significance of equipment cost in the end user's cost structure, allowing specific consideration to depreciation, operating costs, maintenance costs, and crew productivity.

C. The ease of substitution of one packer body type for another (i.e., side loaders for rear loaders).

D. The option of renting or leasing truck-mounted solid waste compactors as an alternative to purchasing the equipment.

TABLE 7-15

ESTIMATED INCREMENTAL PRICE BETWEEN NOISE CONTROL STAGES BY COMPACTOR BODY TYPE

Standard Units	Level	Average Price	Estimated Increase Between Stages	Total Stage 1 Average Price	Total Stage 2 Average Price	Total Stage 3 Average Price	Percent Change Between Stages
Front Loader	To 1	$18,780	$1,290	$20,070	—	--	6.9%
	1-2		1,095		$21,165		5.5
	2-3		190			$21,355	0.9
Side Loader	To 1	7,650	560	8,210	—	—	7.3
	1-2		1,395		9,605		17.0
	2-3		190			9,795	2.0
Rear Loader	To 1	11,580	860	12,440			7.4
	1-2		1,395		13,835		11.2
	2-3		190			14,025	1.4
Quieted Units(1)							
Rear Loader	To 1 (2)		-- (2)				
	1-2	12,740	1,095		13,835		8.6
	2-3		190			14,025	1.4

Source: Exhibits V-1, V-2 and V-3 (Reference 7-1).

Notes: (1) Quieted units are produced for rear loaders only.
(2) No calculation made for Stage 1 rear loaders since price of quieted units exceeded estimated cost for Stage 1 technology.

TABLE 7-16

PERCENT INCREMENTAL PRICE
BETWEEN NOISE CONTROL STAGES

Compactor Body Type	To Stage 1	Stage 1 to 2	Stage 2 to 3
Standard Unit			
Front Loader	6.9%	5.5%	0.9%
Side Loader	7.3	17.0	2.0
Rear Loader	7.4	11.2	1.4
Quieted Unit*			
Rear Loader	**	8.6	1.4

* Quieted front and side loaders are not manufactured.
** Quieted rear loaders are estimated to cost 10 percent more than standard units. This amount exceeds the Stage 1 expected increase.

Source: Table 7-15.

E. The trade-off of new equipment purchases to extending the life of used equipment.

F. The ease of substitution of competitive solid waste collection systems.

G. The potential for achieving greater efficiency of operation.

H. The level of imports and exports.

3b. Cost Estimates of Regulatory Options

EPA considered various regulatory options. The options utilize Stage 1, 2, and 3 technology and their associated costs. The variable elements in each option include: 1) the year of implementation, 2) maximum noise level allowable, and 3) quieting technology. Because the costs of quieting are dependent upon these factors, the costs associated with these options also vary. Estimates for these options have been developed and are summarized in Table 7-17 for the major cost elements;

operating (or fuel) costs, maintenance costs, and equipment costs (direct labor and materials). Table 7-18 shows the percentage cost increase needed to achieve the required noise levels of the regulatory options, as well as the equivalent annual cost for implementing and maintaining the noise level of selected options.

An illustrative example of the interrelationships between the various cost elements and possible regulatory levels is presented in terms of one of the regulatory options considered. This option requires the noise level of truck-mounted solid waste compactor bodies to reach a maximum of 79 dBA in 1980 and 76 dBA in 1982. To achieve the 79 dBA level, Stage 2 technology is assumed for all compactor body types. To reach the overall 76 dBA level, there will be a 3 dBA noise reduction in the truck itself, due to the noise regulation which EPA has promulgated for medium and heavy duty trucks (41 FR 15538). It should be noted that the first regulatory year is 1980 and that the revised measurement methodology has resulted in a 1 dB change in both regulatory levels. In terms of "end-year" results, the option provides the same benefits previously calculated and the economic analysis yields the same results.

The costs for this regulatory option are exactly equal to those costs needed to achieve Stage 2 technology. Using the average price of the compactor body, the estimated increase in price from the baseline to Stage 2 technology for option 7 is 12.7 percent for front loaders, 25.6 percent for side loaders and 19.5 percent for rear loaders. On quieted rear loaders the estimated percentage price increase is 9.5 percent. Estimated maintenance cost increases are small for all compactor body types. They averaged $45.00 for front

TABLE 7-17

SUMMARY OF FUEL, MAINTENANCE AND EQUIPMENT COST ESTIMATES ASSOCIATED WITH PROPOSED REGULATORY OPTIONS

Option	Year	NTE* Level	Treatment Stage	Body Type	Fuel Cost Increment	Maintenance Cost Increment	Equipment Cost Increment
					$	$	$
1	1980	81	Stage 1	Front Loader	-114.00	45.00	1,290.00
				Side Loader	- 99.00	17.50	560.00
				Rear Loader	- 99.00	17.50	860.00
1	1982	76	Stage 2	Front Loader	-114.00	45.00	2,385.00
				Side Loader	- 99.00	77.50	1,955.00
				Rear Loader	- 99.00	77.50	2,255.00
3	1982	80	Stage 1	Front Loader	-114.00	45.00	1,290.00
				Side Loader	- 99.00	17.50	560.00
				Rear Loader	- 99.00	17.50	860.00
5	1982	76	Stage 2	Front Loader	-114.00	45.00	2,385.00
				Side Loader	- 99.00	77.50	1,955.00
				Rear Loader	- 99.00	77.50	2,255.00
7	1980	79	Stage 2	Front Loader	-114.00	45.00	2,385.00
				Side Loader	- 99.00	77.50	1,955.00
				Rear Loader	- 99.00	77.50	2,255.00
7	1982	76	Stage 2	Front Loader	-114.00	45.00	2,385.00
				Side Loader	- 99.00	77.50	1,955.00
				Rear Loader	- 99.00	77.50	2,255.00
a	1980	81	Stage 1	Front Loader	-114.00	45.00	1,290.00
				Side Loader	- 99.00	17.50	560.00
				Rear Loader	- 99.00	17.50	860.00
a	1982	80	Stage 1	Front Loader	-114.00	45.00	1,290.00
				Side Loader	- 99.00	17.50	560.00
				Rear Loader	- 99.00	17.50	860.00
b	1980	79	Stage 2	Front Loader	-114.00	45.00	2,385.00
				Side Loader	- 99.00	77.50	1,955.00
				Rear Loader	- 99.00	77.50	2,255.00
b	1982	75	Stage 3	Front Loader	-114.00	57.50	2,575.00
				Side Loader	- 99.00	90.00	2,145.00
				Rear Loader	- 99.00	90.00	2,445.00

*Not to Exceed

Source: Tables 5-1, 7-5, 7-7.

TABLE 7-18

REGULATORY OPTIONS AND COST IMPACTS

Option No.	1980 Regulatory Level	1980 %Cost Increase	1982 Regulatory Level	1982 %Cost Increase	Equivalent Annual Costs $(Millions)
Baseline	New truck 83 dBA @ 50 feet	0	New truck 80 dBA @ 50 feet	0	0
1	81	3.7	76	6.2*	18.9
3	(not regulated)	0	80	3.7	2.7
5	(not regulated)	0	76	9.9	17.5
7	79	9.9	76	0	21.5

Source: Table 7-15, Table 7-17, and EPA analysis.

*Incremental percentage cost increase due to moving from Stage 1 technology to Stage 2 technology.

loaders and $77.50 for both side and rear loaders. Fuel (operating) costs will decrease due to the reduced engine speeds entailed in the quieted compactors. Front loader fuel reductions are expected to be $114.00 while side and rear loader trash compactors will have reduced fuel expenses of about $99.00 per year.

It should be noted, however, that the percentage price increases are based on the cost of the compactor body alone, not the prices of the complete operational unit which also includes the truck chassis and cab. The effective percentage price increase computed using the total price of the operational unit (which is the price the end user would have to pay) is significantly smaller; about one-half of the figures for the compactor body alone, or about 6.4 percent for front loaders, 12.8 percent for side loaders, and 9.8 percent for rear loaders.

Based on price increases for the complete operational unit, the equivalent annual cost for adoption of the Option 7 regulatory scenario is $21.5 million when the regulatory scenario begins in 1980. Equivalent annual costs for the other options range from $2.7 million to $18.9 million. Quieting costs are computed through 2000.

4a. Price Elasticity of Demand

The price elasticity* of demand is used as a measure of the reaction of the market to a price increase. It relates the change in quantity demanded to the change in price. The estimate of elasticity reflects the total net interaction of the preceding factors affecting the quantity demanded as prices change from present levels.

Background & Assumptions:

A model of the "typical" solid waste compactor body end user was constructed to evaluate the effects of price on volume and to analyze several other economic factors. The model represents a composite of all end user types: large and small private contractors and municipalities. It is summarized in Table 7-19.

The analysis which follows assumes that the "full flow-through" concept is applicable to the market and the industry. Therefore, cost increases experienced by the manufacturer will be passed down through the distributor to the purchasing end user in the form of price increases. The price increases will result in higher collection fees for collection services to the consumer.

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* Mathematically, the price elasticity (e) of demand can be defined as:

$$e = \frac{\text{Percentage Change in Quantity Demanded (q)}}{\text{Percentage Change in Price (p)}}$$

$$e = \frac{dq/q}{dp/p} = \frac{dq}{dp} \cdot \frac{p}{q}$$

The analysis also assumes that demand for solid waste compactor bodies, as an intermediate product, is less sensitive to changes in its own price when that product represents a small proportion of the cost for the final product or service demanded (i.e., solid waste collection).

TABLE 7-19

REPRESENTATIVE SOLID WASTE COMPACTOR
END USER COST STRUCTURE MODEL

Expense Category	Percent of Operating Revenues
Equipment maintenance	11.8
Collection labor	47.5
Equipment operation	3.7
Other expenses	32.6
Depreciation (collection equipment)	4.4
Total expense	100.0%

Source: Reference 7-1.

The rationale is that for a given level of demand for collection services, the impact of a change in compactor body prices is small when compared to the total cost of collection services and the price charged for the services. A relatively small change in the price of collection services implies a relatively small effect on the quantity demanded of both collection services offered and compactor bodies.

Table 7-19 shows that collection equipment (the major component of the depreciation account) represents a small fraction of total operating expenses, less than five percent. This includes truck chassis, bodies and containers. Considering that the purchaser views the price of the compactor body as only a portion of the total price of an operational unit (i.e., truck chassis and cab) the price increases developed for the compactor body alone represent an overestimate of the percentage price increase. Thus the depreciation expense for compactor bodies alone is in effect an even smaller portion (of total operating expenses) than the amount noted here. Therefore, a change in the price of new compactor bodies resulting from noise abatement regulations has a small effect on the "derived" demand for new compactor equipment. This enhances the ability of the compactor body manufacturer to pass through additional costs without reducing production volume significantly.

It is believed that there is a relatively low demand elasticity. The reasons for this are:

A. Equipment cost as reflected in depreciation charges is a small factor in the end user's total cost structure. Our model indicates that these costs represent 4.4 percent of operating revenues.

B. Truck-mounted solid waste compactors presently have a high degree of acceptance in the industry. There are no viable competitive systems.

C. Differential price increases between side and rear loaders could precipitate a change in the mix of these units. At Stage 1, the estimated percentage price increase of these body types is essentially the same. No change in mix attributable to this factor would be expected.

D. The level of imported and exported compactor bodies will not be affected by a price increase at Stage 1, since all imported units will be subject to the same noise abatement standard and exports will not be subjected to the noise attenuation standards.

E. Leasing of compactor bodies will not materially change due to Stage 1 price increases.

F. The increased price for new equipment will not materially change the trade-offs associated with buying new equipment versus extending the life of units currently in operation.

G. Some prebuying will occur in response to higher prices.

It is estimated that the elasticity of demand for truck-mounted compactors remains relatively low for Stage 2 and 3 treatment.

4b. Equivalent Annual Costs For Changes in Demand Elasticity Estimates

To test the sensitivity of the equivalent annual costs relative to changes in the demand elasticity for compactor bodies under noise regulation, scenarios were developed in which widely varying demand elasticities were used for the purpose of comparison.

The equivalent annual costs of regulation for the proposed regulatory scenario are $21.5 million. This scenario assumes: 1) A regulatory process in which Stage 2 technology is adopted in 1980, 2) Cost increment estimates used were those discussed earlier in this section, 3) Demand elasticity of -.20.

Equivalent annual costs also were computed for assumed elasticities of -1.0 and 0. The first case implies an equal reduction in quantity demanded for a given percentage change (increase) in price; the second case assumes no change in quantity demanded for a change in price (of the magnitude discussed here.)

The equivalent annual costs of regulation assuming an elasticity of -1.0 are $19.8 million; assuming an elasticity of 0, the equivalent annual costs are $21.9 million. In these two cases, the equivalent annual costs of regulation vary from the original case, decreasing 7.9% or increasing 1.9%, respectively, from the original estimate of $21.5 million. It is concluded from these results that the economic analysis is relatively insensitive to the assumed value of elasticity, within the magnitude of change considered.

5. Volume Impact

Stage I

Estimated lead time for an orderly adoption of on-the-shelf quieting technology has been conservatively estimated to be 12 to 18 months. The analysis of Stage 1 economic impact is based on the regulation taking effect in 1980.

Estimates of the Stage 1 increased list prices of standard and quieted units are presented in Table 7-20. The calculation of volume impact in all cases is based on the cost of quieting for each category considered. A separate calculation is made for each compactor body type and for standard and quieted units. The volume impact is considered here in terms of the relative increase in the price of the body alone. Analysis of the volume impact, taking into account the total vehicle, is discussed later in this section.

Volume reductions resulting from price increases associated with Stage 1 are estimated based on an elasticity of -.20. The original baseline forecast is presented in Table 7-8 and the expected Stage 1 decreases in demand are shown in Table 7-21. The adjusted baseline forecast resulting from the adoption of Stage 1 for calendar years 1980-87 are shown in Table 7-22.

Table 7-23 summarizes the estimated Stage 1 reduction in unit volume in 1980.

TABLE 7-20

DEVELOPMENT OF ESTIMATED PRICE ADJUSTMENTS
ASSOCIATED WITH STAGE 1
NOISE EMISSION REQUIREMENTS

	STANDARD UNITS				QUIETED UNITS[1]	
Equipment Classification	Average List Price	Expected Price Increase	Adjusted Average List Price	Percent Price Increase	Average Price Increase	Adjusted Average List Price
Front Loaders	$18,780	$1,290	$20,070	6.9%	--[2]	--
Side Loaders[3]	7,650	560	8,210	7.3	--[2]	--
Rear Loaders	11,580	860	12,440	7.4	--	--

Source: Exhibits III-20 and II-6 (Reference 7-1).

Notes:
(1) Cost of Stage 1 quieted units estimated at 10% over standard price which is greater than Stage 1 price increase. No computation of percent made.
(2) Quieted front or side loaders are not manufactured.
(3) Does not include prices for products built and sold as an integral body and chassis unit.

TABLE 7-21

PERCENT VOLUME DECLINE - STAGE 1[1]

	STANDARD UNITS			QUIETED UNITS[2]		
Compactor Body Type	Elasticity	Percent Price Increase	Percent Decrease in Demand	Elasticity	Percent Price Increase	Percent Decrease in Demand
Front Loader	.20	6.9%	1.4%	--	--	--
Side Loader	.20	7.3	1.5	--	--	--
Rear Loader	.20	7.4	1.4	--	--	--

Source: Exhibit V-4 (Reference 7-1).

Notes: (1) Volume impact is based on the cost of quieting each compactor body type as developed in Section II (Reference 7-1)

(2) The number of quieted rear loaders produced is less than 10% of total shipments. Quieted units are produced on an optional equipment, special order basis only at an approximate price of 10% greater than standard units. No incremental costs are expected due to applying the specified noise abatement technology to quieted units since current price premium exceeds the estimated Stage 1 cost.

TABLE 7-22

ADJUSTED BASELINE FORECAST - STAGE 1 (1980 - 1987)

	TOTAL PROJECTED UNITS SHIPPED[1]		FRONT LOADER		SIDE LOADER		REAR LOADER[2]	
Year	Unit Decrease from Baseline	Adjusted Baseline	Unit Decrease	Adjusted Baseline	Unit Decrease	Adjusted Baseline	Unit Decrease	Adjusted Baseline
1980	192	13,508	22	1,578	62	4,038	108	7,892
1981	197	13,788	24	1,656	65	4,240	108	7,892
1982	201	14,083	25	1,739	68	4,452	108	7,892
1983	205	14,393	26	1,826	71	4,675	108	7,892
1984	210	14,718	27	1,918	75	4,908	108	7,892
1985	216	15,059	29	2,013	79	5,154	108	7,892
1986	219	15,362	29	2,054	80	5,258	110	8,050
1987	224	15,669	30	2,095	82	5,363	112	8,211

Source: Exhibits IV-2, V-6, and V-7 (Reference 7-1).

Notes: (1) Unit decrease equals the difference between baseline forecast and the baseline as adjusted for Stage 1 price increases.

(2) Quieted units are not included since the estimated cost of quieted units over standard units is 10% and this exceeds the Stage 1 price increase.

TABLE 7-23

STAGE 1 - ESTIMATED FIRST YEAR UNIT
REDUCTION FROM BASELINE FORECAST, 1980

Compactor Body Type	Reduction in Annual Volume Units	Percent
Front loader	22	1.4%
Side loader	62	1.5
Rear loader	108	1.4
Total	192	1.4

Source: Reference 7-1.

The reduction in unit volume resulting from the adoption of the Stage 1 standard ranges from 22 to 108 units depending on compactor body category, and the total unit reduction is about 1.4 percent of baseline shipments. The largest unit reduction occurs in rear loaders, and the smallest unit reduction occurs in front loaders. Stage 1 does not reduce industry volume below the 1979 baseline forecast shipment level.

Stage 2

The analysis of the Stage 2 economic impact is based on the regulation taking effect in 1982. Estimates of the list price increases associated with the modifications necessary to achieve Stage 2 are presented in Table 7-24. The estimated elasticities, percent price increases, and decreases in demand used to calculate the Stage 2 volume impact are presented in Table 7-25.

The adjusted baseline forecast associated with adoption of Stage 2 for calendar years 1980-90 is shown in Table 7-26. Table 7-27 summarizes the estimated Stage 2 reduction in unit volume in 1982 relative to the baseline volume.

TABLE 7-24

DEVELOPMENT OF ESTIMATED PRICE ADJUSTMENTS
ASSOCIATED WITH STAGE 2
NOISE EMISSION REQUIREMENTS

	STANDARD UNITS				QUIETED UNITS(1)		
Equipment Classification	Average List Price	Expected Price Increase	Adjusted List Price	Percent Price Increase	Expected Price Increase	Adjusted List Price	Percent Price Increase
Front Loaders	$18,780	$2,385	$21,165	12.7%	--(2)	—	—
Side Loaders(3)	7,650	1,955	9,605	25.6	--(2)	—	—
Rear Loaders	11,580	2,255	13,835	19.5	$1,095	$12,675	9.5%

Source: Exhibits III-20 and II-6 (Reference 7-1).

Notes: (1) Cost of quieted units estimated at 10% over standard price.
(2) Quieted front or side loaders are not manufactured.
(3) Does not include prices for products built and sold as an integral body and chassis unit.

TABLE 7-25

PERCENT VOLUME DECLINE - STAGE 2(1)

	STANDARD UNITS			QUIETED UNITS(2)		
Compactor Body Type	Elasticity	Percent Price Increase	Percent Decrease in Demand	Elasticity	Percent Price Increase	Percent Decrease in Demand
Front Loader	.20	12.7%	2.5%	--	--	--
Side Loader	.20	25.6	5.1	--	--	--
Rear Loader	.20	19.5	3.9	.20	9.5%	1.9%

Source: Exhibit V-2 (Reference 7-1).

Notes: (1) Volume impact is based on the cost of quieting each compactor body type as developed in Section II (Reference 7-1).
(2) Quieted units are assumed to require the same technology package as unquieted units for this level. Quieted units are priced ten percent higher than the equivalent unquieted units.

TABLE 7-26

ADJUSTED BASELINE FORECAST - STAGE 2 (1980 - 1990)

	TOTAL PROJECTED UNITS SHIPPED(1)		FRONT LOADER		SIDE LOADER		STANDARD REAR LOADER		QUIETED REAR LOADER(2)	
Year	Unit Decrease from Baseline	Adjusted Baseline	Unit Decrease	Adjusted Baseline	Unit Decrease	Adjusted Baseline	Unit Decrease	Adjusted Baseline	Unit Decrease	Adjusted Baseline
1980	545	13,155	40	1,560	209	3,891	281	6,919	15	801
1981	558	13,427	42	1,638	220	4,085	281	6,919	15	801
1982	571	13,713	44	1,720	231	4,289	281	6,919	15	801
1983	584	14,014	46	1,806	242	4,504	281	6,919	15	801
1984	599	14,329	49	1,896	254	4,729	281	6,919	15	801
1985	614	14,661	51	1,991	267	4,966	281	6,919	15	801
1986	626	14,955	52	2,031	272	5,066	286	7,058	16	800
1987	639	15,254	53	2,072	278	5,167	292	7,199	16	816
1988	651	15,560	54	2,113	283	5,271	298	7,343	16	833
1989	664	15,871	55	2,155	289	5,376	304	7,490	16	850
1990	672	16,194	56	2,199	295	5,483	310	7,640	17	866

Source: Exhibits IV-2, V-6, and V-9 (Reference 7-1).

Notes: (1) Unit decrease equals the difference between the baseline forecast and the baseline as adjusted for the incremental price increase from baseline to Stage 2.

(2) Quieted units are applicable to rear loaders only and estimated at 10% of total units.

TABLE 7-27

STAGE 2 - ESTIMATED FIRST YEAR UNIT REDUCTION FROM BASELINE FORECAST, 1982*

Compactor Body Type	Reduction in Annual Volume: Units	Percent
Front Loaders	44	2.5%
Side Loaders	231	5.1
Rear Loaders	296	3.9
Total	571	4.0%

Source: Tables 7-8 and 7-26.

The total reduction in unit volume resulting from the adoption of a Stage 2 standard is about 4.0 percent and ranges from 44 to 296 units, depending on the type of compactor body. The largest unit reduction occurs in the rear loader category. The largest percentage reduction occurs in the category of side loaders, reflecting the higher cost of meeting a noise standard. The smallest unit and percentage reduction occurs with front loaders. The introduction of a Stage 2 standard reduces industry volume approximately two percent below the 1981 baseline shipment level. The adjusted baseline forecast represents a reduction of about four percent from the average annual volume during the period 1982 to 1990.

Table 7-27 shows the volume impacts (annual volume reduction) for 1982 which would follow from adoption of a regulatory option requiring applicaton at Stage 2 technology starting in 1980. The unit reduction in annual volume for the complete operational unit is one-half of the figures shown in Table 7-27, e.g., total

* The units of volume reduction for Stage 2 assume implementation of that level exclusive of the impact of previous levels.

TABLE 7-28

DEVELOPMENT OF ESTIMATED PRICE ADJUSTMENTS
ASSOCIATED WITH STAGE 3
NOISE EMISSION REQUIREMENTS

	STANDARD UNITS				QUIETED UNITS (1)		
Equipment Classification	Average List Price	Expected Price Increase	Adjusted List Price	Percent Price Increase	Expected Price Increase	Adjusted List Price	Percent Price Increase
Front Loaders	$18,780	$2,575	$21,355	13.7%	--(2)	--	--
Side Loaders(3)	7,650	2,145	9,975	28.0	--(2)	--	--
Rear Loaders	11,580	2,445	14,025	21.1	$1,285	$12,865	11.1%

Source: Exhibits III-20 and II-6 (Reference 7-1).

Notes: (1) Cost of quieted units estimated at 10% over standard unit price.
(2) Quieted front or side loaders are not manufactured.
(3) Does not include prices for products built and sold as an integral body and chassis unit.

TABLE 7-29

PERCENT VOLUME DECLINE - STAGE 3(1)

	STANDARD UNITS			QUIETED UNITS(2)		
Compactor Body Type	Elasticity	Percent Price Increase	Percent Decrease in Demand	Elasticity	Percent Price Increase	Percent Decrease in Demand
Front Loader	.20	13.7%	2.7%	--	--	--
Side Loader	.20	28.0	5.6	--	--	--
Rear Loader	.20	21.1	4.2	.20	11.1%	2.2%

Source: Exhibit V-1 (Reference 7-1) and EPA Contractor estimates.

Notes: (1) Volume impact is based on the cost of quieting for each compactor body type as developed in Section II (Reference 7-1). This includes a separate calculation for each body type.
(2) Quieted units are assumed to require the same technology package as unquieted units for this level. Quieted units are priced ten percent higher than the equivalent unquieted units.

TABLE 7-30

ADJUSTED BASELINE FORECAST - STAGE 3 (1985 - 1993)

	TOTAL PROJECTED UNITS SHIPPED(1)		FRONT LOADER		SIDE LOADER		STANDARD REAR LOADER		QUIETED REAR LOADER (2)	
Year	Unit Decrease from Baseline	Adjusted Baseline	Unit Decrease	Adjusted Baseline	Unit Decrease	Adjusted Baseline	Unit Decrease	Adjusted Baseline	Unit Decrease	Adjusted Baseline
1985	668	14,607	55	1,987	293	4,940	302	6,898	18	782
1986	681	14,900	56	2,027	299	5,039	308	7,036	18	798
1987	695	15,198	57	2,068	305	5,140	315	7,176	18	814
1988	710	15,501	59	2,108	311	5,243	321	7,320	19	830
1989	723	15,812	60	2,150	317	5,348	327	7,467	19	845
1990	738	16,128	61	2,194	324	5,454	334	6,616	19	864
1991	753	16,451	62	2,238	330	5,564	341	7,768	20	881
1992	767	16,780	63	2,283	337	5,674	347	7,924	20	899
1993	783	17,116	65	2,328	343	5,789	354	8,083	21	916

Source: Exhibits IV-2, V-6, and V-11 (Reference 7-1).

Notes: (1) Unit decrease equals the difference between baseline forecast and the baseline as adjusted for the incremental price increase between baseline and Stage 3.

(2) Quieted units are applicable to rear loaders only and estimated at 10% of the total units produced.

reduction in volume for 1982 is 286 representing a 2.0 percent decline in demand. Since the price of the compactor body is approximately one-half the total price of the complete operational unit, the impacts on the complet unit--price increases and declines in demand--are one-half of those impacts considered in terms of the compactor body alone.

Stage 3

The analysis of economic impact is based on Stage 3 regulations taking effect in 1985.

Table 7-28 provides the estimated price increases relted to Stage 3 modifications. The estimated elasticities, percent price increases, and decreases in demand used to calculate Stage 3 volume impact are presented in Table 7-29.

The adjusted baseline forecast associated with the adoption of Stage 3 for the calendar years 1985 through 1993 is shown in Table 7-30. Table 7-31 summarizes the estimated Stage 3 reductions in unit volume for the first year, 1985.

TABLE 7-31

STAGE 3 - ESTIMATED FIRST YEAR UNIT REDUCTION FROM BASELINE FORECAST, 1985*

Compactor Body Type	Reduction in Annual Volume: Units	Percent
Front Loader	55	2.7%
Side Loader	293	5.6
Rear Loader	320	4.2
Total	668	4.3

*The units of volume reduction for Stage 3 assume implementation of that level exclusive of the impact of previous levels.

Source: Tables 7-8 and 7-30.

The total reduction in unit volume resulting from adoption of Stage 3 standards is approximately 4.3 percent. The decrease in projected units ranges from 55 to 320 units. The largest unit reduction is in the rear loader category. The largest percent reduction is in side loaders. The smallest unit decrease and percent reduction are in front loaders. Introduction of Stage 3 standards reduces total projected volume approximately two percent below the 1984 baseline forecast shipment levels.

Impact of Prebuying on Volume

The solid waste compactor body industry will be subject to some prebuying activity immediately prior to the effective date of each noise abatement level. The time period for prebuying is estimated at three months to one year prior to the effective date for each noise level regulation. The amount of prebuying is assumed to depend on three factors:

1. The amount of excess capacity of manufacturers available to produce compactor bodies above the baseline production level at that time.

2. The economic benefit of purchasing compactor bodies earlier and the potential savings resulting from early purchase.

3. The risk of the technology required to quiet the compactor bodies as related to possible increased costs of maintenance and operation.

TABLE 7-32

ESTIMATED EXCESS PRODUCTION CAPACITY BY BODY TYPE IN YEAR PRIOR TO REGULATION

Compactor Body Type	Estimated Unused as Percent of Total Capacity Stage 1 1978-80	Stage 2 1981-82	Stage 3 1984-85
Front Loader	9%	0	0
Side Loader	0	0	0
Rear Loader	20%	20%	20%

Source: Reference 7-1.

* Exhibit V-13 of Reference 7-1 estimates unused capacity in excess of 30 percent for the years prior to each noise level regulation date. EPA estimates this level to be excessive since some rear loader manufacturers will shift production away from rear loaders in favor of side loaders or other non-compactor body production.

Estimates of the excess production capacity available in the year prior to each effective date of the noise level regulation are summarized in Table 7-32, and the prebuying anticipated in the year prior to the effective date for each new noise standard is summarized in Table 7-33.

TABLE 7-33

ANTICIPATED PREBUYING
IN YEARS PRIOR TO EFFECTIVE DATES
(Percent Increase in Total Units
Shipped Over Baseline Forecast)

	1979-80	1981-82	1984-85
Front Loader	2%	0	0
Side Loader	0	0	0
Rear Loader	6%	25%	25%

Source: Reference 7-1.

The unused capacity will allow prebuying to increase the 1979-80 production approximately six percent for rear loaders and two percent for front loaders. There will be no excess capacity available to support prebuying for side loaders. Prebuying is not expected to exceed these percentages, since the technology applied to attain Stage 1 noise abatement has no risk involved to suggest significant increases in maintenance and operations cost.

The Stage 2 price increase for rear loaders is 19.5 percent (based on the body only) above the base period price. It is expected that all available production capacity will be utilized to accommodate prebuying. This assumes an annual cost of capital of ten percent.

At Stage 3, the incremental price difference for rear loader bodies is 21.1 percent. Unused capacity is available for rear loader production and sufficient economic advantage exists to encourage a full year of early purchasing, given an annual cost of capital of ten percent. As in the previous two noise stages, the technology applied to achieve Stage 3 does not involve increased risk and is not considered a factor in stimulating prebuying.

No adjustments to the baseline forecast or the revised baselines for the three levels have been made to reflect prebuying. The adjusted baseline forecast can be modified to reflect prebuying by adding the incremental volume produced in the year preceding the effective date of the noise abatement standards (1979-80, 1981-82, and 1984-85). A similar reduction in the volume of production would be necessary in the first year of each effective noise level to compensate for prebuying. After the first year, it is assumed that shipments will return to the adjusted baseline levels.

Summary

In summary, the anticipated reduction in industry volume at Stage 1, estimated in terms of the compactor body alone, is relatively low (192 units). The potential impact on volume at Stages 2 and 3 is a reduction of 571 and 668 units respectively. For the complete operational unit, the reductions could be 96, 286, and 334 units for Stages 1, 2, and 3, respectively, for the first year of regulation. The effects of respective treatment stages are not additive. Each stage is assumed to include the units of reduction related to moving from the preregulation baseline to the given treatment level. Movement from one treatment stage to the next higher level would involve a reduction of the net difference expected between the two stages. As previously noted, the estimated cost of quieting based on current on-the-shelf technology represents a conservative estimate. Insofar as the actual costs incurred for quieting are lower, the resulting volume impact will be correspondingly lower.

Resource Costs:

* Purpose and Methodology

The resources which will be used to meet each noise standard are estimated in this section, using four measures:

A. The annual increase in capital cost required by end user industries in the first year of enforcement. This represents the additional capital, and required to purchase the more expensive quieted units.

B. The total increase in annual costs in end user segments in the first year of enforcement. Estimates include depreciation, cost of capital, and operation and maintenance costs. This represents the incremental annual costs to own and operate the more expensive quieted units.

C. The total increase in annual costs for operation of a 100 percent quieted population of solid waste compactors based on a future date when nonquieted compactors have been phased out of the population of packer bodies in use.

D. Equivalent annual costs (for Stage 2 only) which are defined as the constant value of an annuity whose present value is the actual annual cost incurred over the period of study.

The estimates of first year capital costs for end user industries are based on the increased purchase price paid and the volume of purchases estimated. Pricing is at the list price level. This measure represents the additional capital which must be financed by end user industries due to the enforcement of the noise standard.

The resource cost factors included in the estimate of the total annual cost increases for end users are:

A. Depreciation. Seven-year, straight-line depreciation of 14.3 percent per year is used. Current Internal Revenue Service guidelines allow solid waste compactors to be depreciated over a five-year period. However, seven years is generally accepted as the average packer body economic life. Therefore, seven years is a better period to use in assessing economic impact.

B. Capital Cost. A return on investment or capital cost rate of ten percent of the additional capital investment is used.

C. Operating Costs. Analysis based on industry information indicates that there will be a reduction in operating costs.

D. Maintenance Costs. Maintenance cost increases associated with the modifications necessary to attain Stage 1 will be negligible.

Stages 2 and 3 are estimated to result in a slight increase in maintenance cost.

Mid-range estimates of resource costs were developed to answer the question: What is the annual bill society pays for quiet solid waste packer bodies? Resource cost estimates are based on the revised baseline forecast and the incremental resource costs from the baseline to each respective regulatory level.

* Estimated Costs

<u>Stage 1</u>

The total increased capital cost to end user industries is estimated to be $10.9 million for the first year of enforcement of the Stage 1 noise standard (Table 7-34). Incremental capital costs represent the adjusted baseline unit forecast multiplied by the increased unit price.

Estimated total annual cost increases in the first year for adoption of a Stage 1 noise standard in 1980 are $1.9 million (Table 7-35).

TABLE 7-34

TOTAL ESTIMATED FIRST YEAR
INCREASED CAPITAL COSTS FOR
END USER INDUSTRIES - STAGE 1, 1980
$(000s)

Compactor Body Type	Increased Capital Costs Mid-Range Estimates
Front Loader	$ 1,939
Side Loader	2,019
Rear Loader	6,923
Total	$10,881

Source: Reference 7-1.

TABLE 7-35

TOTAL ESTIMATED FIRST YEAR
INCREASED ANNUAL COSTS FOR
END USER INDUSTRIES - STAGE 1, 1980
$(000s)

Compactor Body Type	Increased Capital Costs Mid-Range Estimates
Front Loader	$ 383
Side Loader	196
Rear Loader	1,368
Total	$1,947

Source: Reference 7-1.

Stage 2

Increased end user capital costs are estimated at $27.4 million in the first year of enforcement for adopting a Stage 2 noise standard in 1982 (Table 7-36). Again, incremental capital costs are determined by multiplying the adjusted baseline forecast unit shipments by the unit cost increase.

TABLE 7-36

TOTAL ESTIMATED FIRST YEAR
INCREASED CAPITAL COSTS FOR
END USER INDUSTRIES - STAGE 2, 1982
$(000s)

Compactor Body Type	Increased Capital Costs Mid-Range Estimates
Front Loader	$ 3,966
Side Loader	7,820
Rear Loader	15,645*
Total	$27,431

* Cost of quieted units, $839,000 included for rear loaders only.

Source: Reference 7-1.

Estimated total annual cost increases in the first year of enforcement of a Stage 2 noise standard in 1982 are $6.5 million (Table 7-37).

TABLE 7-37

TOTAL ESTIMATED FIRST YEAR
INCREASED ANNUAL COSTS FOR
END USER INDUSTRIES - STAGE 2, 1982
$(000s)

Compactor Body Type	Increased Annual Costs Mid-Range Estimate
Front Loader	$ 954
Side Loader	1,852
Rear Loader	3,714
Total	$6,520

Source: Reference 7-1.

Stage 3

Stage 3 increases in capital cost are presented in Table 7-38.

TABLE 7-38

TOTAL ESTIMATED FIRST YEAR
INCREASED CAPITAL COSTS FOR
END USER INDUSTRIES - STAGE 3, 1985
$(000s)

Compactor Body Type	Increased Annual Costs Mid-Range Estimate
Front Loader	$ 4,931
Side Loader	9,811
Rear Loader	16,909*
	$31,651

*Includes $977,000 for quieted rear loaders.

Source: Reference 7-1.

The total estimated increases in annual costs for Stage 3 are presented in Table 7-39.

TABLE 7-39

TOTAL ESTIMATED FIRST YEAR
INCREASED ANNUAL COSTS FOR
END USER INDUSTRIES - STAGE 3, 1985
$(000s)

Compactor Body Type	Increased Annual Costs Mid-Range Estimates
Front Loader	$1,110
Side Loader	2,114
Rear Loader	3,679
Total	$6,903

Source: Reference 7-1.

The total annual costs (capital expenditures, operating and maintenance costs) for a 100 percent quieted compactor body population in 1993 and beyond are estimated to be $43 million.

The equivalent annual costs represent the stream of equal annual payments needed to cover the sum of discounted future capital and operating and maintenance expenditures due to the regulation, over the time period chosen.

* Summary

Analysis of the resource costs required to quiet solid waste compactor bodies indicates that the capital costs associated with noise control are not insignificant, but are believed to be reasonable in the light of the environmental benefits to be gained from the regulation. Total solid waste compactor body sales were approximately $125 million in 1974. First year capital costs are projected to be approximately $10.8 million for Stage 1, $27.4 million for Stage 2 and $31.6 million for Stage 3.

For a 100 percent quiet population at Stage 3 in 1993 and beyond, total annual costs are estimated to be $43 million.

Equivalent annual costs are $21.5 million for Stage 2 treatment.

Market Impact:

* Purpose

This section describes additional impacts anticipated from the adoption of noise control technology, and includes consideration of both the upstream component suppliers and the downstream distributors and end users.

* Suppliers

General suppliers to truck-mounted solid waste compactor body manufacturers will not be adversely affected by the adoption of noise control technology, mainly because all suppliers derive only a small portion of their business from the packer body industry. The effects of quieting solid waste compactors on the major suppliers are briefly described below:

A. Truck Chassis Manufacturers. The major truck chassis manufacturers are large, financially sound companies with strong technical capabilities. The truck chassis on which solid waste compactors are typically mounted constitutes approximately eight (8) percent of the heavy truck chassis market.

No meaningful change in sales volume is expected as a result of regulation. Using an extremely conservative truck chassis shipment level (i.e., 1975 medium and heavy duty shipments), the unit reductions associated with Stages 1, 2, and 3 are .09, .27 and .31 percent respectively.

B. PTO, Pump and Valve Manufacturers. Power Take-Off units, hydraulic pumps and valves are the major components affected by the proposed regulations. The components utilized by the solid waste compactor body industry are standard product items, and the volume purchased by the industry is insignificant relative to total production and sales. No significant changes are expected.

C. Distributors.

Solid waste compactor body distribution channels and distributor operations will not be significantly affected by the noise emission standards. Although the definition of "manufacturers" under the Noise Control Act includes distributors who assemble the complete vehicle by mounting a compactor body on a chassis, the regulation allows the distributor to rely on the production verification testing done by the compactor body manufacturer, if the distributor assembles the unit in conformance with the body manufacturer's instructions. Consequently, there is expected to be little or no economic impact on distribution due to testing requirements.

D. End Users

The potential impact of the regulation on end users will be reflected in their ability to finance purchases of new packer bodies and the incremental annual costs to operate quieted units.

(1) Ability to Finance New Unit Purchases. End users view the packer truck as being comprised of a packer body and truck chassis as a unit. The regulations under study affect only the packer body. Consequently, the price increases reflected in this report overstate the perceived price increase from an end user perspective. It can be seen in Table 7-40 that the total packer truck price increases are moderate.

TABLE 7-40

ESTIMATED TOTAL PACKER TRUCK PRICE INCREASES BY REGULATORY LEVEL

	STAGE 1		STAGE 2		STAGE 3	
Type of Loader	Compactor Body Price Increase	Compactor Body and Truck Chassis Price Increase*	Compactor Body Price Increase	Compactor Body and Truck Chassis Price Increase	Compactor Body Price Increase	Compactor Body and Truck Chassis Price Increase
Front	6.9%	3.5%	12.7%	6.4%	13.7%	6.9%
Side	7.3	3.7	25.6	12.8	28.0	14.0
Rear	7.4	3.7	19.5	9.8	21.1	10.6

* It is conservatively estimated that the packer body and truck chassis individually account for 50 percent of total purchase price.

Source: Table 7-6.

It is anticipated that price increases may reduce overall demand for packer bodies by both the private hauler and the municipality end user. The level of reduction is reflected in the estimates of price elasticity previously presented.

(2) Incremental Annual Costs. Changes in depreciation, maintenance, capital costs and vehicle operating costs resulting from regulation are reflected in increased annual costs per vehicle as shown in Table 7-41. It should be noted that the total annual costs to operate a quieted compactor vehicle are less than one percent greater than preregulation levels for Stage 1 and less than 1.4 percent greater for Stages 2 and 3 for all types of compactors.

Cost increases of this level will not be difficult to pass on to consumers in the form of either higher collection rates for private haulers or higher taxes to fund municipal collection operations.

Impact on Solid Waste Compactor Manufacturing Operations:

* Purpose

The purpose of this section is to evaluate the potential impacts from adoption of noise standards on manufacturers of solid waste compactor bodies.

The assembly operations in the manufacturing process are most affected by noise abatement technology (Ref. 7-1). Basically, new purchased components are substituted for purchased components currently utilized. Consequently, significantly different plant and equipment investments are not expected to result from regulation.

Assessment of the impact of the regulation on overall industry employment involves consideration of the expected reduction in units produced and the incremental labor required to integrate the new technology. These factors are considered for each regulatory level in the following paragraphs.

TABLE 7-41

TOTAL ANNUAL COST PER VEHICLE
FOR STAGES 1, 2 AND 3

	Annual Costs						Estimated Percent Change in Total Annual Equipment Operating Cost per Vehicle per Year (1)
	Capital Cost	Depreciation	Maintenance Cost	Operating Cost	Impact Maintenance Cost	Total	
Stage 1							
Front Loader	$129	$185	0	$-114	$45	$255	.58%
Side Loader	56	80	0	- 99	18	64	.15
Rear Loader	86	123	0	- 99	18	137	.31
Stage 2							
Front Loader	$238	$342	0	$-114	$45	$521	1.19%
Side Loader	196	280	$60	- 99	18	464	1.06
Rear Loader	226	323	60	- 99	18	537	1.22
Stage 3							
Front Loader	$258	$369	$13	$-114	$45	$581	1.32%
Side Loader	214	307	73	- 99	18	522	1.19
Rear Loader	244	350	73	- 99	18	595	1.36

Source: Exhibits V-4, B-2 and Table III-6 (Reference 7-1).

Notes: (1) Calculated by dividing the total cost for the body type by $43,912, the average annual operations cost per vehicle, Exhibit B-2. (Reference 7-1).

* Stage 1

Total unit reduction under Stage 1 regulation is expected to be approximately 1.5 percent, with a similar reduction in employment. However, this reduction is offset by increases in employment to integrate the new technology. The estimated number of incremental direct labor hours required to integrate the new technology for each regulatory level are shown in the following table:

TABLE 7-42

ESTIMATED CURRENT AND INCREMENTAL DIRECT LABOR HOURS BY REGULATORY LEVEL

Compactor Type	Current Unit Direct Labor Hours*	INCREMENTAL DIRECT LABOR HOURS** Stage 1 Absolute	Stage 1 Percent Increase	Stage 2 Absolute	Stage 2 Percent Increase	Stage 3 Absolute	Stage 3 Percent Increase
Front Loader	290	18	6.2%	27	9.3%	27	9.3%
Side Loader	120	9	7.5	39	32.5	39	32.5
Rear Loader	180	9	5.0	39	21.7	39	21.7

Source: Reference 7-1.

Note that direct labor inputs to produce units increase from 5.0 to 7.5 percent depending upon body type. A net increase in employment is expected under Stage 1.

*Estimated direct labor hours were derived by utilizing the typical manufacturer model shown in Section II (Reference 7-1). Total direct labor costs account for 12 percent of total list price. Labor hours were calculated using $7.80 per hour.

**Incremental direct labor hours are taken from Section II (Reference 7-1).

* Stages 2 and 3

Reduction in demand resulting from Stage 2 regulation would produce an employment reduction of 2.5, 5.1 and 3.9 percent for front, side and rear loaders, respectively, viewed from the perspective of the compactor body alone. If viewed from the standpoint of the complete unit, employment declines resulting from treatment Stages 1, 2, and 3 are 1.3, 2.6, and 2.0 percent, respectively. It can be seen in Table 7-42 that these reductions are more than off-set by increases in direct labor required by the new technology. The same pattern is expected to result under Stage 3.

Foreign Trade:

* Purpose

This section covers the impact of the regulation on export and import patterns for truck-mounted solid waste compactor bodies. Noise regulations do not apply to export products, but do apply to products imported for use in the United States.

* Exports

Domestic solid waste compactor body manufacturers will be able to export quieted and unquieted products to foreign countries depending on the requirements of the foreign market. To the extent that some foreign markets require quiet compactor bodies, domestic manufacturers will be in an improved competitive position.

We expect no negative change in compactor body export patterns to result from regulation.

* Imports

Imports have not significantly penetrated the United States solid waste compactor body market. This indicates that U.S. producers have a net cost/technology advantage over foreign producers. This is not expected to change as a result of regulation.

* Balance of Trade

Based on the factors reviewed above, no material impact on the balance of trade is anticipated from setting any of the noise abatement levels.

Individual Impacts:

* Purpose

This section addresses differential impacts which may develop, affecting a single firm or set of firms.

* Truck-Mounted Solid Waste Compactor Body Manufacturers

The modifications necessary to meet all regulatory levels require a minimum level of technical expertise in quieting technology. Small manufacturers may be less able to support requirements for specialized personnel than larger companies, but the relative impact is considered minimal in view of the technology. Further, it is believed that the lead times are adequate for compliance with the impending regulations. Consequently, no differential impacts on manufacturers of different size or mix of product offering are expected.

Disruptive Impacts:

* Purpose

This section assesses the potential for disruptive economic impacts due to the establishment of noise standards per se. It concerns "real" world impacts as opposed tc impacts which are a change in a forecasted future. With adequate lead time and appropriate planning, business management is able to adjust its plans to reflect changing conditions and avoid adverse impacts on its operations. Future over-capacity, unemployment and other adverse conditions are avoided, through adjustments in planning.

* Assessment

The adoption of the noise emission levels suggested for study could have the following probable effects:

A. Stage 1 -- 1980. No disruptive impacts are indicated at this level. Cost changes for the bodies are from 6.9 to 7.4 percent, and volume changes are minor from baseline conditions. The solid waste compactor body industry would be expected to continue its normal growth pattern with a Stage 1 noise standard. No absolute unemployment would be anticipated.

B. Stage 2 -- 1982. Adoption of a Stage 2 standard could result in high costs reflected in substantial price increases (12.7, 25.6 and 19.5 percent for front, side and rear loader bodies, respectively). This can result in an overall four (4) percent decrease in domestic solid waste compactor body demand. Price increases for the complete units may reach 6.4, 12.8, and 9.8 percent for Stages 1, 2, and 3, respectively. These price increases for the complete operational unit could result in an overall two (2) percent decline in demand. The growth pattern of the solid waste compactor body industry should remain at the baseline average annual rate. No absolute unemployment is anticipated.

C. Stage 3 -- 1985. Compactor body price increases for Stage 3 can range from 13.7 to 28.0 percent. Demand could decrease by 4.3 percent. No absolute unemployment is anticipated and the growth of the industry should continue at the baseline average annual rate.

Given the size of the solid waste compactor body industry, no significant economic disruption to the national or a regional economy should occur from these changes.

Summary:

In this section, the economic impact has been assessed based on product technology modifications required by EPA. A brief summary of the results are:

A. Compactor body prices may increase as shown in Table 7-43 and would probably be passed on to end users.

TABLE 7-43

SUMMARY OF ESTIMATED COMPACTOR BODY LIST PRICE INCREASES

Compactor Body Type	Percent List Price Increase Stage 1	Stage 2	Stage 3
Front Loader	6.9%	12.7%	13.7%
Side Loader	7.3	25.6	28.0
Rear Loader	7.4	19.5	21.1
Quieted Rear Loader	---	9.5	11.1

Source: Tables 7-14, 7-15.

B. Compactor body unit volume will be affected as indicated below:

TABLE 7-44

SUMMARY OF ESTIMATED FIRST YEAR UNIT REDUCTION FROM BASELINE FORECAST

	Unit Reduction		
Compactor Body Type	Stage 1 (1980)	Stage 2 (1982)	Stage 3 (1985)
Front Loader	22	44	55
Side Loader	62	231	293
Rear Loader	108	296	320
Total	192	571	668

Source: Tables 7-24, 7-28 and 7-33.

Stage 1 can result in an overall 1.4 percent decline in unit volume, Stage 2 in an overall 4.0 percent decline in unit volume, and Stage 3 in an overall 4.3 percent decline in unit volume.

Possible price increases and volume demand declines for the complete operational unit are shown below in Table 7-45.

TABLE 7-45

SUMMARY OF LIST PRICE INCREASES
AND DEMAND DECLINES FOR COMPLETE
OPERATIONAL UNIT - FIRST YEAR OF REGULATION

Compactor Body Type	Stage 1 Percent Price Increase	Stage 1 Unit Reduction	Stage 2 Percent Price Increase	Stage 2 Unit Reduction	Stage 3 Percent Price Increase	Stage 3 Unit Reduction
Front Loader	3.5%	11	6.4%	22	6.9%	28
Side Loader	3.7%	31	12.8%	116	14.0%	146
Rear Loader	3.7%	54	9.8%	148	10.6%	160
Total		96		286		334

Source: Tables 7-41, 7-45.

Stage 1 can result in an overall 0.7 percent decline in unit volume, Stage 2 in an overall 2.0 percent decline in unit volume, and Stage 3 in an overall 2.2 percent decline in unit volume.

C. The cost of noise abatement is presented in Table 7-46.

TABLE 7-46

SUMMARY OF THE RESOURCE COSTS
ASSOCIATED WITH NOISE ABATEMENT
$(000s)

Noise Standard	First Year of Enforcement Capital Costs	First Year of Enforcement Annual Costs
Stage 1 - 1980	$10,881	$1,947
Stage 2 - 1982	27,431	6,520
Stage 3 - 1985	31,651	6,903

Source: Reference 7-1.

The cost of noise attenuation is not insignificant in relation to the total 1974 dollar volume of the solid waste compactor body market of approximately $125 million.

D. There should be little effect on upstream component suppliers, or downstream distributors or end users.

E. There should be no effect on factory operations at any of the regulatory levels.

F. No absolute unemployment is expected to occur at any of the regulatory levels.

G. No changes in import and export patterns should occur because of noise regulations.

H. No manufacturers are likely to withdraw from the solid waste compactor body market as a result of regulation.

I. There are no expected disruptive impacts from adoption of noise standards.

REFERENCES
SECTION 7

7-1. "A Study to Determine the Economic Impact of Noise Emissions Standards in the Specialty Truck Components Industry. Truck Mounted Solid Waste Compactor Bodies," A.T. Kearney, Inc. Draft report submitted to EPA Office of Noise Abatement and Control, December 1976.

7-2. Shuster, Kenneth A., "Eleven Residential Pickup Systems Compared for Cost and Productivity," Solid Waste Management, May 1975.

7-3. U.S. Environmental Protection Agency, Residential Collection Systems, (530/SW-97C-1), March 1975.

SECTION 7 EXHIBIT

METHODOLOGY FOR DEVELOPMENT OF COST ESTIMATES

The methodology used to develop cost estimates for applying noise abatement technology is described in this Exhibit.

METHODOLOGY

The approach used to estimate the costs of applying noise abatement technology is summarized below:

1. Conducted plant visits.
2. Collected published data relating to manufacturers' cost structure.
3. Identified costs expected to be affected by noise regulation.
4. Collected component cost data from suppliers, manufacturers and end-users.
5. Utilized industrial engineering analysis of production and in-use changes.
6. Analyzed changes in overhead expenses.
7. Formulated the profile of a typical company and developed the overall estimated cost and charges resulting from noise regulation.

Plant Visits

The plants of several manufacturers of truck-mounted solid waste compactor bodies were visited in order to obtain an understanding of the production process, the level of vertical integration in manufacturing major components, and the nature of other products being made at these plants.

The basic manufacturing process for compactors is similar among the manufacturers, although a wide variation appears to exist in the technical sophistication of the process. In general, compactors are manufactured in the following sequence:

1. Purchased sheet steel is cut to size using shears and torch-burning equipment. (One manufacturer purchases coil stock, which is more economical, and shears the coil sheet to size).
2. The cut-outs are formed and machined to final specifications.
3. The basic body parts are kitted and moved to the first assembly station where they are placed in assembly fixtures and spot welded.
4. Dimensions and tolerances are checked and welding of the body is completed.
5. Welds are ground down and checked for quality.
6. The balance of the compactor components, including the hydraulic system, are assembled onto the body.
7. The body is moved to the paint shop for prime and top coats.
8. The completed body is inspected (and reworked if necessary) and then moved into storage or to the mounting area.
9. The compactor bodies are lifted onto the truck chassis and secured. Hydraulic and control systems are installed, and the completed unit inspected prior to shipment.

Some of the individual characteristics of compactor manufacturers are discussed in more depth subsequently.

Manufacturers' Cost Structure

An overall estimate of manufacturer cost structure was constructed from data from the 1972 Census of Manufacturers and Dun & Bradstreet, Analytical Financial Reports for selected companies. The Agency's own experience with the operating ratios of similar industries was also utilized in this analysis. A representative cost structure for the industry is shown in the following table:

TABLE 7-47

REPRESENTATIVE SOLID WASTE COMPACTOR MANUFACTURER COST AND PROFIT STRUCTURE

Element	Net Percent of Sales Revenue	
Direct Material	44%	
Direct Labor	12	
Manufacturing Overhead	24	
Total Cost of Goods		80%
General, Sales, and Administrative		13
Profit		7
Total		100%

Source: Reference 7-1.

Impacted Costs

The nature of costs expected to be impacted by noise regulation are specified below in accordance with the sequence in the production process:

1. Planning. The planning effort associated with noise control is a one-time overhead cost consisting of preliminary design and review in the functional areas of engineering, marketing, and data processing. The engineering effort generally includes:

   a. A review and possible redesign of affected components and systems.
   b. Testing of prototype vehicles to assure desired results.
   c. A review of manufacturing facilities, layout, equipment, tooling, etc., to insure optimal manufacturing practices.

The marketing effort consists of a review of sales and technical literature, updating of training programs, and evaluations of warranty and other policies. The data processing effort includes design or modification of manufacturing support systems required by process changes.

2. Implementation. Implementation of the noise control technology is a one-time overhead cost incurred as a result of location of sources of material, tooling and equipment acquisition, production facility changes, hiring

and training, management information system modifications, and marketing changes.

3. Production. The production cost represents an ongoing incremental cost associated with each unit produced. It is comprised of direct labor and direct material costs. The direct labor cost reflects the additional time required to manufacture and/or assemble quieting components. It also includes the cost of any additional production checking or inspections. The direct material cost reflects the cost of additional raw materials and components or the cost increase over existing levels.

4. Enforcement/Compliance. The enforcement/compliance costs represent an on-going overhead cost related to product warranty and anticipated EPA requirements related to testing and recordkeeping. Additional warranty costs may result if the noise control technology reduces the component life and/or reliability of the equipment. Testing costs include sound measurement equipment and the cost of administering tests. Recordkeeping costs relate to the need to maintain test data for product verification and selective enforcement audits.

Overhead Expense

Overhead is broken down into two areas: manufacturing overhead; and, general, sales, and administrative (GS&A) overhead. Overhead costs are usually allocated to a product as a percentage of the direct labor cost. As indicated in Table 7-47, manufacturing overhead is estimated to be 200 percent (24/12) of direct labor and GS&A is estimated to be an additional 108 percent (13/12) of direct labor. It is likely that the application of noise control technology will result in some increases in overhead cost, but it is unlikely that the increase will be as large as that derived by applying the existing rates to the additional labor cost resulting from the quieting technology.

COMPANY PROFILE

The typical company developed for the purposes of estimating costs does not represent an existing manufacturer, but instead reflects a composite of firms in the industry. The composite is based on an evaluation of the industry in terms of production rates, manufacturing processes, and estimated cost and profit structure. The following paragraphs describe the general and specific assumptions on which the typical company is based, and the factors used to estimate the cost of noise control technology.

(a) Background and General Assumptions

The general manufacturing process for truck-mounted solid waste compactor bodies is described in Section 2 (Ref. 7-1). While the basic process is essentially the same for all manufacturers, there are some variations in the methods of operation. The following paragraphs describe the differences among manufacturers noted in terms of manufacturing methods and technology, product mix, production rates, and level of vertical integration.

The differences in manufacturing methods and technology are most pronounced in the areas of physical plant, tooling, and equipment sophistication. These differences are characterized in the following company profiles. One manufacturer has a large, modern plant, a large number of technologically advanced, numerical control machines, and sophisticated assembly jigs and fixtures. A second manufacturer also has a modern plant, but does not have as much state-of-the-art equipment as the first.

The third manufacturer has a very old and generally run down facility, does not appear to have any numerical control equipment, and uses relatively unsophisticated jigs and fixtures in the assembly process.

Although the range of labor intensive to capital intensive manufacturers is considerable, the Agency concluded that the proposed noise control technology would not have a significant impact on either existing manufacturing operations or labor. Therefore, the regulation should not result in unique cost advantages to either the labor intensive or the capital intensive manufacturer.

Differences were also noted in production rates. Some manufacturers produce truck-mounted compactors in sufficient volume to justify continuous production lines, while others produce in intermittent small lots. The proposed quieting treatment is concentrated primarily in the mounting operation where the compactor body is mounted on the chassis. The technology has little impact on the actual production of the compactor body itself. Thus, the quieting technology does not appear to result in cost disadvantages to either continuous or intermittent producers.

All of the manufacturers visited produce items other than truck-mounted compactors, including stationary compactors, dump bodies, hoists, and trash containers. The overall product mix varies with each company. The primary reason for the industry's general product mix is commonality of manufacturing processes.

According to manufacturers, there is very little commonality of non-purchased components between these products. Thus, it was concluded that product mix should not be a factor in the cost of applying quieting technology.

It appears that the make versus buy mix for the components affected by the quieting technology is similar among manufacturers. All manufacturers purchase power take-off units, instrumentation and speed control components from the same group of vendors. In addition, most companies purchase the hydraulic pumps used on compactors. However, it appears that most companies produce their own hydraulic cylinders since the process is relatively simple and the necessary equipment can be used to produce cylinders for a wide line of products.

The implementation of noise standards should not significantly affect the existing make versus buy mix. It can be assumed that those components presently purchased will still be purchased after quieting, and the same type of purchase savings will be achieved. The only potential impact of significance relates to the in-house production of hydraulic cylinders for rear loading vehicles. If cushioned cylinders are required to reduce impact noise, then some manufacturers may elect to purchase these items rather than incur the expense of redesigning the cylinder and production process.

In summary, the Agency concluded that the proposed noise control technology would not result in any major changes or disruptions in the existing patterns of operation. Consequently, the Agency developed cost estimates for noise control technology based on the profile of a "typical" company.

(b) Specific Assumptions for the Typical Company

1. Production Rates. The estimated production levels for the industry and estimated market share of existing companies have been presented in the economic profile phase of this study. Using this information, the following production rates have been assumed for the typical company manufacturing one of the three types of equipment:

TABLE 7-48

ESTIMATED UNIT PRODUCTION
OF A TYPICAL COMPANY

Manufacturers of:	Typical Company Production (units/year)
Front Loader	200
Side Loader	300
Rear Loader	400

Source: Reference 7-1.

The production rates for the typical company have been used to estimate annualized unit cost (i.e., annual cost/units per year = cost per unit).

2. Cost Structure and Profitability. Manufacturers have not divulged cost and profitability data, so it was necessary to develop estimates based on Analytical Financial Reports (Dun and Bradstreet,Inc.), industry statistics (1972 Census of Manufacturers), and the Agency's experience in similar industries. The following cost and profit estimates are assumed to be representative of the "typical" company:

TABLE 7-49

ESTIMATED COST STRUCTURE
FOR A TYPICAL COMPANY

Cost Category	Percent of COGS*	Percent of Average Sales Price
Direct Material	58%	44%
Direct Labor	15	12
Manufacturing Overhead	30	24
General, Sales and Administrative	--	13
Gross Profit	--	7
Total	100%	100%

*Cost of Goods Sold.

Source: Dun and Bradstreet, Inc., Analytical Financial Reports and 1972 Census of Manufacturers.

This breakdown shows that direct material represents the largest cost element, and the total cost of goods sold is approximately 80 percent of the average sales price.

3. Overhead Expenses. Based on the assumed overhead cost structure for the typical company, the full overhead allocation would be 308 percent of direct labor costs.** It is unlikely that quieting will lead to overhead cost increases of this magnitude and, therefore, estimates of the actual incremental overhead expenses for the typical company have been developed.

**Full Overhead = [Manufacturing Overhead (24%) + GS&A (13%)] /Direct Labor (12%) = 308%

SECTION 8

ENFORCEMENT

GENERAL

The EPA enforcement strategy will place a major share of the responsibility on the manufacturers who will be required to conduct pre-sale testing to determine the compliance of truck-mounted solid waste compactors with this regulation and noise emission standards. Besides relieving EPA of an administrative burden, this approach benefits the manufacturers by leaving their personnel in control of many aspects of the compliance program and imposing only a minimum burden on their business. Therefore, monitoring by EPA personnel of the tests and manufacturers' actions taken in compliance with these regulations is advisable to ensure that the Administrator is provided with the accurate test data necessary to determine whether the compactors distributed in commerce by manufacturers are in compliance with these regulations. Accordingly, the regulations provide that EPA Enforcement Officers, under previously promulgated and recently modified regulations (40 CFR Part 205 Subpart A), are empowered to inspect records and facilities in order to assure that manufacturers are carrying out their responsibilities properly. Under a recent U.S. Supreme Court decision (Marshall v. Barlow's, Inc., 436 U.S. 307, (1978)), such inspections may be conducted so long as (1) the manufacturer consents or (2) the officers have obtained a warrant.

The enforcement strategy proposed in these regulations consists of three parts: (1) Production Verification, (2) Selective Enforcement Auditing, and (3) In-Use Compliance Provisions.

PRODUCTION VERIFICATION

Production verification is testing by a manufacturer of selected early production models of a configuration intended for sale. The objective is to verify that a manufacturer has the requisite noise control technology in hand to comply with the standard at the time of sale and is capable of applying the technology to the manufacturing process. The early production models of a configuration tested must not exceed the level of the standard minus the noise level degradation factor (NLDF) before any models in that configuration may be distributed in commerce. Any testing shall be done in accordance with the proposed test procedure.

Production verification does not involve any formal EPA approval or issuance of certificates subsequent to manufacturer testing, nor is any extensive testing required of EPA. All testing is performed by the manufacturer. However, the Administrator reserves the right to be present to monitor any test (including simultaneous testing with Agency equipment) or to require that a manufacturer supply the Agency with products for testing at EPA's Noise Enforcement Facility in Sandusky, Ohio or at any other site the Administrator may find appropriate.

The production unit selected for testing is a product configuration. A product configuration is defined on the basis of the parameters delineated in section 205.205-3 of the regulation. The basic parameters for configuration identification include the type of truck engine, compactor body, compactor power system or power take-off and the exhaust orientation.

A manufacturer shall verify production products prior to sale by one of two methods. The first method will involve testing an early production product (intended for sale) of each configuration.

Alternatively, production verification testing of all configurations produced by a manufacturer may not be required where a manufacturer can establish that the sound levels of some configurations (based on tests or on engineering judgment) are consistently representative of other configurations. In such a case, that product which emits the highest noise level would be the only configuration requiring verification testing.

This second method allows a manufacturer, in lieu of testing products of every configuration, to group configurations into categories. A category will be defined by basic parameters of truck engine type, compactor type, and compactor power system. Again, the manufacturer may designate additional categories based on additional parameters of his choice.

Within a category, the configuration emitting the highest A-weighted sound pressure level at the end of the Acoustical Assurance Period is determined either by testing or good engineering judgment. The manufacturer can then satisfy the production verification requirements for all configurations within that category by demonstrating that the loudest configuration complies with the applicable standard minus the NLDF for that configuration. This can eliminate the need for a substantial amount of testing. However, it must be emphasized that the loudest configuration must be clearly identified and the NLDF for each configuration must be reported.

These regulations also provide that the Administrator may test products at a manufacturer's facility using Agency equipment. This will provide the Administrator with an opportunity to determine that the manufacturer's test facility satisfies the requirements of section 205.204 and is qualified as specified in section 205.204 to conduct the tests required by this subpart. If it is determined that the equipment or facilities are not qualified, the

Administrator may disqualify them from further use for testing under this subpart. Procedures that are available to the manufacturer subsequent to disqualification are delineated in the regulation.

A production verification report for a configuration must be filed by the manufacturer before any products of that configuration are distributed in commerce. A product configuration is considered to be production verified when the manufacturer has shown, based on the application of the noise measurement test, that a configuration conforms to the standard, and when a timely report has been mailed to EPA indicating that it complies with the standard.

If a manufacturer is unable to test due to weather conditions or other conditions beyond his control, the production verification of a configuration may be delayed for a period of up to 90 consecutive days without the manufacturer's request provided that the test is performed on the first day that the manufacturer is able and the manufacturer maintains records of the conditions which make testing impossible. If testing has not begun by the 45th day the manufacturer has 5 days to notify the Administrator in writing that the products have been distributed and must provide documentation of the conditions which have prevented testing. This procedure will minimize disruptions to manufacturing facilities.

If a manufacturer adds a new configuration to a product line or changes or deviates from an existing configuration with respect to any of the parameters which define a configuration, the manufacturer must verify the new configuration either by testing a product and submitting data or by filing a report which demonstrates verification on the basis of previously submitted data.

Production verification is an annual requirement. However, the Administrator, upon request by a manufacturer, may permit the use of data from previous production verification reports for specific product configurations or categories. The considerations that are cited in the regulation as being relevant to the Administrator's decision are illustrative and not exclusive. The manufacturer can submit all data and information that he believes will enable the Administrator to make a reasoned decision. It must be again emphasized that the manufacturer must request the use of previous data. If the manufacturer fails to do so, then all categories and configurations for each subsequent year must be production verified.

The manufacturer need not verify configurations at any particular point in a year. The only requirement is that a configuration be verified prior to distribution in commerce. The inherent flexibility in the scheme of categorization in many instances will allow a manufacturer to either verify, based on representation, a configuration that may not be produced until late in a year, or else wait until actual production of that configuration to verify it.

If a manufacturer fails to properly verify and a configuration is found not to conform with the regulations, the Administrator may issue an order requiring the manufacturer to cease the distribution in commerce of products of that configuration. The Administrator will provide the manufacturer the opportunity for a hearing prior to the issuance of such an order.

Production verification performed on the early production models provides EPA with confidence that production models will conform to the standards and limits the possibility that nonconforming products will be distributed in commerce. Because the possibility still exists that subsequent models may not conform, selective enforcement audit testing of assembly line products will be made a part of this enforcement strategy in order to determine whether production products continue to comply with the standard.

DISTRIBUTOR MANUFACTURER

Under Section 3(6) of the Noise Control Act, a "manufacturer" is "any person engaged in the manufacturing or assembling of new products, or the importing of new products for resale, or who acts for, and is controlled by, any such person in connection with the distribution of such products." This definition encompasses a distributor who mounts a compactor body and attendant power take-off (PTO) equipment on truck chassis and is the last person to have control of the completed vehicle before it enters the stream of commerce.

At the same time EPA recognizes the difficulties the production verification requirements could pose for a small distributor. EPA also is aware of the close relationship between the manufacturer and distributor and the implications it may have in easing the distributor's difficulty. Distributors have stated that, in assembling a vehicle, they follow the compactor body manufacturer's detailed installation instructions. If an unusual configuration is encountered, the distributor generally consults with the body and/or chassis manufacturer. In view of this close relationship, section 205.205-1(d) has been revised to allow distributors and any other manufacturers who only mount compactor bodies on chassis, to rely on the completed production verification tests of the compactor body manufcturer if they follow the compactor body manufacturer's installation instructions.

If the distributor fails to follow the instructions given to him, then the responsibility for compliance with production verification testing requirements is shifted back to him.

SELECTIVE ENFORCEMENT AUDIT

Selective enforcement auditing (SEA) is the term used to describe the testing of a statistical sample of production products from a specified product category or configuration selected from a particular assembly plant in order to determine whether production products comply with the noise emission standard and to provide the basis for further action in the case of noncompliance. The selective enforcement audit plan is designed to determine the acceptability of a sample of items for which one or more inspection criteria have been established. As applied to product noise emissions, the items being inspected are compactors and the inspection criterion is the noise emission standard.

Testing is initiated by a test request which will be issued to the manufacturer by the Assistant Administrator for Enforcement or his authorized representative. A test request will address itself to either a category or a configuration. The test request will require the manufacturer to test a sample of products of the specified category or configuration produced at a specified plant. An alternative category or configuration may be designated in the test request in the event products of the first category or configuration are not available.

Upon receipt of the test request the manufacturer will select the sample from the next run of products of the specified category or configuration that is scheduled for production.

The Administrator reserves the right to designate specific products for testing. Generally, a sample will be defined as the number of products produced during a time period specified in the test request. A sample defined in this manner will allow the Administrator to select sample sizes small enough to keep the number of products to be tested at a minimum and still enable EPA to eventually draw statistically valid conclusions about the noise emission performance of all products of the category or configuration which is the subject of the test request.

One important factor that will influence the decisions of the Administrator not to issue a test request to a manufacturer is the evidence that a manufacturer offers to demonstrate that a product category or configuration complies with the applicable standard. If a manufacturer can provide evidence that his products are meeting the noise emission standard based on testing results, the issuance of a test request may not be necessary.

A product is considered a failure if it exceeds the noise emission standard.

An acceptable quality level (AQL) of 10% was chosen to take into account some test variability. The number of failing products in a sample is compared to the acceptance and rejection numbers for the appropriate sampling plan. If the number of failures is less than or equal to the acceptance number, then there is a high probability that the percentage of noncomplying products is less than the AQL and the SEA will have been passed. On the other hand, if the number of failing products in the sample is equal to or greater than the rejection number, then the SEA has been failed.

Regardless of whether an SEA is passed or failed, failed products would have to be repaired or adjusted and pass a retest before they can be distributed in commerce.

It is anticipated that the audit plan will establish two types of inspection criteria. These are normal inspection (SEA) and continued testing. Normal inspection (SEA) is used until a decision can be made as to whether a sample has passed or failed. When a sample is tested and passed in response to a test request, the manufacturer will not be required at that time to do any further testing pursuant to that test request. When a sample is tested and failed, then the Administrator may require continued testing of the compactors of that category or configuration produced at that plant. The Administrator will notify the manufacturer of the intent to require continued testing. The manufacturer can request a hearing on the issues of whether the audit was properly conducted, and whether the criteria for a sample failure have been met. The manufacturer may also raise issues or supply any information he believes to be relevant to the appropriateness or scope of a continued testing order.

Since the number of compactors tested in response to a test order may vary considerably, a fixed time limit cannot be placed on completing all testing. The purpose of the approach is to establish the time limit on a test-time-per-product basis, taking transportation requirements, if any, into consideration. The manufacturer will be allowed a reasonable amount of time to transport products to a test facility if one is not available at the assembly plant. The Administrator estimates that manufacturers can test a minimum of five (5) compactors per day.

ADMINISTRATIVE ORDERS

Section 11(d)(1) of the Act provides that:

"Whenever any person is in violation of section 10(a) of this Act, the Administrator may issue an order specifying such relief as he determines is necessary to protect the public health and welfare."

Clearly, this provision of the Act is intended to grant to the Administrator discretionary authority to issue administrative orders to supplement the penalties of Section 11(a). If compactors which were not designed, built, and equipped so as to comply with the noise emission standard at the time of sale were distributed in commerce, such an act would be a violation of Section 10(a) and remedy of such non-compliance would be appropriate. Remedy of the affected products shall be carried out pursuant to an administrative order.

The regulation provides for the issuance of such orders in the following circumstances: (1) recall for the failure of a product or group of products to comply with the applicable noise emission standard, (2) cease to distribute products not properly verified, and (3) cease to distribute products for failure to test. These provisions do not limit the Administrator's authority to issue orders, but give notice of cases where such orders would in his judgment be appropriate. In all such cases, notice and opportunity for a hearing will be given.

COMPLIANCE LABELING

This regulation requires that compactors subject to it shall be labeled to provide notice that the product complies with the noise emission standard. The label shall contain a notice of tampering prohibitions. The effective date of the applicable noise emission standard is also required on the label. A coded rather than actual date of manufacture may be used so as to avoid disruption of marketing and distribution patterns.

APPLICABILITY OF PREVIOUSLY PROMULGATED REGULATION

Manufacturers who will be subject to these regulations must also comply with the general provisions of 40 CFR Part 205 Subpart A. These include the provisions for inspection and monitoring by EPA Enforcement Officers of manufacturers' actions taken in compliance with this regulation and for granting exemptions from this regulation for testing, preverification products, national security reasons, and export products.

IN-USE COMPLIANCE

These provisions include a requirement that the manufacturer provide a warranty to purchasers [required by Section 6(d)], assist the Administrator in fully defining those acts which constitute tampering [under Section 10(a)(2)(A)], and provide retail purchasers with instructions specifying the proper maintenance, use and repair required to minimize degradation during the life of the compactor, and with a log book to record maintenance and repairs performed.

SECTION 9

EXISTING LOCAL, STATE, AND FOREIGN NOISE REGULATIONS

According to Section 6 of the Noise Control Act of 1972, the Federal noise regulation for new truck-mounted solid waste compactors will preempt new product standards at the local and state levels* unless those standards are identical to the Federal standards. Further, according to Section 9 of the Act, regulations will be issued to carry out the provisions of the Act with respect to new products imported or offered for importation.

EPA conducted a comprehensive assessment of state and local noise programs in 1977 and early 1978 (Ref. 9-2). The major element of the assessment was a survey questionnaire mailed to officials in the 50 states and 2 territories, and to all 824 communities with a population greater than 25,000. This was supplemented with information obtained from other studies and surveys.

From this information an assessment can be made of the number of existing regulations that are applicable to refuse truck noise and that may be affected by the proposed Federal regulation. Of the 50 states queried, 38 responded to the questionnaire. Of these states, four responded that they had enacted legislation that includes noise performance provisions for truck-mounted solid waste compactors. Two

*Local and state governments are not prohibited from "establishing or enforcing controls on environmental noise through licensing, regulation or restriction of the use, operation or movement of any product" or from establishing or enforcing new product noise standards for types of equipment not regulated by the Federal Government.

of the four states that have applicable legislation responded that they have carried out enforcement actions under their legislation. However, none of the states responded that their program had made significant progress in reducing the noise levels or noise intrusiveness of truck-mounted solid waste compactors.

The EPA survey also queried 824 communities with populations of over 25,000. Of these, 562 communities responded to the survey. Sixty-six of the responding communities stated that they had enacted legislation that includes noise performance provisions for truck-mounted solid waste compactors. Twenty-seven of the sixty-six have carried out enforcement actions under their legislation. Of the communities responding, 42 stated that their program had made significant progress in reducing the noise levels or noise intrusiveness of truck-mounted solid waste compactors.

A representative sample of the existing state and local laws that apply to noise from truck-mounted solid waste compactors is presented in the following sections. This information comes from a study conducted for EPA (Ref. 9-1) as part of the regulatory analysis process. The laws are summarized in Table 9-1, where it can be observed that there is a great deal of variation from one jurisdiction to the next. Some specify sound levels; some rely upon curfew provisions, usually applying only to residential areas, prohibiting night collections of refuse; and some contain both types of provisions.

TABLE 9-1

EXAMPLE LOCAL SOLID WASTE COMPACTOR TRUCK NOISE LAWS

Source: Reference 9-1.

Jurisdiction	Regulation Applies to	Level dB(A)	Distance (feet)	Curfew Hours	Effective Date	Administering Agency	Site of Enforcement	Penalties	Comment
Los Angeles, Calif.	Scavenger Operations	None	—	9 pm-6 am	1/1/71	Police Department	Streets	Fine up to $500, imprisonment up to 6 mo.	Curfew only
San Anselmo, Calif.	Compactor	75	50	None	2/11/75	Police Department	Streets	Treated as infraction	Not unlawful if sound deadening devices used to the extent reasonably feasible.
San Diego, Calif.	Vehicle	None	—	7 pm-7 am Residential areas	12/31/71	Environmental Quality Dept., Noise Abatement & Control	Streets	Fine up to $500, imprisonment up to 6 mo.	Amendment of law in 1977 removed source noise level limit of 86 dB(A) at 50 ft.
San Francisco, Calif.	Compactor	80 75	50 50	None	1/18/73 1/18/78	Bureau of Environmental Health	Streets	Fine up to $500, imprisonment up to 6 mo.	Active enforcement program. Scavenger companies cooperating by retrofitting compactor quieting. Noise measurements of street operations of compactors by mobile enforcement units.
San Jose, Calif.	Vehicle	75	25	6 pm-6 am	10/28/75	Housing & Community Development, Property Codes Department	Noise measurement test sites	Revocation of refuse truck license	Noise provisions in city contract with scavenger company.
Arvada, Col.	Vehicle	74	50	None	2/75	Police Department	Streets	Fine up to $300	
Englewood, Col.	Scavenger Operations	None	—	10 pm-7 am	7/18/74	Dept. of Community Development	Streets	Fine up to $300, imprisonment up to 90 days	Curfew only. Residential district or within 300 feet of a hotel or motel.
Greeley, Col.	Compactor	80	25	—	10/5/76 Enacted	—	—	—	
Lakewood, Col.	Scavenger Operations	None	—	10 pm-7 am	8/8/73	Dept. of Community Development	Streets	Fine up to $300	Curfew only. Residential district or within 300 feet of a hotel or motel.
Littleton, Col.	Scavenger Operations	None	—	10 pm-7 am	5/74	Dept. of Community Development	Streets	Fine up to $300	
Chicago, Ill.	Scavenger Operations	None	—	9:30pm-7 am	12/16/69	Police Department	Streets	Fine up to $500 for second offense	Curfew only.
Dubuque, Iowa	Scavenger Operations	None	—	9 pm-7 am	4/8/74	Police Department	Streets	Fine up to $100, imprisonment up to 30 days	Curfew only. Residential areas.
Saginaw, Mich.	Compactor	85	50	—	6/30/77	Office of Environmental Improvement & Police Department	Streets	Court appearance	Consideration given to voluntary compliance.
Princeton, N.J.	Scavenger Operations	None	—	7 pm-7 am & Sunday	10/10/72	Police Department	Streets	Fine up to $200, imprisonment up to 90 days	Curfew only. Provisions for emergency garbage collection.
Springfield, N.J.	Vehicle	94	50	10 pm-7 am	3/75	Health Department	Streets	Fine up to $200, imprisonment up to 90 days	
New Rochelle, N.Y.	Compactor	80	50	—	4/11/76 Enacted	Police Department	Streets	Fine up to $50, up to 6 mo. imprisonment	Department of Public Works vehicles exempt until quiet vehicles authorized by City Council.
New York, N.Y.	Vehicle	75 70	10 10	None	12/31/74 12/31/78	Environmental Protection Administration	Noise measurement test sites	Fine up to $5000, imprisonment up to 6 mo. for third offense	Applies to sale and operation of vehicles manufactured after 12/31/74 and 12/31/78 respectively.
Toledo, Ohio	Loading or Compacting Equipment	87 day 80 night	50	7 am-9 pm 9 pm-7 am	1/14/75	Pollution Control Agency	Streets	$100; $1000 organization. Each day constitutes separate offense	Only quiet equipment can operate at night. 5 dB additional allowed for impulsive sounds.
		82 day 80 night	50	7 am-9 pm 9 pm-7 am	1/14/79				
Norman, OK.	Compactor	74	50	9 pm-7 am Residential areas	6/21/77 Enacted	Environmental Protection Officer & Police Department	Streets	Fine up to $100, up to 30 days imprisonment	Environmental Protection Officer can recommend dismissal of first offense if voluntarily comply before court appearance.
Ogden, Utah	Scavenger Operations	None	—	7 pm-6 am	5/25/72	Health Department	Streets	Fine up to $300, imprisonment up to 30 days	Curfew only. Applies in areas zoned residential.
Salt Lake City, Utah	Scavenger Operations	None	—	9 pm-7 am	8/16/72	City-County Health Department	Streets	Fine up to $299, 6 mo. imprisonment	Curfew only. Applies in areas zoned residential.
Sacramento County, Calif.	Compactor	80 75	50 50	None	1/1/77 1/1/80	Health Agency	Noise measurement test sites	Fine up to $500, imprisonment up to 6 mo.	
Cook County, Ill.	Scavenger Operations	None	—	6 pm-7 am	11/16/72	Dept. of Environmental Control	Streets	$25-300 fine, up to 6 mo. imprisonment	Curfew for residential zones.
Salt Lake County, Utah	Compactor	74	50	9 pm-7 am Residential areas	4/18/77 Enacted	City-County Health Department & Police Departments	Streets	Fines up to $300, up to 6 mo. imprisonment	

LOCAL LAWS APPLICABLE TO REFUSE TRUCK NOISE

The local solid waste compactor truck noise laws which specify a maximum source level have a very wide variation in those levels. The degree of variation is shown by the scale in Figure 9-1, which shows the source levels in equivalent terms of dB(A) at 7 meters. Those regulations which call for a different measurement distance have been normalized to equivalent 7-meter levels, assuming a 6 dB decrease per doubling of distance in the spreading of sound. It can be observed that the normalized levels range from 91.7 dB(A) for Saginaw to 62.8 dB(A) for New York City. (The apparent higher level of the Springfield, N. J. law is discussed on page 9-11).

The community programs vary as much in their degree of enforcement as in their levels, ranging from continuous in-use enforcement on all garbage trucks to no enforcement at all. In the subsections which follow, each of the local noise laws listed in Table 9-1 is briefly discussed. The last subsection presents the texts of the refuse truck noise provisions for each jurisdiction. The order of discussion is cities first and then counties, with cities addressed in alphabetical order by the states in which they are located.

1. Los Angeles, California

The Los Angeles noise law provides for a 9:00 p.m. to 6:00 a.m. curfew on garbage collections. There is no numerical sound level specified in this law for truck-mounted solid waste compactors. As in other laws that specify curfews, the provisions apply to the scavenger operations themselves rather than to the truck or the compactor. Violations of the law are treated as a misdemeanor, as in most municipalities, with

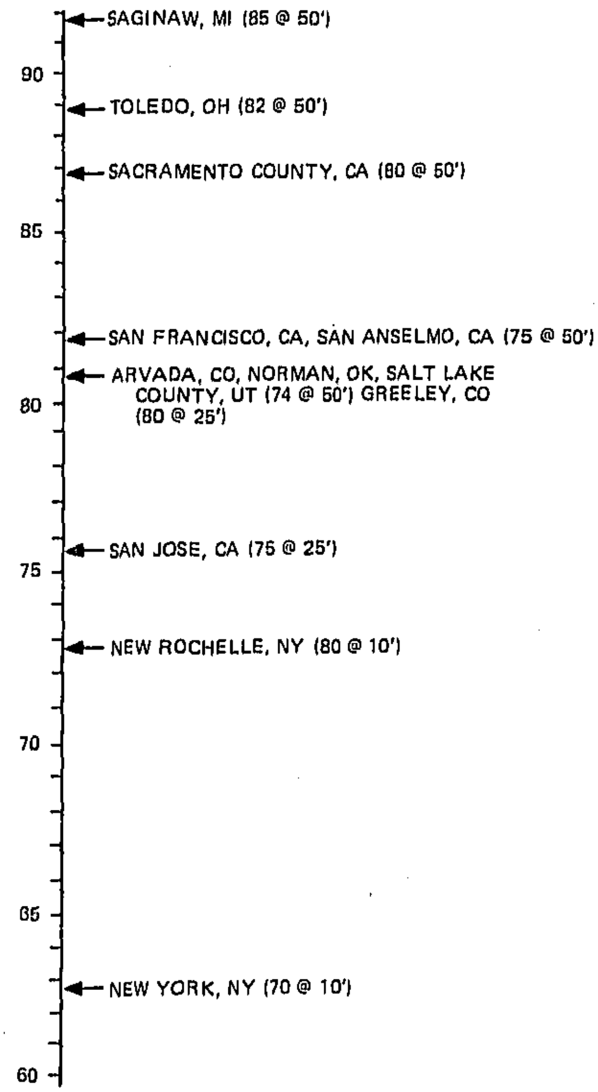

FIGURE 9-1

RANGE OF MAXIMUM SOURCE LEVELS FOR SOLID WASTE COMPACTOR TRUCKS IN NOISE ORDINANCES*

*All levels not measured at 7 meters have been normalized to an equivalent level at 7 meters.

fines ranging up to $200 or imprisonment ranging up to 6 months. The law is enforced by the Los Angeles Police Department, with the cooperation of the Acoustics Division of the Department of Environmental Quality.

2. San Anselmo, California

San Anselmo has a law specifying a maximum source level for the compactor of 75 dB(A) at 50 feet. There is an unusual provision in the San Anselmo law that states that noise is "not unlawful if sound deadening devices are used to the extent reasonably feasible." The law is enforced by the Police Department.

3. San Diego, California

The former San Diego noise law was one of only a few in the nation that contained both a curfew provision and a maximum source level provision for refuse trucks. However, an amended version of the law was adopted in March, 1977 which struck the source level provision and left only the curfew. The maximum source noise level provision was repealed because it was not felt to be as effective as the curfew in their situation.

The maximum source level provisions of the noise law in San Diego were administered by the Noise Abatement and Control Administration of the Building Inspection Department. This was one of the more active noise programs in the nation. They performed noise measurements of solid waste compactor trucks at a test site near the Chollar landfill. The measurements were made at a distance of 50 feet at four points: front, rear, and both sides. The tests were conducted on a spot check basis, with the duration of each test running one to five minutes for two compacting cycles. The company name, license number, and vehicle type were recorded for each test. Scavenger companies received copies of the test reports on their vehicles and were required to correct vehicles found to be excessively noisy.

The remaining portion of the law, the garbage curfew provision, is enforced by the Noise Abatement and Control Administration. The refuse companies have cooperated by planning their routes and schedules around the curfew.

4. San Francisco, California

San Francisco has one of the most active refuse truck noise abatement programs of any city in the United States. The noise standard of 75 dB(A) at 50 feet is enforced on an in-use basis by mobile units operated by the Bureau of Environmental Health. These units generally operate from marked cars equipped with sound level meters and strip chart recorders. The sound measurements they perform are unannounced spot checks of refuse vehicles operating on the streets, often in the pre-dawn hours of the morning.

One of EPA's study investigators observed the San Francisco refuse truck noise measurement procedure during an actual enforcement operation. After locating a refuse truck on the street, an Environmental Health employee pulled his car up 50 feet to the rear of the truck. This particular truck was rear-loader No. 3941, operated by Company F, having a Company I compactor and a Company K chassis. Measurements were made with a GR 1933 sound level meter with the microphone on a 5-foot probe out the driver's side car window. Sound levels were recorded on a Simpson Model 2745 strip chart recorder. In recording a compacting cycle, the peaks from the sounds of bottles popping and cans crushing during compaction were noted on the strip chart. The sound level assigned to the trace was 76 dB(A), the highest level attained aside from the extraneous peaks. When this measurement was taken the standard was 80 dBA at 50 feet, so this vehicle was in compliance.

In the course of enforcing the San Francisco refuse truck noise law, over 150 such strip chart recordings have been made by the Department of Environmental Health. On the basis of the strip chart recordings, the Department has issued abatement orders to the scavenger companies when trucks have been found to exceed the noise limit. The companies have generally been cooperative in retrofitting their trucks when necessary to meet the limit.

5. San Jose, California

The San Jose refuse truck noise level is a part of the regulation of garbage and rubbish vehicles which was added in October of 1975. The law is administered by the Property Codes Department of the Bureau of Housing and Community Development. The Department has tested newly-manufactured refuse trucks and found them to comply with the law. Besides enforcement through refuse truck licensing, San Jose puts similar wording in its contracts with scavenger companies for municipal trash collection.

6. Arvada, Colorado

The Arvada noise ordinance provides a maximum noise level of 74 dB(A) at 50 feet. The administering agency for the noise law is the Police Department. Penalties up to $300 are provided for violations.

7 & 8. Lakewood, Colorado and Englewood, Colorado

The Lakewood noise ordinance has been in effect since 1973. It provides a 10 p.m. to 7 a.m. curfew on scavenger operations in residential districts or within 300 feet of a hotel or motel. Lakewood has an active enforcement program for the curfew using a "soft fuzz" (i.e., gentle enforcement) approach. Good cooperation has been obtained from the scavenger companies by the Department of Community Development in changing routes and schedules. The Department has required these changes on several occasions in response to citizen complaints of refuse truck noise at night.

The Englewood, Colorado, refuse truck noise provision was apparently patterned after that of Lakewood, Colorado.

9. Greeley, Colorado

The Greeley noise ordinance was enacted on October 5, 1976. It declares that it is unlawful to operate, or cause to be operated or used, any refuse compacting vehicle which creates a sound pressure level in excess of 80 dBA at 25 feet (7.5 m) directly to the rear of the vehicle.

10. Littleton, Colorado

Littleton, Colorado, is another community located near Denver with considerable noise awareness. The population of 30,000 people has an active noise abatement program dating from 1974. The refuse truck noise provision provides a curfew of 10 p.m. to 7 a.m., which was copied from the Lakewood ordinance. In drafting the Littleton noise ordinance the noise officer used as inputs the Lakewood ordinance and the National Institute of Municipal Law Officers (NIMLO)/EPA model ordinance.

The enforcement approach is similar to Lakewood and Englewood in trying to work with the scavenger companies in getting them to change routes and schedules in response to complaints. In Littleton, however, one scavenger company refused to cooperate, and it was cited and taken to court. The company was convicted and issued a $30 fine. Apparently this was still not convincing enough for them and they were later brought into court again for a second violation and received a $45 fine. Upon being convicted the second time the company changed its schedules.

The Littleton refuse truck curfew appears to be a success, like its neighbors in Lakewood and Englewood. After proving the seriousness of the law with convictions, Littleton appears to be receiving cooperation from the scavenger companies.

11. Chicago, Illinois

The Chicago noise ordinance provides a 9:30 p.m. to 7 a.m. curfew for all areas of the city except the downtown business district and the airport. The ordinance is enforced by the Police Department and provides fines up to $500 for the second and subsequent offenses.

12. Dubuque, Iowa

The Dubuque noise ordinance provides a 9 p.m. to 7 a.m. curfew on scavenger operations in residential areas. The law is enforced by the Police Department. The law provides penalties of fines up to $100 and imprisonment of up to 30 days.

13. <u>Saginaw, Michigan</u>

The noise law in Saginaw became effective June 30, 1977, and declares that it is unlawful to operate a garbage compactor which produces a noise level in excess of 85 dBA at 50 feet. The Office of Environmental Improvement and the Police Department are responsible for the law's enforcement. Violators are required to appear in court. However, consideration is given to voluntary compliance with the law before the court appearance.

14. <u>Princeton, New Jersey</u>

The Princeton noise ordinance provides a 7 p.m. to 7 a.m. curfew on scavenger operations Monday through Saturday, with scavenger operations prohibited completely on Sunday. This particular law is unusual in providing a provision for its own suspension for emergency garbage collections. The law is enforced by the Police Department, and penalties for violations can go up to a $200 fine or 90 days imprisonment.

15. <u>Springfield, New Jersey</u>

The Springfield, New Jersey, noise law specifies a maximum noise level for garbage trucks of 94 dB(A) at 50 feet. This level is far higher than that specified in any other noise law. The reason is that an erroneous provision of the New Jersey Model Community Noise Ordinance was copied by Springfield. According to the State of New Jersey Noise Control Office, the New Jersey Model Community Noise Ordinance (discussed further in this report under state laws) supplied noise levels for the NIMLO/EPA model ordinance. Unfortunately, the level which they supplied for "compactor" was copied from another noise ordinance, which referred to a piece of construction equipment used for compacting the ground and not to a device which goes on a garbage truck. The writers of the Springfield ordinance accepted the 94 dB(A) level without checking any further or making any measurements. This level is so high that even the noisiest compactor is not likely to exceed it.

The Springfield noise law also contains a curfew provision of 10 p.m. to 7 a.m. They receive about 5 complaints per year for refuse truck compactor noise, which is approximately what they received before passage of the law. The rate of complaints generally runs higher in the summer when people keep their windows open. The scavenger companies have resisted any changes in schedule, claiming that the changes interfere with the logistics of getting to the dump on time.

Apparently the noise law had been passed primarily with quarry noise in mind and with the refuse truck provisions as an afterthought. There was no input from the scavenger companies in formulating the noise law and there was no discussion of the refuse truck provisions at the hearings. One difficulty with the noise law is that it was passed as a Board of Health ordinance rather than a township ordinance, which makes its enforcement weaker. Besides the quarry noise situation, the law has been used primarily in neighbor vs neighbor noise complaints.

16. New Rochelle, New York

The New Rochelle noise law was enacted April 13, 1976. Under the ordinance, it is unlawful to operate or to permit to be operated, any refuse collection vehicle such that the noise exceeds 80 dBA at 10 feet from any surface of the unit during collection or compaction. The law is enforced by the Police Department and a violation is a misdemeanor. The penalty is up to a $50 fine and/or up to six months in jail. The Police Department can also order violators to cease and desist and, with a court order, can seal any device that is in violation of the law. An interesting provision of the ordinance states that Department of Public Works vehicles are exempt until vehicles are available that comply with the law and until the City Council authorizes their acquisition.

17. New York, New York

The New York noise ordinance as amended provides a maximum noise level of 70 dB(A) at 10 feet for vehicles manufactured after December 31, 1978. The law calls for measurements with the "slow" scale of the sound level meter. The earlier version of the New York noise law called for 70 dB(A) measured at 10 feet from the side of the compactor using the "fast" scale. However, the city was not able to obtain trucks which met the provision and held up in service. The amended version of the law, therefore, relaxed the requirement to 70 dB(A) at a distance of 10 feet from the hopper with the "slow" scale. The New York City Environmental Protection Agency has measured newly-manufactured refuse vehicles which meet the relaxed requirement.

Since New York's noise law applies to newly-manufactured refuse vehicles, it is the type of law which would be preempted by a Federal new product noise regulation for truck-mounted solid waste compactors when it is promulgated by EPA.

18. Toledo, Ohio

The Toledo noise ordinance is unique in its refuse truck provision in that it provides a curfew-like maximum noise level requirement, with a higher level permitted during the day. The daytime level is 82 dB(A) at 50 feet and the nighttime (9 p.m. - 7 a.m.) level is 80 dB(A) at 50 feet. This, in effect, provides that only quieted equipment may operate at night. An additional margin of 5 dB is allowed for impulsive sounds from the compactor.

The law is administered by the Toledo Pollution Control Agency. It has an unusual penalty provision, in that the fine is $100 for an individual but $1000 for an organization.

19. Norman, Oklahoma

The noise control act in Norman was enacted on August 23, 1977. It is a violation of the Act to operate, or cause or permit to be operated or used, any refuse compacting vehicle which creates a sound pressure level in excess of 74 dBA at 50 feet (15 m) from the vehicle. It is also a violation to collect garbage, waste, or refuse between 9 p.m. and 7 a.m. the following day in, or within 300 feet of, any area zoned residential or in any land use district so as to cause a noise disturbance. Enforcement of the Act is carried out by the Environmental Protection Officer and the Police Department. Violators of the law are subject to up to a $100 fine and/or up to 30 days imprisonment. The city can also get a summary restraining order or injunction against any source considered to be a nuisance. The Environmental Protection Officer can recommend dismissal of first offenses if they are voluntarily brought into compliance before the court appearance.

20. Ogden, Utah

Ogden, Utah, has a 7 p.m. to 6 a.m. curfew on scavenger operations in areas zoned residential. The law has been in effect there since 1972, with enforcement responsibility given to the City Manager. Penalties provided are fines up to $300 and imprisonment of up to 30 days.

21. Salt Lake City, Utah

The Salt Lake City noise law provides a curfew of 9 p.m. to 7 a.m. for scavenger operations. The curfew applies in areas zoned residential and is enforced by the City-County Health Department. Penalties provided in the law are fines up to $299 and imprisonment of up to 6 months.

22. Sacramento County, California

The Sacramento County, California, noise ordinance became effective on July 1, 1976. The maximum refuse truck noise level provision of 80 dB(A) at 50 feet, however, became effective on January 1, 1977. This level will be lowered to 75 dB(A) at 50 feet on January 1, 1980. The refuse truck provisions are quite similar to those in nearby San Francisco except for the later effective date.

The noise ordinance was written by a committee which included the industrial hygienist who administers the noise program. There have been a large number of complaints of garbage collection noise at night in Sacramento County, typically averaging about 200 per year. This is particularly true of areas near hotels and schools in the city areas, where complaints often refer to such things as banging of cans and racing the motor.

The law has a maximum penalty of a $500 fine or 6 months imprisonment and is enforced by the Environmental Health Office.

23. Cook County, Illinois

Cook County, Illinois, in which Chicago is located, has a noise law which provides a 6 p.m. to 7 a.m. curfew for scavenger operations in residential zones.

Cook County's enforcement program is unique because of the policy of routinely giving citations for refuse truck curfew violations. It is estimated that 15 citations per year are handed out to the scavenger companies. When this occurs the company has to appear in court with its lawyer. Convictions almost always are returned. The only exception is when the arresting officer has a discrepancy in his report, such as an error in transcribing the license number. Fines of $50 are typically required. Generally, the scavenger companies become very careful in their schedules once they have gone through the inconvenience of hiring a lawyer and appearing in court to answer a citation. Because of this policy of strict prosecution, the situation has come to the point where most of the firms cited are small new companies that do not know the law. There has been good cooperation from the larger firms in obeying curfews.

24. Salt Lake County, Utah

The Salt Lake County noise law was enacted on April 18, 1977. Operating, or causing or permitting to be operated, any refuse compacting vehicle which creates a sound pressure level in excess of 74 dBA at 50 feet (15 m) from the vehicle is a violation of the law. It is also a violation to collect garbage, waste, or refuse between 9 p.m. and 7 a.m. the following day in, or within 300 feet of, an area that is zoned residential or in any land use district so as to cause a noise disturbance. Primary enforcement responsibility for the law rests with the Salt Lake City-County Health Department and the local law enforcement agencies. Violators are subject to up to a $300 fine and/or up to six months imprisonment. Each day of violation is considered to be a separate offense.

Conclusions - Local Refuse Truck Noise Laws

The laws described above indicate that refuse truck noise laws specifying curfews seem to be more popular and to be enforced more effectively than those specifying maximum noise levels.

Curfews, however, have varying effects on the garbage collection process in different local areas. The interference with collection logistics appears to be least in flat areas with wide streets that are not too densely populated. In those areas where curfews can be applied, largely rural areas, they appear to offer the possibility of relief from refuse collection noise. A vigorous enforcement of the curfew, however, is a necessary factor in such an approach.

STATE LAWS APPLICABLE TO REFUSE TRUCK NOISE

The States of Florida and New Jersey have model community noise ordinances which have provisions covering refuse vehicles. The text of their refuse truck provisions are provided below as examples.

Model Community Noise Control Ordinance, Florida

8.1.1 Refuse Collection Vehicles. No person shall collect refuse with a refuse collection vehicle between the hours of 7 p.m. and 7 a.m. the following day in a residential area or noise sensitive zone.

It is apparent from the above language that this is a typical curfew provision, similar to the ones found in the local jurisdictions discussed in the previous section.

Model Community Noise Ordinance, New Jersey

9.1.3 Refuse Collection Vehicles. No person shall:

(a) On or after (2 years) following the effective date of this ordinance, operate or permit the operation of the compacting mechanism of any motor vehicle which compacts refuse and which creates, during the compacting cycle, a sound level in excess of 86 dB(A) when measured at 50 feet from any point on the vehicle

it the operation of the compacting mechanism of any motor vehicle which compacts refuse, between the hours of 8 p.m. and 6 a.m. the following day in a residential area or noise sensitive zone;

(c) Collect refuse with a refuse collection vehicle between the hours of 8 p.m. and 6 a.m. the following day in a residential area.
[Choose b or c]

The above provisions have been recommended by New Jersey since 1976. Before that time a provision with a 94 dB(A) level had appeared in the New Jersey Model Community Noise Ordinance, as shown below:

6.2.11 Refuse Compacting Vehicles. The operating or permitting to be operated, of any motor vehicle which can compact refuse and which creates, during the compacting cycle, a sound pressure level in excess of 94 dB(A) when measured at 50 feet from any point of the vehicle, or between the hours of 10 p.m. and 7 a.m. the following day (in residential use districts).

This provision combines a maximum sound level and curfew similar to the method recommended in the NIMLO/EPA model ordinance. The difficulty in the above model ordinance is that it contains an erroneously high level of

94 dB(A) at 50 feet for the compactor noise requirement. This resulted when those who promulgated the New Jersey Model Ordinance mistook the word "compactor" in another ordinance for a solid waste compactor. The "compactor" whose 94 dB(A) level they put into their model ordinance was in fact a piece of construction equipment used for compacting the ground.

Other applicable state laws are those specifying general truck noise levels. These have been tabulated by the Motor Vehicle Manufacturer's Association (Exhibit 9-1). These general truck noise laws are only of limited interest for this study because:

- Those truck noise laws that specify levels of newly-manufactured vehicles are preempted by the recent EPA new truck noise regulation.
- The laws specify passby levels. Since the compactor is generally not in operation when the truck is underway, the passby tests do not measure compactor noise.

FEDERAL REGULATIONS APPLICABLE TO SPECIALTY TRUCK NOISE

Current Federal regulations applicable to specialty truck noise are the EPA noise emission standards for motor carriers engaged in interstate commerce (39 FR 38208) and the EPA noise emission standards for medium and heavy trucks (41 FR 15538). The U.S. Bureau of Motor Carrier Safety of the U.S. Department of Transportation has also issued regulations for the purpose of establishing measurement procedures and methodologies for determining whether commercial motor vehicles conform to the Interstate Motor Carrier Noise Emission Standards of EPA.

EPA Interstate Motor Carrier Noise Regulation

The above mentioned regulation was promulgated by EPA under authority of the Noise Control Act of 1972. Section 18 of the Noise Control Act requires the Administrator to promulgate noise emission regulations for motor carriers engaged in interstate commerce. The Secretary of Transportation is responsible for promulgating regulations to insure compliance with the EPA standards, through the enforcement and inspection powers authorized by the Interstate Commerce Act, the Department of Transportation Act, and the Noise Control Act of 1972.

Section 18(c)(1) of the Act requires that "no State or political subdivision thereof may adopt or enforce any standard applicable to the same operation of such motor carrier unless such standard is identical to a standard applicable to noise emissions resulting from such operation prescribed by any regulation under this section."

On February 1, 1973, an Advance Notice of Proposed Rulemaking was published in the Federal Register soliciting public comment. Proposed standards were published in the Federal Register (38 FR 20102) on July 17, 1973, and final noise emission standards were established on October 29, 1974 (39 FR 38208). The standards went into effect on October 15, 1975. The maximum noise level under test conditions established by DOT is 86 dB(A) at 50 feet from the centerline of the lane of travel on highways with speed limits of 35 mph or less; or 90 dB(A) at 50 feet on highways with speed limits of more than 35 mph.

The interstate motor carrier emission standards are relevant to future specialty truck noise emission regulations. The proposed standards did not originally specify clearly whether "auxiliary equipment" noise is to be included in the specified "total vehicle" noise levels. Based on the comments received during the public comment periods and hearings, the final regulation included a clarification as follows:

> "The provisions of subpart B (Interstate Motor Carrier Operations Standards) do not apply to auxiliary equipment which is normally operated only when the transporting vehicle is stationary or is moving at a speed of 5 miles per hour or less. Examples of such equipment include but are not limited to, cranes, asphalt spreaders, ditch diggers, liquid or slurry pumps, air compressors, welders, and trash compactors."

The noise from trash compactors is not included in the "total vehicle" noise. The Interstate Motor Carrier Noise Emission Compliance Regulations issued by the U.S. Department of Transportation on September 12, 1975, included additional language in the scope of the regulations. It is stated that the rules do not apply to the sound generated by auxiliary equipment which is normally operated only when the motor vehicle on which it is installed is stopped or is operating at a speed of 5 mph (8 kph) or less, unless such a device is intentionally operated at speeds greater than 5 mph (8 kph) in order to preclude an otherwise valid noise measurement. Trash compactor noise would be included in the total vehicle noise under such circumstances. The need for this language arose out of comments received by the Director of the Bureau of Motor Carrier Safety after publication of a text of the proposed regulations in the Federal Register (40 FR 8658). Several commenters suggested that it would be possible to intentionally thwart noise measurements by sounding warning devices or by operating auxiliary equipment even if it is not designed for operation above 5 mph.

EPA Noise Emission Standards for New Medium and Heavy Duty Trucks

The EPA new truck noise standards appeared in the Federal Register on April 13, 1976 (41 FR 75538). The standards set a new truck low speed acceleration passby noise level of 83 dB(A) at 50 feet, effective January 1, 1978. The level will be reduced to 80 dB(A) effective January 1, 1982, and may be reduced further to an as yet unspecified level effective January 1, 1985.

The medium and heavy truck noise regulation standards apply to any vehicle which has a gross vehicle weight rating (GVWR) in excess of 10,000 pounds, which is capable of transportation of property on a highway or street, and which meets the definition of the term "new product" in the Act. However, in paragraph 205-50(b) of Subpart B, it is stated that the vehicle noise emission standards included in this subpart "do not apply to highway, city, and school buses or to special purpose equipment which may be located on or operated from vehicles. Tests performed on vehicles containing such equipment may be carried out with the special purpose equipment in nonoperating condition. For purposes of this regulation special purpose equipment includes, but is not limited to, construction equipment, snow plows, garbage compactors, and refrigeration equipment."

Clearly, the intent of this statement is that garbage compactors are to be regulated under independent rules and operating conditions, after the Administrator has determined that noise emission standards are feasible for these types of special purpose equipment.

FOREIGN SPECIALTY TRUCK NOISE LAWS

The only foreign specialty truck noise law on which information has been found is a municipal solid waste compactor truck noise ordinance which is in effect in Stockholm, Sweden. The law sets a noise limit during loading of 70 dB(A) at a distance of 3 meters from the truck side. It is comparable to the New York City noise ordinance level of 70 dB(A) at 10 feet which went into effect on December 31, 1978.

An extensive effort has been made to uncover other foreign laws relating specifically to specialty trucks. For example, there appear to be no specialty truck noise laws in such industrialized nations as Australia, Japan, Switzerland, or Germany. The Stockholm law is, indeed, the only one known by EPA.

MODEL LOCAL REFUSE COLLECTION VEHICLE NOISE ORDINANCES

This section provides suggested sections dealing with solid waste compactor trucks that can be included as part of a comprehensive local noise law.

As can be observed from examining the local noise laws discussed earlier, there are many different legal approaches to controlling refuse truck noise. Basically the approaches are of two types: maximum source noise level standards and curfews. The approach proposed here, which combines both, is patterned after the section dealing with refuse trucks of the model community noise control ordinance prepared by the National Institute of Municipal Law Officers (NIMLO) in conjunction with EPA. The NIMLO model provision for refuse trucks is as follows:

Refuse Collection Vehicles. No person shall:

(a) On or after (2 years) following the effective date of this ordinance, operate or permit the operation of the compacting mechanism of any motor vehicle which compacts refuse and which creates, during the compacting cycle, a sound level in excess of ___ dB(A) when measured at ___ feet (meters) from any point on the vehicle; or

(b) Operate or permit the operation of the compacting mechanism of any motor vehicle which compacts refuse, between the hours of ___ p.m. and ___ a.m. the following day in a residential area or noise sensitive zone; or

(c) Collect refuse with a refuse collection vehicle between the hours of ___ p.m. and ___ a.m. the following day in a residential area or noise sensitive zone.

The only modifications which have been made to the NIMLO model are to introduce some noise measurement procedures which are used in the San Francisco enforcement program and to include maximum sound levels which reflect the levels set in the EPA noise emission regulation for newly-manufactured truck-mounted solid waste compactors.

(1) Definition

In each noise law a definition of each product to be regulated is usually provided. The definition adopted by EPA is:

"A truck-mounted solid waste compactor is a vehicle comprising an engine-powered truck cab and chassis or trailer, equipped with machinery for receiving, compacting, transporting and unloading solid waste."

The above definition was chosen to specifically exclude non-compacting container handling vehicles, non-compacting open top dump trucks, stationary compactors not mounted on trucks, and containers.

(2) Model Ordinance Provision

By combining the NIMLO provision with the San Francisco measurement procedure and the EPA regulatory levels, one can generate a broad and effective ordinance, as follows:

Refuse Collection Vehicles. No person shall:

(a) While engaged in the collection of refuse, cause to be emitted noise levels in excess of 76 decibels as measured within three feet of the closest doorway or window of the residence closest to the point of collection. (NOTE: If the collection point is closer than 25 feet from the measurement point, or the collection takes place in a narrow alley, suitable correction factors may be applied.) This noise level limit applies to noise caused either by operation of the refuse collection vehicle or its compaction, by banging of containers or container lids against vehicle components, by dropping or otherwise mishandling refuse containers, or by any other overt action, such as loud conversation or whistling; or

(b) Operate or permit the operation of the compacting mechanism of any motor vehicle which compacts refuse, between the hours of _____ p.m. and _____ a.m. the following day in a residential area or noise sensitive zone; or

(c) Collect refuse with a refuse collection vehicle between the hours of _____ p.m. and _____ a.m. the following day in a residential area or noise sensitive zone.

Note that, in the above model provision, the hours of the curfew have been left blank. The curfew hours should be strictly at the option of each community. In the ordinances surveyed, the curfews were observed to start as early as 6 p.m. and as late as 10 p.m. Curfews ran until 6 a.m. in some localities and 7 a.m. in others. As EPA noise levels are specified for an empty compactor, some adjustment may have to be made in the noise level in the above community noise ordinance, to account for the slight additional noise when loaded, and possible reverberant effects in narrow streets and alleys.

The provision in the model ordinance for load condition as found on the street is patterned after the successful San Francisco program. There is much to be said for the repeatability of measuring vehicles in an open-area, isolated test site, away from the sound reflecting surfaces of the city streets, using a standard empty compactor condition, as required by the Federal regulation. However, in an in-use enforcement such as this, it is more important that the noise measurement be applicable to impromptu spot checks and that it disturb the waste collection process as little as possible. The fact that spot checks are being made also seems to encourage the refuse collectors to be quieter in other parts of the process not connected with compaction, such as banging cans and shouting to one another.

MUNICIPAL SOLID WASTE COMPACTOR TRUCK NOISE LAWS (FULL TEXT)

Los Angeles, California (1/24/73)

SEC. 113.01. Rubbish and Garbage Collections and Disposal. It shall be unlawful for any person engaged in the business of collecting or disposing of rubbish or garbage in any residential zone or within 500 feet thereof to collect, load, pickup, transfer, unload, dump, discard or dispose of any rubbish or garbage as such terms are defined in Sec. 66.00 of this Code between the hours of 9:00 p.m. of one day and 6:00 a.m. of the next day, unless a permit therefore has been duly obtained beforehand from the Board of Police Commissioners. Such permits shall be issued pursuant to standards established by said Board and approved by the City Council by ordinance.

No permit shall be required to perform emergency work as defined in Sec. 11.01(c) of this chapter.

San Anselmo, California (2/11/75)

Section 4-7.09. Refuse Collection.

(a) It shall be unlawful for any person authorized to engage in waste disposal services or garbage collection to provide such services in such a manner a reasonable person of normal sensitiveness working or residing in the area is caused discomfort, annoyance, or whose peace is disturbed. For the purpose of this section noise emitted by equipment shall not be deemed unlawful if the person engaged in such services has, to the extent reasonably feasible in the judgment of the Director of Public Works incorporated available sound-deadening devices into equipment used in rendering those services.

(b) Any person authorized to engage in waste disposal services or garbage collection shall not operate any truck-mounted waste or garbage loading and/or compacting equipment or similar mechanical device acquired after the effective date of this chapter in a manner to create noise exceeding 75 dBA measured at a distance of 50 feet from the equipment.

(c) Mechanical street sweepers shall not operate in the manner to create noise exceeding 80 dBA and 75 dBA six (6) months and twenty-four (24) months respectively after the effective date of this chapter.

San Diego, California

Present Law [since March 22, 1977]

SEC. 59.5.0406. Refuse Vehicles and Parking Lot Sweepers. No person shall operate or permit to be operated a refuse compacting, processing or collection vehicle or parking lot sweeper between the hours of 7:00 p.m. to 7:00 a.m. in any residential area unless a permit has been applied for and granted by the Administrator.

Repealed March 22, 1977

SEC. 59.5.0406. Refuse Vehicles. No person shall operate or permit to be operated a refuse compacting, processing or collection vehicle after December 31, 1973, within the City of San Diego which when compacting creates a sound level in excess of eighty-six (86) decibels when measured at a distance of fifty (50) feet from any point of the compacting vehicle unless a variance has been applied for and granted by the Administrator or Appeals Board. No refuse collection shall be permitted from 7:00 p.m. to 7:00 a.m. in any residential area. Notwithstanding the above, on or after a date forty-eight (48) months after the effective date of this article, no person shall operate or permit to be operated, a refuse, compacting, processing or collection vehicle which when compacting creates a sound level in excess of eighty (80) decibels when measured at a distance of fifty (50) feet from any point of the compacting vehicle.

San Francisco, California (9/18/72)

SEC. 2904. Waste Disposal Services. It shall be unlawful for any person authorized to engage in waste disposal services or garbage collection to provide such services so as to create an unnecessary amount of noise, in the judgment of the Director of Public Health or his authorized representative. For the purpose of this section or Sec. 2915, noise emitted by equipment shall not be deemed unnecessary or without justification if the person engaged in such services has, to the extent reasonably feasible in the judgment of the Director, incorporated available sound-deadening devices into equipment used in rendering those services.

Notwithstanding the foregoing, it shall be unlawful for any person authorized to engage in waste disposal services, or garbage collection to operate any truck-mounted waste or garbage loading and/or compacting equipment or similar mechanical device in any manner so as to create any noise exceeding the following levels when measured at a distance of 50 feet from the equipment:

(a) On and after a date 6 months after the effective date of this Article . . . 80 dBA

(b) On and after a date 66 months after the effective date of this Article . . . 75 dBA

San Jose, California (10/14/75)

PART 7A. REGULATION OF GARBAGE AND RUBBISH VEHICLES

5307.20. Garbage and Rubbish Vehicles, Noise Levels.

No refuse collector shall use, in his business, for the purpose of collecting, transporting or disposing of any refuse within the City of San Jose any motor vehicle or any motor vehicle and trailer which exceeds, during stationary compaction, 75 dB at a distance of 25 feet from said vehicle at an elevation of 5 feet from the horizontal base plane of said vehicle.

Notwithstanding the above provisions specifying refuse vehicle noise levels, the Council may arrange for other or different noise level requirements, or dispense with noise level requirements for certain refuse vehicles, as the Council may deem necessary.

Arvada, Colorado (2/75)

Section 2.2.14 Refuse Compacting Vehicles. The operating, causing or permitting to be operated or used, any refuse compacting vehicle which creates a sound pressure level in excess of 74 dB(A), at 50 feet (15 meters) directly to the rear of the vehicle (is prohibited).

Englewood, Colorado (7/18/74)

SEC 6-8-5. SPECIFIC PROHIBITIONS

The following acts are declared to cause unnecessary noise in violation of this Ordinance provided however that the following enumerations shall not be deemed to be exclusive.

(d) Loading Operations - The loading, unloading, opening or otherwise handling (of) boxes, crates, containers, garbage containers or other objects in such a manner as to cause a disturbance; the loading of any garbage, trash or compactor truck, or any other truck, whereby the loading, unloading or handling of boxes, crates, equipment or other objects is conducted within a residential district nor within 300 feet of any hotel or motel between the hours of 10:00 p.m. and 7:00 a.m.

Greeley, Colorado (10/5/76)

Sec. 15-133. Unlawful Noise - Special Cases.

(a) The following noises shall be unlawful:

(7) The operating, causing or permitting to be operated or used, any refuse compacting vehicle which creates a sound pressure level in excess of 80 dB(A), at 25 feet (7.5 meters) directly to the rear of the vehicle.

Lakewood, Colorado (7/23/73)

9.52.130. Truckloading. No person shall load any garbage, trash or compactor truck, or any other truck, whereby the loading, unloading or handling of boxes, crates, equipment or other objects is conducted within a residential district nor within three hundred (300) feet of any hotel or motel between the hours of 10 p.m. and 7 a.m.

Littleton, Colorado (5/74)

Truckloading. No person shall load any garbage, trash or compactor truck, or any other truck, whereby the loading, unloading or handling of boxes, crates, equipment or other objects is conducted within a residential district nor within three hundred (300 feet) of any hotel or motel between the hours of 10 p.m. and 7 a.m.

Chicago, Illinois (12/16/69)

167.8. Scavengers. Zone of Non-Operation: No private scavenger, its agents or employees shall grind garbage, refuse or other matter (as defined in Section 267-3 of this Chapter), between the hours of 9:30 p.m. and 7:00 a.m., within the boundaries of the City of Chicago, except that this Section shall not apply to that area within the boundaries of O'Hare International Airport and within that area bounded by Michigan Avenue on the East, and south branch of the Chicago River on the West, the North branch of the Chicago River on the North and Roosevelt Road on the South.

Any person violating this Section shall be subject to a fine of not less than $25.00 nor more than $200.00 for the first offense, not less than $50.00 nor more than $500.00 for the second and each subsequent offense in any one hundred and eighty (180) day period.

Dubuque, Iowa (4/8/74)

Section 2. Noises Prohibited.

(h) Garbage collection. The collection of garbage, waste or refuse by any person in any area zoned residential except between the hours of 7:00 a.m. and 9:00 p.m. of any day and then only in a manner so as not to create a loud or excessive noise.

Saginaw, Michigan (6/20/77)

Section 603. Definitions. "Garbage Compactor." Garbage compactor is a motor vehicle used for the collection and transport of garbage and refuse which has as a part of its integral operation an auxiliary mechanism for the compaction or compression of collected garbage and refuse.

Section 604. Unlawful Motor Vehicle Noise 604.1. It shall be unlawful for any person to operate a motor vehicle or combination of vehicles within the city limits which produces a noise or level of sound which exceeds the sound level limits set out in Table 1.

TABLE 1 (in part)

LIMITING SOUND LEVELS (dB(A))

. . . . The dB(A) limits set forth herein are based on a 50 ft. distance between the microphone location point and the microphone target point unless otherwise specified . . . .

. . .

(D) Garbage Compactor while compacting - 85

. . .

Princeton, New Jersey (10/10/72)

(k) Refuse collection. The collection, transportation or disposal of garbage, trash, cans, bottles, and other refuse by persons engaged in the business of scavenging or garbage collection, whether private or municipal, at any time on Sundays, or other than between the hours of 7:00 a.m. and 7:00 p.m. on all other days, except in case of urgent necessity in the interest of public health and safety, and, if the nature of the emergency will admit of the prior procurement of a permit, then only in accordance with a permit first obtained from the Borough Engineer pursuant to section 4 hereof.

Springfield, New Jersey (3/75)

6.2.11. Refuse Compacting Vehicles.

The operating or permitting to be operated, any motor vehicle which can compact refuse and which creates, during the compacting cycle, a sound pressure level in excess of 94 dB(A) when measured at 50 feet from any point of the vehicle, or between the hours of 10 p.m. and 7 a.m. the following day (in residential use districts).

New Rochelle, New York (4/13/76)

SECTION 1.03. DEFINITIONS

23. REFUSE COLLECTING VEHICLE shall mean any motor vehicle designed to compact and transport refuse.

SECTION 3.03. REFUSE COLLECTING VEHICLES

No person shall operate, or permit to be operated, a refuse collecting vehicle which when collecting or compacting exceeds a sound level of 80 dB(A) at a distance of 10 feet from any surface of the collecting or compacting unit. (N.Y.S. Recommendation)

New York, New York (4/23/75)

1403.3-5.15. Refuse Compacting Vehicles. No person shall sell, offer for sale, operate or permit to be operated a refuse compacting vehicle manufactured after the effective dates set out in Table IIIA, which when compacting produces a maximum sound level, when measured by a sound level meter set for slow response at a distance of ten feet from the center line of the face of the compacting unit, exceeding the applicable sound level set out therein.

Table IIIA

Effective date	Allowable sound level
December 31, 1974	75 dB(A)
December 31, 1978	70 dB(A)

This local law shall take effect immediately.

Toledo, Ohio (1/4/75)

SECTION 17-15-115. Waste Disposal Services.

It shall be unlawful for any person authorized to engage in waste disposal services or garbage collection to provide such services so as to create an unnecessary amount of noise. For the purpose of this section, noise emitted by equipment shall not be deemed unnecessary or without justification if the person engaged in such services has to the extent reasonably feasible in the judgment of the Director of Pollution Control, incorporated available sound-deadening devices into equipment used in rendering those services.

Notwithstanding the foregoing, it shall be unlawful for any person authorized to engage in waste disposal services, or garbage loading and/or compacting (to operate such) equipment or similar mechanical device in any manner so as to create any noise exceeding the following levels when measured at a distance of 50 feet from the equipment when within 500 feet of a residential zone:

(a)	On or after a date one (1) year after the effective date of this ordinance	9 p.m. - 7 a.m. 80 dB(A)	7 a.m. - 9 p.m. 87 dB(A)
(b)	On or after a date 48 months after the effective date of this ordinance	9 p.m. - 7 a.m. 80 dB(A)	7 a.m. - 9 p.m. 82 dB(A)

(c) Impulsive sounds must not exceed the levels specified in (a) or (b) of this section by more than 5 dB(A)

unless said person has filed an Application for Variance in accordance with the provisions of this ordinance.

Norman, Oklahoma (8/23/77)

Sec. 10-307. Noise Prohibited

(b) Specific Prohibitions: The following acts are declared to be in violation of this ordinance:

(6) Loading Operation. Loading, unloading, opening or otherwise handling boxes, crates, containers, garbage containers or other objects between the hours of 9 p.m. and 7 a.m. the following day in such a manner as to violate Section 10-304 or cause a noise disturbance.

(16) Refuse Compacting Vehicles. The operating or causing or permitting to be operated or used any refuse compacting vehicle which creates a sound pressure level in excess of 74 dB(A) at 50 feet (15 meters) from the vehicle.

(17) Garbage Collection. The collection of garbage, waste or refuse between the hours of 9 p.m. and 7 a.m. the following day:

(a) in any area zoned residential, or within 300 feet of an area zoned residential;

(b) in any land use district so as to cause a noise disturbance.

Ogden, Utah (5/25/72)

19.9.2. Prohibited acts specifically. The following acts, among others, are declared to be loud, disturbing or unnecessary noises in violation of this ordinance, . . . namely:

L. Garbage trucks. The operation of any garbage pick up in any area zoned residential on at least one side of the street by the zoning ordinance between the hours of 7 p.m. and 6 a.m.

Salt Lake City, Utah (8/16/72)

Section 39-9-3. Noises Prohibited - Standards. The following acts, among others, are declared to be in violation of this ordinance . . .:

(i) Garbage collection. The collection of garbage, waste or refuse by any person in any area zoned residential except between the hours of 7:00 a.m. and 9:00 p.m. of any day and then only in a manner so as not to create a loud or excessive noise.

COUNTY SOLID WASTE COMPACTOR TRUCK NOISE LAWS

Sacramento County, California

6.68.140. Waste Disposal Vehicles.

It shall be unlawful for any person authorized to engage in waste disposal service or garbage collection to operate any truck-mounted waste or garbage loading and/or composting equipment or similar mechanical device in any manner so as to create any noise exceeding the following level, when measured at a distance of fifty feet from the equipment in an open area.

(a) New equipment purchased or leased on or after a date six months from the effective date of this chapter shall not exceed a noise level of 80 dB(A).

(b) New equipment purchased or leased on or after forty-two months from the effective date of this chapter shall not exceed a noise level of 75 dB(A).

(c) Present equipment shall not exceed a noise level of 80 dB(A) on or after five years from the effective date of the chapter.

The provisions of this section shall not abridge or conflict with the powers of the State over motor vehicle control.

Cook County, Illinois

9.5 Scavenger Operations

All scavenger operations in the County of Cook, commercial and municipal, shall limit the actual contact hours involved in the pickup of refuse and all other solid waste in any residential or business-commercial zone (R1 through R6 and B1 through B5) whenever regular human occupancy is involved by virtue of residence only and such place of regular residence or the institutional equivalents (hospitals, nursing homes, etc.) to the period of 7:00 a.m. to 6:00 p.m. These limits apply only to those contact periods wherein the collection function is in progress in R1 through R6, B1 through B5 and contiguous portions of M1 through M4 zones and are not intended to include or confine such functions as start up and shut down operations at the central operating point (transfer station, sanitary landfill, incinerator, etc.) or the transit time of the first trip to and the last trip from the defined collection areas. Noise levels in such central operating points shall be governed by the property line values applicable for their location (Section 9.14 through 9.17). The exemptions on engine operation when parked, of Section 9.7 shall apply as will the restrictions on new vehicles of Section 9.8(b) and vehicle use of Section 9.9(a). When under severe conditions it can be shown to the satisfaction of the Director that operation outside these hours is in the overall public interest or operationally essential, a special variance can be requested for such period as can likewise be shown necessary.

Salt Lake County, Utah (4/18/77)

Sec. 16-15D-4. Noises Prohibited.

b. Specific Prohibitions. The following acts are declared to be in violation of this ordinance:

6. Loading Operation. Loading, unloading, opening or otherwise handling boxes, crates, containers, garbage containers or other objects between

the hours of 9 p.m. and 7 a.m. the following day in such a manner as to violate Section 5 or cause a noise disturbance.

16. Refuse Compacting Vehicles. The operating or causing or permitting to be operated or used any refuse compacting vehicle which creates a sound pressure level in excess of 74 dB(A) at 50 feet (15 meters) from the vehicle.

17. Garbage Collection. The collection of garbage, waste or refuse between the hours of 9 p.m. and 7 a.m. the following day:

a. in any area zoned residential, or within 300 feet of an area zoned residential;

b. in any land use district so as to cause a noise disturbance.

REFERENCES
Section 9

9-1. "Legal Review Report on Specialty Truck Noise Abatement," Booz Allen Applied Research, Draft report submitted to the EPA Office of Noise Abatement and Control, July 1976.

9-2. U.S. Environmental Protection Agency, State and Local Noise Control Activities, 1977-1978, Office of Noise Abatement and Control, Washington, D. C., April 1979.

EXHIBIT 9-1

STATE AND LOCAL LAWS AND REGULATIONS

ON

MOTOR VEHICLE NOISE

CONTENTS

1. List of states, counties and cities having noise laws and regulations and date of enactment of adoption.

2. A table showing the decibel limits of each law and ordinance and the test procedure utilized.

Prepared by

State Relations Department

Motor Vehicle Manufacturers Association
of the United States, Inc.

June 24, 1975

MOTOR VEHICLE NOISE

Laws and Regulations

California	law enacted 1967 (amended 1971, 1975)
Colorado	law enacted 1971
Connecticut	by regulation enacted 1971 (amended 1973)
Florida	law enacted 1974 (amended 1975)
Hawaii	by regulation enacted 1972
Idaho	law enacted 1971
Indiana	law enacted 1971
Minnesota	law enacted 1971 (repealed 1974)
Nebraska	law enacted 1972
Nevada	by regulation enacted 1971
New York	law enacted 1965
Oregon	by regulation enacted 1974
Pennsylvania	law enacted 1972
Washington	by regulation enacted 1975

City Ordinances

Albuquerque (New Mexico)	law enacted 1975
Barrington (Illinois)	law enacted 1973
Billings (Montana)	law enacted 1972
Birmingham (Michigan)	law enacted 1973
Boston	law enacted 1972
Boulder (Colorado)	law enacted 1971
Chicago	law enacted 1971
Denver (Colorado)	law enacted 1974
Des Plaines (Illinois)	law enacted 1972
Grand Rapids (Michigan)	law enacted 1973
Helena (Montana)	law enacted 1972
Lakewood (Colorado)	law enacted 1973
Madison (Wisconsin)	law enacted 1972
Minneapolis	law enacted 1971 (amended 1972)
Missoula (Montana)	law enacted 1972
New York	law enacted 1972
Ogden (Utah)	law enacted 1972
San Francisco	law enacted 1972
Sparta (New Jersey)	law enacted 1972

County Ordinances

Arlington (Virginia)	law enacted 1974
Cook (Illinois)	law enacted 1972
Montgomery (Maryland)	law enacted 1975
Salt Lake (Utah)	law enacted 1972

Administrative Authorities

Baltimore (Maryland)	law enacted 1972
Louisiana	law enacted 1972
Maryland	law enacted 1973 (amended 1974)
Milwaukee (Wisconsin)	law enacted 1973
Minnesota	law enacted 1974
New Jersey	law enacted 1971
North Dakota	law enacted 1971
Washington	law enacted 1974

Other

New Jersey Turnpike Authority	law enacted 1974

TABLE OF MOTOR VEHICLE NOISE LEVEL LIMITS
(STATUTES, REGULATIONS AND ORDINANCES)

State Law	Regulates	Automobiles	Trucks	Test Procedure
California	Manufacturer (Dealer authorized to certify compliance)	Before 1/1/73, 86 dBA After 1/1/73, 84 dBA After 1/1/75, 80 dBA	Before 1/1/73, 88 dBA After 1/1/73, 86 dBA After 1/1/75, 83 dBA After 1/1/78, 80 dBA After 1/1/88, 70 dBA	Based on SAE
	Operator	Under 35 mph, 76 dBA Over 35 mph, 82 dBA	After 1/1/73, 86 dBA under 35 mph 90 dBA over 35 mph	
Colorado	Manufacturer	Before 1/1/73, 86 dBA After 1/1/73, 84 dBA	Before 1/1/73, 88 dBA After 1/1/73, 86 dBA	Based on SAE
	Operator	Under 35 mph, 82 dBA Over 35 mph, 86 dBA	After 1/1/73, 86 dBA under 35 mph 90 dBA over 35 mph	
Connecticut	Operators Only	76 dBA under 35 mph 82 dBA over 35 mph	After 1/1/75, 84 dBA under 35 mph 88 dBA over 35 mph	Measured 50 feet from center lane of travel
Florida	Manufacturer (Certification required)	Before 1/1/75, 84 dBA After 1/1/75, 80 dBA After 1/1/79, 75 dBA	*Before 1/1/77, 86 dBA After 1/1/77, 83 dBA After 1/1/81, 80 dBA After 1/1/83, 75 dBA	Based on SAE
	Operator	Before 1/1/79, 76 dBA 35 mph or less 82 dBA over 35 mph After 1/1/79, 70 dBA 35 mph or less 79 dBA over 35 mph	*After 1/1/75, 86 dBA 35 mph or less 90 dBA over 35 mph	

* Gross vehicle weight over 10,000 pounds

State Law	Regulates	Automobiles	Trucks	Test Procedure
Hawaii	Operators Only	Before 1/1/77, 73 dBA 35 mph or less After 1/1/77, 65 dBA 35 mph or less	After 1/1/74, 84 dBA 35 mph or less 84 dBA more than 35 mph After 1/1/77, 75 dBA 35 mph or less 75 dBA more than 35 mph	Based on SAE Measured 50 feet from the center lane of travel
		Also specified noise level limits for automobile and truck posted speed limits at 25 mph or less to 60 mph or more; measured at 20 feet, 25 feet and 50 feet; and time periods when applicable for trucks.		
Idaho	Operators Only	After 6/1/71, 92 dBA	No provision	Measured at "not less than" 20 feet from vehicle under any condition of operation
Indiana	Operators Only	76 dBA under 35 mph 82 dBA over 35 mph	88 dBA under 35 mph 90 dBA over 35 mph	Measured at "at least" 50 feet from vehicle under any condition of operation
Minnesota	Decibel law repealed 10/1/74.			
		Pollution Control Agency shall promulgate motor vehicle noise regulations.		
Nebraska	Manufacturer		After 1/1/72, 88 dBA After 1/1/73, 86 dBA After 1/1/75, 84 dBA After 1/1/80, 80 dBA	Based on SAE

State Law	Regulates	Automobiles	Trucks	Test Procedure
Nebraska (Cont'd)	Operator		After 1/1/75, 86 dBA under 35 mph 90 dBA over 35 mph	
		Gross vehicle weight of 10,000 pounds or more.		
Nevada	Manufacturer	1/1/72 to 1/1/73, 86 dBA After 1/1/73, 84 dBA	1/1/72 to 1/1/73, 88 dBA After 1/1/73, 86 dBA	Based on SAE
	Operator	76 dBA under 35 mph 82 dBA over 35 mph	After 1/1/73, 86 dBA under 35 mph 90 dBA over 35 mph	
New York	Operators Only	88 dBA	88 dBA	Based on SAE with vehicle speeds under 35 mph.
		Model Year	Model Year	
Oregon	Manufacturer (Certification required)	1975, 83 dBA 1976-1978, 80 dBA after 1978, 75 dBA	*1975, 86 dBA 1976-1978, 83 dBA after 1978, 80 dBA	Measured at 50 feet from the center lane of travel
	Operator	Before 1976, 81 dBA 35 mph or less 85 dBA over 35 mph	*Before 1976, 86 dBA 35 mph or less 90 dBA over 35 mph	Measured at 50 feet or greater from the center lane of travel
		1976-1978, 78 dBA 35 mph or less 82 dBA over 35 mph	1976-1978, 85 dBA 35 mph or less 86 dBA over 35 mph	
		After 1978, 73 dBA 35 mph or less 77 dBA over 35 mph	After 1978, 82 dBA 35 mph or less 84 dBA over 35 mph	

State Law	Regulates	Automobiles	Trucks	Test Procedure
Oregon (Cont'd)		*Truck and Bus Truck - Gross vehicle weight of 6,000 pounds or more. Bus - Vehicle designed and used for carrying passengers and their personal baggage and express for compensation. Also specifies noise level limits for used motor vehicles as measured by a stationary test at 25 feet or greater; and time periods when ambient noise limits are applicable.		
Pennsylvania	Manufacturer	After 1/1/73, 84 dBA	*After 1/1/73, 90 dBA	Based on SAE
	Operator	After 9/1/71, 82 dBA under 35 mph 86 dBA over 35 mph	After 9/1/71, 90 dBA under 35 mph 92 dBA over 35 mph	
		*Manufacturer's gross vehicle weight rating of 7,000 pounds or more.		
Washington	Manufacturer	After 1/1/76, 80 dBA	*After 1/1/76 and Before 1/1/77, 86 dBA	Measured at 50 feet from the center lane of travel
	Operator	After 7/1/75, 76 dBA under 35 mph 80 dBA over 35 mph	*After 7/1/75, 86 dBA under 35 mph 90 dBA over 35 mph	
		*Gross vehicle weight of 10,000 pounds or more		
City Ordinance				
Albuquerque (New Mexico)	Operators Only	After 6/1/75, 76 dBA under 40 mph 82 dBA over 40 mph	*After 6/1/75, 86 dBA under 40 mph 90 dBA over 40 mph	Measured at 50 feet from the center lane of travel
		*Gross vehicle weight of 8,000 pounds or more		

City Ordinance	Regulates	Automobiles	Trucks	Test Procedure
Barrington (Illinois)	Manufacturers Only (Certifi- cation required)	Before 1/1/73, 86 dBA After 1/1/73, 84 dBA After 1/1/75, 80 dBA After 1/1/80, 75 dBA	*After 1/1/70, 88 dBA After 1/1/73, 86 dBA After 1/1/75, 84 dBA After 1/1/80, 75 dBA	Measured 25 feet from the noise source
		*Gross vehicle weight of 8,000 pounds or more		
Billings (Montana)	Operators Only	After 11/27/72, 74 dBA 80 dBA	*After 11/27/72 82 dBA 88 dBA	Measured at: 50 feet 25 feet from the center lane of travel
		*Gross vehicle weight of 10,000 pounds or more		
Birmingham (Michigan)	Operators Only	Before 7/1/78, 76 dBA under 35 mph 82 dBA over 35 mph After 7/1/78, 70 dBA under 35 mph 79 dBA over 35 mph	*Before 7/1/78 86 dBA under 35 mph 90 dBA over 35 mph After 7/1/78 82 dBA under 35 mph 86 dBA over 35 mph	Measured not less than 50 feet from vehicle
		*Gross vehicle weight of 10,000 pounds or more		
Boston	Manufacturers Only	Before 1/1/73, 86 dBA After 1/1/73, 84 dBA After 1/1/75, 80 dBA After 1/1/80, 75 dBA	*After 1/1/70, 88 dBA After 1/1/73, 86 dBA After 1/1/75, 84 dBA After 1/1/80, 75 dBA	Measured 50 feet from the center lane of travel
		*Gross vehicle weight of 10,000 pounds of more		
Boulder	Operators Only	80 dBA	*88 dBA	Measured "at least" 25 feet from a noise source located within the right-of-way

*Within the City during the hours of 7:00 a.m. to 6:00 p.m. on Monday through Saturday with a manufacturer's gross weight rating of 10,000 pounds and above.

City Ordinance	Regulates	Automobiles	Trucks	Test Procedure
Chicago	Manufacturer (Certification required)	After 1/1/73, 84 dBA After 1/1/75, 80 dBA After 1/1/80, 75 dBA	*After 1/1/73, 86 dBA After 1/1/75, 84 dBA After 1/1/80, 75 dBA	Measured at "not less" than 50 feet from the center lane of travel
	Operator	Before 1/1/78, 76 dBA under 35 mph 82 dBA over 35 mph		
		After 1/1/78, 70 dBA under 35 mph 79 dBA over 35 mph	After 1/1/73, 86 dBA under 35 mph 90 dBA over 35 mph	
		*Gross vehicle weight of 8,000 pounds or more		
Denver (Colorado)	Operators Only	80 dBA	*88 dBA	Measured 25 feet from the vehicle
		*Gross vehicle weight over 10,000 pounds		
		Limit applicable between hours of 7:00 a.m. and 10:00 p.m. Between hours of 10:00 p.m. and 7:00 a.m., limit is 80 dBA in residential areas and 88 dBA on heavily traveled highways and freeways.		
Des Plaines (Illinois)	Manufacturer (Certification required)	After 1/1/73, 84 dBA After 1/1/75, 80 dBA After 1/1/80, 75 dBA	*After 1/1/73, 86 dBA After 1/1/75, 84 dBA After 1/1/80, 75 dBA	Measured at "not less" than 50 feet from the center lane of travel
	Operator	Before 1/1/78, 76 dBA under 35 mph 82 dBA over 35 mph		
		After 1/1/78, 70 dBA under 35 mph 79 dBA over 35 mph	After 1/1/73, 86 dBA under 35 mph 90 dBA over 35 mph	
		*Gross vehicle weight of 8,000 pounds or more		

City Ordinance	Regulates	Automobiles	Trucks	Test Procedure
Grand Rapids (Michigan)	Manufacturer	After 1/1/73, 84 dBA After 1/1/75, 80 dBA After 1/1/80, 75 dBA	*Before 7/1/73, 88 dBA After 7/1/73, 86 dBA After 1/1/75, 84 dBA After 1/1/80, 75 dBA	Measured 50 feet from center line of travel
	Operator	Before 7/1/78, 78 dBA under 35 mph 82 dBA over 35 mph		Measured "not less" than 50 feet from center line of travel
		After 7/1/78, 73 dBA under 35 mph 79 dBA over 35 mph	After 7/1/73, 86 dBA under 35 mph 90 dBA over 35 mph	
		*Gross vehicle weight of 10,000 pounds or more		
Helena (Montana)	Operators Only	After 10/5/72, 80 dBA	*After 10/5/72, 88 dBA	Measured from public right-of-way a distance of at least 25 feet from center of nearest traffic lane
		*Gross vehicle weight of 10,000 pounds or more		
Lakewood (Colorado)	Operators Only	80 dBA	88 dBA	Measured 25 feet from the vehicle, four feet above the ground
Madison (Wisconsin)	Manufacturers Only	After 1/1/75, 86 dBA	*After 1/1/75, 88 dBA	Based on SAE
		*Gross vehicle weight of 6,000 pounds or more		

City Ordinance	Regulates	Automobiles	Trucks	Test Procedure
Minneapolis (Minnesota)	Operators Only	Before 1/1/77, 73 dBA 35 mph or less After 1/1/77, 65 dBA 35 mph or less	After 1/1/74, 84 dBA 35 mph or less 84 dBA more than 35 mph After 1/1/77, 75 dBA 35 mph or less 75 dBA more than 35 mph	Based on SAE Measured 50 feet from the center lane of travel
	Also specifies noise level limits for automobile and truck posted speed limits at 25 mph or less to 60 mph or more; measured at 20 feet, 25 feet and 50 feet; and time periods when applicable for trucks.			
Missoula (Montana)	Manufacturers Only	Before 1/1/73, 91 dBA After 1/1/73, 89 dBA	Before 1/1/73, 93 dBA After 1/1/73, 91 dBA	Measured at 25 feet from the center lane of travel
New York	Operators Only	Before 1/1/78, 76 dBA under 35 mph 82 dBA over 35 mph After 1/1/78, 70 dBA under 35 mph 79 dBA over 35 mph	*After 9/1/72, 86 dBA at 35 mph or less 90 dBA over 35 mph	Measured 50 feet plus or minus 2 feet from center of the lane of the public highway in which the motor vehicle is idling or is traveling
		Before 1/1/78, 82 dBA under 35 mph 88 dBA over 35 mph After 1/1/78, 76 dBA under 35 mph 85 dBA over 35 mph	*After 9/1/72, 92 dBA at 35 mph or less 96 dBA over 35 mph	Measured 25 feet plus or minus 2 feet from center of lane of public highway in which the motor vehicle is idling or traveling

*Gross vehicle weight of 8,000 pounds or more

City Ordinance	Regulates	Automobiles	Trucks	Test Procedure
Ogden (Utah)	Operators Only	After 1/1/73, 86 dBA in residential area 90 dBA in other areas	After 1/1/73, 86 dBA in residential area 90 dBA in other areas	Measured "not less" than 50 feet from the line of travel
San Francisco (California)		(ONLY APPLICABLE TO OFF-ROAD VEHICLES)		
Sparta (New Jersey)	Operators Only	After 3/28/72, 88 dBA within township limits	After 3/28/72, 88 dBA within township limits	Measured at least 25 feet from noise source located within the public right-of-way
County Ordinance				
Arlington (Virginia)	Operators Only	After 1/1/75, 76 dBA under 35 mph 84 dBA over 35 mph	*After 1/1/75, 86 dBA under 35 mph 90 dBA over 35 mph	Based on SAE
		*Gross vehicle weight of 10,000 pounds or more		
Cook (Illinois)	Manufacturer (Certification required)	After 1/1/73, 84 dBA After 1/1/75, 80 dBA After 1/1/80, 75 dBA	*After 1/1/73, 86 dBA After 1/1/75, 84 dBA After 1/1/80, 75 dBA	Measured 50 feet from the center line of travel
	Operator	Before 1/1/78, 76 dBA under 35 mph 82 dBA over 35 mph After 1/1/78, 70 dBA under 35 mph 79 dBA over 35 mph	Before 1/1/73, 88 dBA under 35 mph 90 dBA over 35 mph After 1/1/73, 86 dBA under 35 mph 90 dBA over 35 mph	Measured "not less" than 50 feet from the center line of travel
		*Gross vehicle weight of 8,000 pounds or more		

County Ordinance	Regulates	Automobiles	Trucks	Test Procedure
Montgomery (Maryland)	Operators Only	After 10/1/76, 76 dBA under 35 mph 82 dBA over 35 mph	*After 10/1/76, 86 dBA under 35 mph 90 dBA over 35 mph	Measured 50 feet from the center line of travel
		*Gross vehicle weight of 10,000 pounds or more		
Salt Lake (Utah)	Operators Only	After 1/1/73, 76 dBA under 35 mph 83 dBA over 35 mph	*After 1/1/73, 86 dBA under 35 mph 90 dBA over 35 mph	Measured 50 feet from the center lane of travel
		*Gross vehicle weight of 6,000 pounds or more		
Other New Jersey Turnpike Authority	Operators Only	After 6/1/74, 76 dBA under 35 mph 82 dBA over 35 mph	*After 1/1/75, 86 dBA under 35 mph 90 dBA over 35 mph	Measured 50 feet from the center lane of travel
		After 1/1/78, 70 dBA under 35 mph 79 dBA over 35 mph	After 1/1/78, 80 dBA under 45 mph 84 dBA over 45 mph	
			After 1/1/90, 75 dBA under 45 mph 78 dBA over 45 mph	
		*Gross vehicle weight over 10,000 pounds		

Appendix A

DOCKET ANALYSIS

OF

PROPOSED NOISE EMISSION REGULATION

FOR

TRUCK-MOUNTED SOLID WASTE COMPACTORS

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

A-1. INTRODUCTION

This docket analysis is the formal review of comments made by the public regarding the proposed Truck-Mounted Solid Waste Compactor Noise Emission Regulation. The proposed regulation was published in the Federal Register on August 26, 1977. The formal public comment period extended from this date until November 25, 1977. During this period, two public hearings were held by the Office of Noise Abatement and Control, Environmental Protection Agency. One was held on October 18, 1977, in New York City and the other was held on October 20, 1977, in Salt Lake City, Utah.

All comments received by the EPA concerning the proposed regulation during the formal public comment period are reviewed and responded to in this analysis. Those persons or organizations contributing comments have been grouped into the following categories: (1) compactor manufacturers, (2) manufacturers related to the compactor industry, (3) compactor distributor/dealers, (4) trade associations, (5) governmental agencies, (6) citizens groups, and (7) private citizens. A list of the specific contributors in each of these categories is provided in §A-2 of this Appendix. Each contributor has been given an identification number.

§A-3 provides a summary of the issues raised in comments received and the EPA response to these issues. The issues have beeen grouped into general categories. Comments received in each category in §A-3 are cross-referenced with the contributors listed in §A-2.

Only submissions made to EPA during the formal docket period are identified in this analyis. Submissions to EPA concerning the proposed regulation that were received after the close of the docket period have received consideration by EPA in the responses to the issues, but are not formally identified as submissions to the docket.

A-2. LIST OF CONTRIBUTORS

This section lists all persons or organizations contributing comments pertaining to the regulation during the formal comment period of August 26, 1977 through November 26, 1977. Following each contributor's name in parentheses are identification numbers of the submission to the docket: numbers preceded by a 'D' identify the docket number of written submissions to the docket; numbers preceded by 'NYC' denote testimony presented at the New York City public hearing; and numbers preceded by 'SLC' denote testimony presented at the Salt Lake City public hearings.

Under the heading 'Comments' following each contributor's name, numbers are found identifying those areas in which each contributor made comments. These numbers correspond directly to the categories of comments in §A-3.

A-2.1 COMPACTOR MANUFACTURERS

A-2.1.1 Dempster Dumpster Systems Division
Carrier Corporation
Knoxville, Tennessee
(D-067, D-091, NYC-8)

Comments: A-3.3.2, A-3.4.2, A-3.4.4, A-3.4.6, A-3.4.7, A-3.4.8, A-3.5.2, A-3.5.5, A-3.5.9, A-3.7.1, A-3.7.2, A-3.7.5, A-3.8.1

A-2.1.2 Peabody International Corporation
Galion, Ohio
(D-080)

Comments: A-3.4.4, A-3.4.12, A-3.5.5, A-3.5.9, A-3.7.1, A-3.7.3

A-2.1.3 Leach Co.
Oshkosh, Wisconsin
(D-104)

Comments: A-3.2.1, A-3.3.1, A-3.4.2, A-3.4.4, A-3.4.9, A-3.4.12, A-3.5.2, A-3.5.4, A-3.5.9, A-3.6.3, A-3.7.2, A-3.7.3, A-3.8.1

A-2.1.4 The Heil Co.
Knoxville, Tennessee
(NYC-2)

Comments: A-3.2.3, A-3.3.2, A-3.4.2, A-3.4.5, A-3.5.4, A-3.5.5, A-3.5.9, A-3.7.1, A-3.7.2, A-3.7.3, A-3.8.1

A-2.2 MANUFACTURERS RELATED TO COMPACTOR INDUSTRY

A-2.2.1 Ford Motor Company
Dearborn, Michigan
(D-113)

Comments: A-3.1.2, A-3.2.1, A-3.2.3, A-3.4.1, A-3.4.4, A-3.4.10, A-3.4.11, A-3.5.1, A-3.5.2, A-3.5.5, A-3.5.8, A-3.5.9, A-3.7.2, A-3.7.3, A-3.7.5

A-2.3 COMPACTOR DISTRIBUTORS/DEALERS

A-2.3.1 Capital Equipment Company, Inc.
Richmond, Virginia
(D-087)

Comments: A-3.7.5

A-2.3.2 Sanitation Equipment Corp.
Paramus, New Jersey
(D-074)

Comments: A-3.7.5

A-2.3.3 General Equipment, Inc.
Baton Rouge, Louisiana
(D-083)

Comments: A-3.1.1, A-3.2.1, A-3.3.1, A-3.4.12, A-3.7.1

A-2.3.4 MacQueen Equipment, Inc.
St. Paul, Minnesota
(D-084)

Comments: A-3.7.1, A-3.7.5

A-2.3.5 GranTurk Sanitation Equipment Co., Inc.
Warrington, Pennsylvania
(D-085)

Comments: A-3.7.5

A-2.3.6 Bell Equipment Company
Troy, Michigan
(D-105)

Comments: A-3.3.1, A-3.7.1

A-2.3.7 Truck Equipment
Baltimore, Maryland
(D-107)

Comments: A-3.7.5

A-2.3.8 C. N. Wood, Co., Inc.
Watertown, Massachusetts
(D-108)

Comments: A-3.4.12, A-3.7.1, A-3.7.5

A-2.3.9 Elgin Leach Corporation
Chicago, Illinois
(D-109)

Comments: A-3.2.1, A-3.7.1, A-3.7.5

A-2.3.10 Connecticut Truck & Trailer Service Co.
New Haven, Connecticut
(D-110)

Comments: A-3.2.1, A-3.7.1, A-3.7.5

A-2.3.11 Theodore J. Burke & Son, Inc.
Flushing, New York
(D-111)

Comments: A-3.7.1, A-3.7.5

A-2.4 TRADE ORGANIZATIONS

A-2.4.1 National Solid Wastes Management Association (NSWMA)
Washington, D.C.
(D-078, NYC-6)

Comments: A-3.1.1, A-3.1.2, A-3.2.1, A-3.2.3, A-3.3.2 A-3.3.4, A-3.4.4, A-3.4.12, A-3.5.2, A-3.5.5, A-3.5.6, A-3.5.7, A-3.5.9, A-3.6.1, A-3.6.2, A-3.7.1, A-3.7.2, A-3.7.3, A-3.7.4, A-3.7.5, A-3.8.1

A-2.4.2 Institute for Solid Wastes
American Public Works Association
Washington, D.C.
(D-090)

Comments: A-3.1.1, A-3.3.1, A-3.3.2, A-3.5.9, A-3.8.1

A-2.5 GOVERNMENTAL AGENCIES (STATE, LOCAL, FEDERAL)

A-2.5.1 Air Pollution and Noise Control Section
Montgomery County, Maryland
(SLC-14)

Comments: A-3.8.5

A-2.5.2 Village of Hamburg
New York
(D-012)

Comments: A-3.8.5

A-2.5.3 Public Works Department
City of Fort Worth, Texas
(D-025)

Comments: A-3.8.2

A-2.5.4 City of West Palm Beach
Florida
(D-028)

Comments: A-3.3.1, A-3.5.3

A-2.5.5 Public Service Department
City of Sioux City, Iowa
(D-036)

Comments: A-3.2.4, A-3.3.2, A-3.5.6, A-3.6.4

A-2.5.6 City of Syracuse
New York
(D-040, D-059)

Comments: A-3.3.1

A-2.5.7 Noise Control Administration
City of Colorado Springs, Colorado
(D-041)

Comments: A-3.5.5, A-3.5.9

A-2.5.8 DeKalb Sanitation Department
DeKalb County, Georgia
(D-061)

Comments: A-3.1.1

A-2.5.9 Upper San Juan Regional Planning Commission
Pagosa Springs, Colorado
(D-086)

Comments: A-3.1.1, A-3.3.1, A-3.6.4

A-2.5.10 Department of Streets & Public Improvements
Salt Lake City Corporation
Salt Lake City, Utah
(D-076)

Comments: A-3.6.4

A-2.5.11 City of San Diego
California
(D-089)

Comments: A-3.4.4, A-3.5.3

A-2.5.12 Department of Environmental Quality
State of Oregon
(D-112)

Comments: A-3.1.1, A-3.4.1, A-3.5.3, A-3.6.5

A-2.5.13 City of Beverly Hills
California
(D-117)

Comments: A-3.4.4

A-2.5.14 Chicago City Council
Committee on Environmental Control
Chicago, Illinois
(NYC-4)

Comments: A-3.3.1, A-3.6.6

A-2.5.15 Bureau of Noise Abatement
Department of Air Resources
City of New York, New York
(NYC-3)

Comments: A-3.2.2, A-3.4.1, A-3.4.3, A-3.5.3, A-3.5.9,
A-3.6.4

A-2.5.16 House of Representatives (R, N.Y.)
Washington, D.C.
(NYC-1)

Comments: A-3.3.3

A-2.5.17 Metropolitan Council of Governments
Washington, D.C.
(NYC-10)

Comments: A-3.8.5

A-2.5.18 Health Systems Agency
New York, New York
(NYC-11)

Comments: A-3.4.1, A-3.5.3

A-2.5.19 Salt Lake City Health Department
Salt Lake City, Utah
(SLC-1)

Comments: A-3.8.5

A-2.5.20 Salt Lake City Public Works Department
Salt Lake City, Utah
(SLC-12)

Comments: A-3.3.3, A-3.6.4

A-2.5.21 City of Boulder
Colorado
(SLC-2)

Comments: A-3.5.5, A-3.8.4

A-2.5.22 Provo City Corporation Sanitation Department
Provo City, Utah
(SLC-6)

A-2.5.23 California Department of Health
Office of Noise Control
State of California
(SLC-9)

Comments: A-3.1.2, A-3.2.4, A-3.5.6

A-2.5.24 S.F. Department of Environmental Services
San Francisco, California
(SLC-10)

Comments: A-3.5.3

A-2.6 CITIZENS GROUPS

A-2.6.1 Washington Square Village Tenants' Assoc.
New York City, New York
(D-072)

Comments: A-3.8.5

A-2.6.2 Federation of West Side Block Associations
New York City, New York
(NYC-5)

Comments: A-3.4.1, A-3.5.5, A-3.8.3

A-2.6.3 Citizens for a Quieter City
New York, New York
(NYC-7)

Comments: A-3.1.1, A-3.1.2

A-2.6.4 Citizens Against Noise
Honolulu, Hawaii
(SLC-13)

Comments: A-3.3.2, A-3.4.1, A-3.4.3, A-3.5.3, A-3.5.9, A-3.6.4, A-3.6.5, A-3.8.3, A-3.8.4

A-2.6.5 Senior Citizens
Salt Lake City, Utah
(SLC-4)

Comments: A-3.2.4

A-2.7 PRIVATE CITIZENS

A-2.7.1 K. Martin
Reseda, California
(D-001)

Comments: A-3.8.1

A-2.7.2 William K. Evarts, Jr.
New York, New York
(D-008)

Comments: A-3.8.5

A-2.7.3 Richard F. Hahn
Woodstock, Illinois
(D-011)

Comments: A-3.1.1, A-3.3.1

A-2.7.4 Terry N. Struve
Richmond, Indiana
(D-013)

Comments: A-3.1.1, A-3.3.1

A-2.7.5 Geraldine Graf
Wauwatosa, Wisconsin
(D-015)

Comments: A-3.8.5

A-2.7.6 Samuel T. Bodine
Buffalo, New York
(D-016)

Comments: A-3.3.1

A-2.7.7 Vern D. Kornelsen
Denver, Colorado
(D-017)

Comments: A-3.8.5

A-2.7.8 Henry Jordan
(D-024)

Comments: A-3.8.5

A-2.7.9 Barry Benepe
New York City, New York
(D-027)

Comments: A-3.4.1, A-3.5.9, A-3.6.3

A-2.7.10 William F. Fuchs
Fairfax, Virginia
(D-029)

Comments: A-3.3.1

A-2.7.11 Norman L. Arenander
DeWitt, New York
(D-031)

Comments: A-3.8.5

A-2.7.12 Jonathan L. Eisenberg
New Haven, Connecticut
(D-034)

Comments: A-3.4.3, A-3.5.3

A-2.7.13 Roy E. de la Houssaye, Jr.
New Orleans, Louisiana
(D-037)

Comments: A-3.5.5, A-3.8.3

A-2.7.14 Joan B. Williamson, Ph.D.
New York City, New York
(D-038)

Comments: A-3.8.3

A-2.7.15 Barbara Sadagopan
Sindelfingen, Germany
(D-060)

Comments: A-3.3.2

A-2.7.16 William Wale
Indianapolis, Indiana
(D-062)

Comments: A-3.3.1

A-2.7.17 Alan L. Weiser
Silver Spring, Maryland
(D-063)

Comments: A-3.3.1, A-3.3.4, A-3.3.5, A-3.4.1, A-3.4.3
A-3.5.9

A-2.7.18 W. H. Mathieu
(D-065)

Comments: A-3.8.3

A-2.7.19 Robert Weisberg
New York City, New York
(D-068)

Comments: A-3.5.3

A-2.7.20 Ranier Esslen
New York, New York
(D-069)

Comments: A-3.8.3

A-2.7.21 R. T. Cook
(D-070)

Comments: A-3.3.1

A-2.7.22 Jack Bratcher
Salt Lake City, Utah
(D-071)

Comments: A-3.8.5

A-2.7.23 Harry Perlstadt
E. Lansing, Michigan
(D-073)

Comments: A-3.6.4

A-2.7.24 Patti Breitman
New York City, New York
(D-075)

Comments: A-3.8.5

A-2.7.25 Braham and Diane Horwitz
(D-077)

Comments: A-3.8.5

A-2.7.26 Mones E. Hawley
Washington, D.C.
(D-079)

Comments: A-3.8.5

A-2.7.27 Yvonne Vandenengel
Montreal, Canada
(D-081)

Comments: A-3.8.5

A-2.7.28 Francis A. Lackner, Jr.
New York City, New York
(D-082)

Comments: A-3.2.4, A-3.6.4

A-2.7.29 Charles K. McWhorter
New York City, New York
(D-106)

Comments: A-3.3.1

A-2.7.30 J. W. Mellinger
Cocoa, Florida
(D-114)

Comments: A-3.8.5

A-2.7.31 Erick Pfeffer
Albany, New Yrok
(D-116)

Comments: A-3.3.1

A-2.7.32 Thomas H. Fay, Ph.D.
New York, New York
(NYC-9)

Comments: A-3.2.4, A-3.4.1

A-2.7.33 L. K. Irvine
Salt Lake City, Utah
(SLC-7)

Comments: A-3.8.3

A-2.7.34 Steve Harmsen
Salt Lake City, Utah
(SLC-3)

Comments: A-3.5.9, A-3.6.4

A-2.7.35 Robert B. Chaney, Jr., Ph.D.
Missoula, Montana
(SLC-8)

Comments: A-3.1.2, A-3.4.2

A-2.7.36 Martin S. Robinette, Ph.D.
Salt Lake City, Utah
(SLC-11)

Comments: A-3.8.5

A-2.7.37 David Moore
Salt Lake City, Utah
(SLC-5)

A-3. SUMMARY OF COMMENTS AND RESPONSES

This section summarizes the comments received from the contributors identified in §A-2 and EPA's response to these comments.

A-3.1 HEALTH AND WELFARE BENEFITS.

A-3.1.1 Magnitude of Benefits

Seven commenters (A-2.3.3, A-2.4.1, A-2.4.2, A-2.5.8, A-2.5.9, A-2.7.3, A-2.7.4) indicated that the health and welfare benefits derived from the proposed regulation were too small. One commenter remarked that noise from truck-mounted compactors did not damage hearing and two other commenters indicated that compactor noise was not a serious problem. However, two commenters stated that the regulation should be more stringent to increase the benefits.

Response: EPA's definition of health and welfare is based upon the definition developed by the World Health Organization which includes factors other than the absence of clinical disease. The phrase "health and welfare" denotes personal comfort and well-being including the absence of mental anguish, disturbance, and annoyance as well as the lack of transient or permanent hearing loss and demonstrable physiological injury. These factors have been considered in the EPA analysis of health and welfare benefits. For example, the reduction of nighttime noise that is of sufficient intensity and duration to disturb a sleeping person has been analyzed.

All of these impacts need to be considered in judging the health and welfare benefits of the proposed regulation. Compactor noise that results in sleep disturbances or interference of speech is a significant aspect of the impact of compactor noise. Ignoring these important factors when analyzing the potential benefits of a regulation would only present a portion of the total benefits that could be anticipated. Truck-mounted solid waste compactor noise results in significant impacts in both of these areas, as shown in the health and welfare analysis and as corroborated by several commenters.

EPA has selected a regulatory level that represents the best means of obtaining optimal health and welfare benefits within the constraints of the best available technology. A more stringent regulation at this time would not significantly improve the health and welfare benefits and could place an unreasonable economic burden on the compactor industry.

A-3.1.2 Computation of Benefits

Three commenters indicated that the health and welfare benefits were underestimated. One commenter (A-2.6.3) thought the criterion of L_{dn} = 55 dB for adequate protection of health and welfare was too high and suggested an optimum goal of L_{dn} = 35 dB. Another commenter (A-2.5.23) indicated that EPA may have underestimated the impact of noise on people who live in mobile homes. A third commenter (A-2.7.35) remarked that criteria for limiting sleep disturbance, speech interference and annoyance due to noise characteristics other than the level of noise need to be incorporated into EPA's requirements for protecting the public's health and welfare.

Two commenters (A-2.2.1 and A-2.4.1) commented that the health and welfare benefits may have been overestimated since the compactor truck does not compact trash at every stop.

Response: The EPA health and welfare model represents the EPA's best estimate of the frequency of occurrence, duration, and intensity of truck-mounted solid waste compactor noise and the location of compactor noise in the environment. The model necessarily depends on statistical representations of reality because it must address the nation as a whole, not just a specific geographical location. Therefore, the model may not accurately represent individual situations that vary significantly from the norm, i.e., mobile homes.

The criterion of L_{dn} = 55 dB was determined by the Agency to be the noise level requisite to protect the public health and welfare outdoors, with an adequate margin of safety for both activity interference and hearing loss (p.28 - Levels Document). Therefore, a level of L_{dn} = 35 dB would not appreciably add to the public's protection, and would be unrealistic and impractical to achieve. An L_{dn} of 55 dB, the attainment of which will involve a concerted effort by Federal, state and local governments over many years, is a target goal which protects the public from the impacts of noise with a margin of safety.

Inclusion of characteristics of noise other than the frequency of occurrence, duration, and level of noise in the model is not feasible at this time. There is no accepted method for relating these other characteristics quantitatively to human impact.

As for the parameters describing the frequency of the compactor operation in relationship to the number of collection stops, the compactor truck was assumed to compact refuse after every fourth stop when operating in low density residential neighborhoods.

In certain respects, the health and welfare model may overestimate impacts; however, in other situations, impacts may be underestimated. When it was necessary to choose between an assumption that could potentially overestimate the impact and another assumption that most likely would underestimate the impact, the latter assumption was chosen. In general, these situations tended to balance each other and if any of the premises used are in error, they should tend to underestimate the total impact of refuse collection noise on the nation's population.

A-3.2 NOISE CONTROL TECHNOLOGY

A-3.2.1 Power Take-Off (PTO)

Several commenters (A-2.4.1, A-2.1.3, and A-2.2.1) including three distributors (A-2.3.3, A-2.3.9, A-2.3.10) indicated that the flywheel PTO and front PTO that were suggested noise control features for compactor vehicles were not readily available nor applicable to many chassis.

Response: As the demand for quiet PTOs increases, EPA anticipates that manufacturers will offer improved designs to meet the regulatory standards.

Some existing quieted refuse trucks use transmission PTOs. Use of a gear ratio that allows lower engine speeds is helpful. The noise from the PTO gears may be reduced considerably by grinding gears to a finer finish, or by wrapping the transmission and PTO case with sound deadening material. One manufacturer of transmission PTOs is considering a finer tooth design or helical gear as an alternative to an acoustic enclosure.

Front power take-offs have been adapted successfully to front, rear, and side loaders. One major truck manufacturer offers front power take-offs on its quieted trucks and another company offers the front PTO as a "Limited Production Option". Two other manufacturers plan to offer the front PTO as an option this year.

Only one company presently offers the flywheel power take-off option on their engines. However, another manufacturer has supplied a number of flywheel power take-offs on their chassis and reports success with both gasoline and diesel engines.

A-3.2.2 Best Available Technology

Two commenters (A-2.7.15 and A-2.5.15) indicated that some European countries have very quiet trash collection services. They suggested that EPA study these systems further and incorporate some of the methods used there into the EPA's definition of best available technology so that lower standards could be promulgated.

Response: The EPA studies focused on the best technology currently available within the United States. To propose standards based on technology that is only being used in Europe (such as electric trucks) would place undue economic hardships on U.S. manufacturers. However, in order to meet current noise standards or in response to the LNEP program which encourages production of quiet compactor trucks, U.S. manufacturers may adopt, for their own use, some of the European methods.

A-3.2.3 Fuel Consumption

Three commenters (A-2.1.4, A-2.4.1, and A-2.2.1) noted that factors other than reduced engine speed could affect fuel consumption. They expressed concern over increased engine temperatures and reduced engine life resulting from lower speeds.

Response: EPA recognizes that factors other than reduced engine speed can affect fuel consumption. However, reduced speed is the only noise control feature for compactors that should affect fuel consumption. EPA studies indicate that low speed operation reduces fuel consumption without a decrease in engine life or an increase in engine temperature. One manufacturer lists reduced fuel consumption as one of the benefits of quieted units in his promotional literature. EPA estimates an annual savings of 2 million gallons of gasoline and 1.2 million gallons of diesel fuel when the present day fleet of refuse collection vehicles is replaced by quieted units.

A-3.2.4 Noise Sources Not Included in the Regulation

Three commenters (A-2.5.23, A-2.6.5, and A-2.7.32) favored placing some controls on the brake noise of compactor vehicles. One commenter (A-2.5.5) indicated that vehicles equipped with "121 brakes" (Motor Vehicle Safety Standard 121, DOT) should be explicitly excluded from the regulation. A private citizen (A-2.7.28) indicated that air horns should be banned.

Response: This regulation aims to control chassis and compactor noise only during the compaction cycle of a stationary truck, and is not intended to control noise sources common to all truck chassis during transit operations. Brake noise is not a problem characteristic of only refuse vehicles, but is inherent in all medium and heavy trucks.

Air horns are not subject to Federal regulations because the noise emitted is intended as a safety measure.

A-3.3 ECONOMIC IMPACT

A-3.3.1 Magnitude of Costs

Thirteen commenters* indicated that they opposed regulation of truck-mounted solid waste compactors because the costs of regulation were too high or because the regulation was not cost-effective. Two of the above commenters indicated that the cost of a refuse vehicle could increase by as much as $5,000, and one commenter questioned EPA's view that capital equipment is a minor cost element in the cost of collecting trash.

*(A-2.5.4, A-2.7.10, A-2.5.14, A-2.7.21, A-2.7.6, A-2.7.4, A-2.5.6, A-2.7.3, A-2.3.3, A-2.4.2, A-2.1.3, A-2.7.31, A-2.7.16)

Another commenter (A-2.7.17) suggested that relief from some of the costs should be provided so that the price of the equipment would not have to be raised. This would diminish incentives for repairing rather than replacing.

Response: EPA expects that the costs of compliance with the regulation will be passed through to the user of refuse collection services. From the economic analysis studies that the Agency has conducted, EPA estimates that the annual increase in cost for refuse collection will average nationwide about 50 cents per household served. The Agency believes that this is a rather modest cost to achieve the health and welfare benefits expected from the regulation, which we estimate will significantly reduce the noise exposure (caused by refuse collection vehicles) of about 19 million Americans.

EPA estimates that the increase in cost of a compactor body will be $2000 to $3000 (in 1976 dollars, which would translate to perhaps as much as $4000 in 1979 dollars). However, our analysis is based conservatively on a possible increase in vehicle cost of about 10 percent. EPA has been given estimates of as high as $75,000 for a modern, fully equipped refuse collection vehicle which could entail a $7500 allowance for noise control while remaining within the bounds of the EPA economic impact analysis. Estimates from large refuse collection organizations that have done their own engineering of quieting features have been somewhat higher than EPA estimates. However, a review of the higher estimates suggests that certain of the features included in the cost were not needed for noise control. New York City has purchased a large number of quieted refuse collection vehicles that meet the Federal standard at an incremental cost of $2000 for the quieting features.

EPA estimates of the cost of compliance are based on industry-wide compliance to the regulation. When products are custom designed for a limited market then costs may be higher. The costs estimated by EPA may, in fact, decrease over time, after initial production line changes are made and as manufacturers become more familiar with various types of noise control features.

As regards the importance of vehicle capital cost in total costs of refuse collection, independent studies have confirmed EPA's estimate that the capital costs of vehicles represent no more than 5 percent of the total cost of refuse collection service.

The Noise Control Act, under which this regulation is being promulgated, makes no provision for financial relief for the industry impacted by the regulation. Consequently, no funds are available to EPA for providing financial relief nor does EPA have the authority to develop other mechanisms that would provide some form of financial relief for the affected industry.

A-3.3.2 Computation of Costs

Two compactor manufacturers (A-2.1.1 and A-2.1.4), two trade associations (A-2.4.1 and A-2.4.2), and one municipality (A-2.5.5) commented that some of the costs of compliance were not included in the economic impact analysis. Costs that were underestimated, according to some of the commenters, are:

- Recordkeeping
- Engineering
- Testing
- Warranty
- Production Verification

Costs that were omitted, according to some of the commenters, are:

- Costs of quieting containers
- Costs to manufacturers of providing mounting facilities
- Transportation costs related to mounting by the compactor manufacturer
- Costs related to the decreased number of service shops
- Costs due to decreased productivity of equipment
- Costs of not regulating compactors, such as medical bills, energy costs

Response: The costs that were considered by commenters to be underestimated were studied carefully in the EPA economic analyses of the industry and presented in the background document. Estimates were based on knowledge of the current operating procedures of the compactor manufacturing industry provided to EPA by compactor manufacturers. In the original economic analysis the production verification costs were estimated based on testing 15% of the units produced. Many manufacturers indicated that the percentage requiring testing would far exceed 15%. The production verification scheme has been revised to reduce the number of units requiring testing so the costs related to PV testing are likely to be lower than originally estimated. EPA estimates that fewer than 5% of the units manufactured will have to be tested, and that very few, if any, PV tests will be performed by distributors in view of the revisions in the regulation.

The requirement for testing compactors with the container attached has been deleted from the regulation; therefore, no costs for quieting containers will result from this regulation. Nevertheless, EPA believes that many communities may be interested in abating the noise caused by container handling during trash collection. Actions to this end taken locally undoubtedly will entail costs. Such costs will be the result of local decisions and action, and are not attributable directly to this regulation. (See Section A-3.5.5).

Many of the manufacturers identified in the EPA studies currently mount some of the compactor bodies at the manufacturing plant. Therefore, there should be no additional cost to manufacturers for mounting facilities. Also, with the regulation revised to permit distributors who mount chassis to depend on the body manufacturers' PV testing, there should be little or no shift in mounting practices from the current arrangements.

Transportation costs related to mounting by compactor manufacturers were not included in the original economic analysis. Since no change in mounting practices is expected, based on the regulations as revised, there should be no appreciable change in transportation costs between body manufacturers and distributors.

Commenter-suggested costs related to the decreased numbers of service shops are based on the assumption that distributors will eliminate their service shops due to the regulation. Since mounting practices are not expected to change, related industry practices, including the provision of service, are not expected to change. In any case, it seems unlikely that distributors, as the primary sales agents, would give up providing service for compactor vehicles. The provision of service is a major selling point to most purchasers.

The quieting features that are expected to be used by manufacturers should not affect the productivity of the equipment with respect to the amount of refuse the truck can hold. Reduction of the engine speed could increase the compactor cycle time, if no compensating action were taken. However, the cycle times for quieted trucks observed by EPA were not significantly longer than those for unquieted trucks. In many cases, the cycle time for quieted trucks was shorter than the cycle time for similar non-quieted trucks. Shorter or equal cycle times were achieved by using a larger hydraulic pump. As the engine speed is reduced, the pumping capacity of the pump must be increased accordingly.

The costs of not regulating compactors, such as medical bills, were not assessed in the EPA economic analysis. The impact was measured in terms of the number of persons adversely impacted by compactor noise. There is no generally accepted method of analysis for assigning a monetary value to sleep disturbance, activity interference, annoyance or an overall reduction in the quality of life due to the adverse effect of noise. Nevertheless, the adverse effects of noise represent a real social disbenefit, and to the extent that the regulation results in reduction of these adverse effects, there will be cost savings that reduce the out-of-pocket costs of the regulation.

With respect to energy costs, these have been taken into account in EPA's economic analysis, in that the expected reduction of fuel costs results in a lower net cost of compliance.

A-3.3.3 Cost/Benefit Analysis

One commenter (A-2.5.20) remarked that the costs of the regulation should be justified in terms of the benefits received. A second commenter

(A-2.5.16) pointed out that it was impossible to quantify the costs of not regulating, but that he believed the benefits of the regulation are worth the cost.

Response: To perform a cost/benefit analysis of the regulation would entail assigning a monetary value to the benefits so that they can be weighed against the costs. EPA has reviewed various suggested approaches to the problem of assigning dollar values to the disbenefits (negative impacts) of noise and to the benefits of noise abatement. No method of analysis has been found that has broad acceptance by the scientific community. Consequently, EPA believes that it is not feasible in the present state of knowledge to assess the benefits of noise abatement in terms of dollar values.

In view of the moderate costs of the regulation and the number of persons whose noise exposure will be reduced (as discussed under A.3.3.2), the Agency believes that the regulation is cost-effective, and that the benefits outweigh the costs.

A-3.3.4 Exports

A trade association (A-2.4.1) commented that costs of equipment produced for export will be increased, resulting in a reduced demand for exported equipment. Another commenter (A-2.7.17) indicated that those companies that cannot maintain dual production lines will lose export business.

Response: Manufacturers may continue to produce unregulated equipment for export. To the extent that some foreign markets may require quieted compactor trucks, manufacturers will be in an improved competitive position.

Many of the noise control features identified for compactor vehicles consist of using components with more advanced noise control technology. Most of these components are not an integral part of the production process.

They are used only in the assembly of the total vehicle which tends to be a custom assembly for each unit according to manufacturers and not a production line process. Utilizing components that may be less expensive (albeit noisier) appears to be a viable alternative for exported equipment.

A-3.3.5 Unemployment

Another economic impact assessment questioned by commenter A-2.7.17 was the conclusion that no unemployment would occur as a result of the regulation. This commenter thought the conclusion unreasonable since many workers would be displaced.

Response: The determination of unemployment is based upon the total number of persons employed by the affected industry. This and other economic impacts of various regulatory alternatives are carefully assessed by EPA prior to promulgating regulations. In selecting a regulatory standard, EPA attempts to minimize these effects as much as possible. The decrease in production as a result of the compactor regulation should result in unemployment for less than two percent of the total affected industry (i.e., fewer than 40 persons). EPA anticipates that the job positions created by the required application of noise control technology and by the testing and compliance program will sufficiently offset this unemployment and may even result in increased employment.

A-3.4 TEST PROCEDURE

A-3.4.1 Noise Level Determination

Several commenters had questions concerning the use of energy averaging for computing the regulatory noise level. One commenter (A-2.5.15) indicated that the energy average could permit a noise level as much as 6 dB higher than the regulated level on one side of the truck. Another commenter (A-2.2.1) suggested that an arithmetic average would be preferable to the energy average.

One commenter (A-2.2.1) remarked that there appeared to be no justification for using microphones at seven meters because at that distance the compactor is less like a point source (than at the 50-feet distance used in the passby test procedures for truck chassis). Also, using four microphones will make correlation with existing stationary test procedures for trucks difficult. Another commenter (A-2.7.17) questioned whether the distance (7 meters) of the microphones could be considered relatively close.

Several commenters expressed concern that the test procedure did not adequately represent actual conditions under which compactor noise is heard. A number of commenters, representing local governments (A-2.5.18), citizens groups (A-2.6.2 and A-2.6.4) and a private citizen (A-2.7.9) were concerned that the levels did not take into account additional noise generated by reflection of noise off buildings and other barriers usually present when trash is being collected. Possible solutions suggested by commenters (A-2.5.15, A-2.5.12 and A-2.5.18) included making the regulatory level applicable to the maximum noise emission on any side of the compactor rather than the average and reducing the distance at which the noise is measured (A-2.5.18).

Response: The Agency believes that the logarithmic (energy) average of the levels at the four microphone positions provides a more representative measure of the noise emissions of the vehicle than the arithmetic average. The logarithmic average of the sound levels is closely related to the sound power emitted, which is the physical quantity generally regarded as best expressing the "amount" of noise radiated by a noise source. Many standards for defining the noise of machinery are based on determinations of sound power. It should be noted, however, that the actual measurements are made in sound pressure level. The sound power (level) is determined by computation, using the sound pressure level data.

The comment that the energy average could permit a level as much as 6 dB above the standard on one side of the truck is purely theoretical. To achieve this, the measurements on the other three sides would have to be at least 14 decibels lower than the level on the noisiest side. Since the compactor is not a highly directional noise source, such an occurrence is most unlikely. In all the noise measurements made of refuse collection vehicles by EPA, the largest spread in noise level observed among the four measurement positions was 7 decibels, for one vehicle. In most cases, the spread (between the highest and lowest noise levels measured at the four positions) was about 3 or 4 decibels.

If the regulation were to be based on a single maximum reading, a large number of measurements would be required to determine at which point the maximum reading occurs. EPA believes that the use of four microphones placed at the same position for each test provides the best approach to ensuring consistent and representative measures of the noise emission of a refuse collection vehicle without introducing unnecessary complexity into the test procedure.

The distance (7 meters) of the microphones from the vehicle surfaces is considered to be close when the size of the product being tested is taken into consideration. If the microphones were placed closer, the measurements might be affected excessively by individual noise sources and would not necessarily be characteristic of the vehicle as a whole.

With respect to the reverberation effects of nearby buildings on compactor noise: the purpose of the measurement procedure is to provide a standard method, as simple as possible, by which noise measurements can be made on refuse collection vehicles to determine if they meet the Federal standard. Therefore, it is necessary to eliminate, to the extent feasible, those factors which represent non-standard and complicating conditions. The reverberant effects of reflecting surfaces of buildings have been taken into account in EPA's analysis of health and welfare impacts of garbage truck noise, and therefore are reflected in the regulatory limits.

A-3.4.2 Definition of Maximum Steady Sound Level

Three compactor manufacturers (A-2.1.1, A-2.1.3, and A-2.1.4) indicated that the proposed test procedure results could be interpreted differently. One of the manufacturers (A-2.1.1) suggested using the L_{eq} metric since it is a more consistent measure of sound emissions. It was further suggested that the L_{eq} be calculated over a 10 second period and the use of the graphic level recorder not be permitted. Another commenter (A-2.7.35) indicated that the L_{eq} was unworkable for individual occurrences.

Response: EPA recognizes that there was some ambiguity in defining the "maximum steady sound level". Several revisions have been made to the proposed test procedure, and the term "maximum steady sound level" has been replaced by "maximum noise level" (defined in 205.201(a)(17)), to clarify EPA's intent.

If the noise fluctuates irregularly by several decibels during the measurement, it may be difficult to determine what the "average maximum" level is either by observing the swings of a meter needle (or the changing numbers of a digital meter display) or by "eyeballing" the trace on a graphic level recorder.

During the course of additional noise testing and analysis conducted by EPA following the hearings and comment period, it became apparent that the difficulties mentioned above introduced subjective variations in the readings made by different observers. Further analysis of the tape recorded data, including review of the earlier data, showed that this variation could be minimized by reading the maximum value using the "slow" response of the meter. With respect to impulse noises, all units that had impulse peaks in "fast" response of less than 83 dBA showed maximum values under 79 dBA in "slow" response. This is to be expected, since the impulse response of the sound level meter in "slow" setting is generally about 4 decibels lower than it is in "fast" setting.

Consequently, EPA reached the conclusion that the test procedure could be simplified and the meter reading process made more reliable by setting a single noise level limit of 79 dBA based on a reading of the maximum noise level observed with the meter in the "slow" response setting. This replaces the proposed procedure, which required two separate readings, one of "maximum steady" and one of "maximum impact", using the "fast" meter setting. The increase of one decibel in the not-to-exceed limit accounts for the damped response of the meter to a mild impulse (such as was allowed in the proposed impulse overshoot of 5 decibels in "fast" mode, in the proposed regulation) while not degrading significantly the control of continuous noise implied in the earlier "maximum steady" limit of 78 dBA.

Consideration also was given to other methods of reducing the uncertainty of the meter reading, such as use of an integrating/averaging sound level meter, also known as an "L_{eq} meter." Although this approach has potential merit, it has not been specified in the test standard because of the lack of a national or international standard for such meters. The Agency believes that, to ensure consistency and accuracy of the primary measurement which establishes conformity to a regulatory limit, the instrument used should conform to a widely recognized and accepted consensus standard.

A-3.4.3 Empty Truck

Four commenters (A-2.5.15, A-2.6.4, A-2.7.17 and A-2.7.12) indicated that the compactor should be tested while compacting refuse or that the standard should be applicable to the compactor whether or not it is loaded.

Response: One of the primary considerations in developing the noise emission test procedure was to design a procedure that produced consistent and repeatable results. To require testing while refuse was actually being compacted would necessitate defining a "standard" load of refuse in order to ensure some consistency between tests. The concept of a "standard" load of refuse was considered to be too complex and unwieldy to be practical for test purposes.

Several noise tests have been conducted while the vehicle was compacting an actual load of refuse. These tests have shown that some loads do increase the noise level slightly while others may decrease the noise level, but generally the differences are small. Refuse loads containing a large number of glass bottles or other hard debris typically result in greater noise levels than those measured with an empty truck. However, loads that contain soft debris such as garbage and paper can reduce the noise level to below that of an empty truck since the soft material acts as a sound damping material when it is pressed against the insides of the compactor. In general, considering that the two types of refuse loads are either noisier or quieter than the empty truck, the empty truck noise levels are considered to be a good representation of the "average" noise emitted from a compactor and greatly simplify compliance testing.

A-3.4.4 Operating Cycle

A trade association (A-2.4.1), three compactor manufacturers (A-2.1.1, A-2.1.2 and A-2.1.3), and a truck manufacturer (A-2.2.1) commented about the need for guidelines regarding normal operating procedure for manually operated compactors.

Two local governments (A-2.5.11 and A-2.5.13) indicated that many refuse trucks compact while in motion, so the test procedure should reflect this or more explicitly define normal operating procedure.

Response: §205.204(f)(4) has been revised to clarify the normal operating procedure for manually operated compactors. The compactor engine shall be operated at a speed in rpm corresponding to the maximum allowable speed of the hydraulic pump which powers the compactor mechanism.

The regulation was not intended to cover compacting while the truck is in motion. This omission should not reduce benefits for those areas where compacting in motion is the normal operating procedure. If the compactor manufacturers limit the maximum allowable engine speed during compaction, as anticipated, this will prevent the compactor truck from moving very fast while compacting and also from compacting at the maximum allowable engine speed for the moving truck. Therefore, the total noise emission resulting from compacting while in motion should not exceed emissions of compacting while stationary.

A-3.4.5 Meter Error

A manufacturer (A-2.1.4) commented that no allowance was made for meter error in the test procedure.

Response: The regulation assumes tht manufacturers will design equipment to a level at least 2 decibels below the level specified in the standard. EPA considers this margin to be adequate for dealing with meter error or any slight variations in noise emissions between compactors of the same configuration.

A-3.4.6 Tachometer

A manufacturer (A-2.1.1) commented that the truck mounted tachometers could be used to record engine speed if the accuracy requirement for tachometers was omitted from the regulation.

Response: EPA has revised the regulation to allow use of the instrument panel tachometer installed in the truck, and to increase the allowable error for the tachometer reading from 2% to 5%.

A-3.4.7 Barometric Pressure

A manufacturer (A-2.1.1) requested that the requirement for recording barometric pressure be omitted from the regulation.

Response: Large differences in barometric pressure may have an effect on the noise measurements and the field-check calibration, particularly by affecting pistonphone (field calibrator) output. This requirement is necessary to allow EPA to evaluate potential differences in test results.

A-3.4.8 Standing Water

A manufacturer (A-2.1.1) requested that the requirement for no standing water on the test pad be omitted from the regulation.

Response: The basic intent of this provision is to ensure that there is no snow on the test pad. The regulation has been modified to denote this. Liquid standing water should not have any appreciable effect on the measurements.

A-3.4.9 Radiator Fan

One manufacturer (A-2.1.3) commented that the truck regulation does not require the radiator fan to be operating during the test procedure. The compactor regulation should be the same.

Response: The radiator fan is not required in the medium and heavy truck regulation because the fan (in a vehicle equipped with a fan clutch) is not usually in operation when the vehicle is moving at road speeds. Since the noise emission tests for compactors will be conducted with the engine at low speeds, the fan is needed to cool the engine. However, the noise contribution of the fan operating at low engine speeds is expected to be negligible, based on data obtained by EPA.

A-3.4.10 Agreement of Readings Within 2 dBA

A truck manufacturer (A-2.2.1) commented that it is unclear why readings must agree within 2 dBA. Further, if the readings have to agree within 2 dBA at each microphone this would be a very difficult requirement.

Response: The energy average of the readings from each of the four microphones should agree within 2 dBA for the two complete compaction cycles to be tested for noise emissions. It is not expected that, under normal test procedures, readings will disagree by more than 2 dBA. However, certain situations such as extraneous noises, improper operation of the product being tested, measurement equipment problems, or incorrect interpretations could result in readings not agreeing within 2 dBA. This type of situation would need to be corrected before the test results could be considered valid.

The appropriate section of the regulation has been clarified to indicate that agreement within 2 dBA applies only to the four-microphone energy average, not to the readings from each microphone.

A-3.4.11 Cost of Testing

A truck manufacturer (A-2.2.1) commented that the test procedures were too costly for small manufacturers and distributors.

Response: The costs related to the test procedure were considered in the EPA economic analysis of the regulation. Care was taken to simplify the test procedure thereby reducing costs wherever feasible.

There are several possibilities that small manufacturers could explore to further reduce the costs associated with testing. For example, the test pad does not necessarily have to be specially constructed or even owned by the manufacturer or distributor. The Agency has found paved parking lots to be very suitable test pads. The manufacturer can also consider contracting testing service on an "as required" basis, thus eliminating the overhead burden of full time test personnel. Furthermore, the necessity for testing by distributors has been minimized as discussed in the §A-3.7.5 response.

A-3.4.12 Weather Conditions

Two manufacturers of compactors (A-2.1.3 and A-2.1.2), two compactor vehicle distributors (A-2.3.3 and A-2.3.8), and a trade organization (A-2.4.1) commented on potential difficulties due to adverse weather conditions in meeting the 45 day deadline for performing tests. Particular concern was expressed over the early months of the calendar year when the probability of snow, rain, or winds in excess of 12 mph precluding testing on a given day could be higher than 50 percent.

Response: Section 205.205-2(a)(2) has been rewritten to allow for delay of up to ninety (90) days due to weather and conditions beyond the manufacturer's control. Records of the conditions preventing testing must be maintained and, if testing cannot begin by the 45th day, the manufacturer must so notify the Administrator within 5 days (by the 50th day). If the Administrator so requests after such notification, the manufacturer must ship products to an EPA designated facility for testing.

A-3.5 REGULATORY CRITERIA

A-3.5.1 Identification as a Major Source of Noise

A truck manufacturer (A-2.2.1) commented that, in their understanding, the criterion for identifying truck-mounted solid waste compactors as a major source of noise was based upon this product's Environmental Noise Impact (ENI) (Note: ENI is actually Equivalent Noise Impact). Since the ENI for this product is 0.2% of the population (Note: using the figures concerned, the ENI is actually 0.8%), and much of the health and welfare analysis utilized other noise metrics, the commenter questioned the identification of truck-mounted solid waste compactors as a major source of noise.

Response: The environmental noise impact was one of many factors considered by EPA in identifying truck-mounted solid waste compactors as a major source of noise. The environmental noise impact analysis involved calculating both the intensity (loudness and duration) and extent (population affected) of the noise source impact. The overall noise impact is determined by Fractional Impact methodology (the preferred term now is "Level-Weighted Population" (LWP)). Therefore, it is not correct to say that only 0.8% of the population is affected. Many persons experience an individual impact that is not a "100 percent" impact. Each individual impact is fractionally weighted according to the intensity and severity of noise exposure. Simply put, 10 persons adversely impacted 10 percent are equivalent to one person impacted 100 percent. The actual population that is affected by truck-mounted solid waste compactor noise is estimated at 19.7 million persons in the baseline year for analysis (1976), or approximately 9% of the U.S. population. Many of these persons are impacted to a partial extent, i.e. fractionally. When the population impact is determined using the Fractional Impact methodology, the computed Equivalent Noise Impact (ENI) or Level-Weighted Population (LWP) is approximately 2.11 million equivalent persons who are impacted 100%.

As mentioned above, the noise impact analysis is only one of the primary factors considered by the Administrator in determining which sources of noise are to be identified as major sources. Other key factors are:

1. Whether the product, alone or in combination with other products, causes noise exposure in defined areas under various conditions, which exceed the levels requisite to protect the public health and welfare with an adequate margin of safety;
2. Whether the spectral content or temporal characteristics, or both, of the noise make it irritating or intrusive, even though the noise level may not otherwise be excessive;
3. Whether the noise emitted by the product causes intermittent exposure leading to annoyance or activity interference.

In the case of truck-mounted solid waste compactors, this regulation provides for noise control standards consistent with standards already proposed for new medium and heavy trucks as noted in the Federal Register notice on May 28, 1975, in which the Administrator of EPA identified truck-mounted solid waste compactors as a major source of noise. The notice further stated that EPA recognized that the "...noise impact from such special purpose equipment (compactors) alone is of a lower order of magnitude. However, in view of the actions already taken to control noise emissions from medium and heavy duty trucks, control of these sources is required to avoid reducing the effectiveness of those regulations".

A-3.5.2 Data Base

A trade association (A-2.4.1), two compactor manufacturers (A-2.1.1 and A-2.1.3), and a truck manufacturer (A-2.2.1) commented about the data base used in the technology assessment of truck-mounted solid waste compactor noise emissions. The commenters were concerned about the size of the data base and apparent inconsistencies in the measurement procedures utilized. Specifically, these commenters believed that the data base was not large enough to be representative, that too many quieted compactors were included, and that all the compactors were not tested under identical conditions (i.e., some were tested with containers, some without; some tested on different surfaces; and some tested with variable engine speeds and cycle times).

Response: EPA made measurements of a number of vehicles which are believed to be representative of those in service. The data base contains examples of front, rear, and side loaders, as well as both gasoline and diesel fueled trucks.

Regarding the consistency of the test procedure, EPA recognizes that data were collected under varying conditions. However, the measurements were made by trained acoustical personnel with high precision instruments. Through extrapolation and conversion factors, measurements taken under variable conditions were adjusted to allow for different test conditions and measurement distances. In setting forth the regulation, test conditions are prescribed in detail to minimize testing variability and to eliminate uncertainties in data acquisition.

Subsequent to publication of the August, 1977 Background Document, additional noise tests of truck-mounted solid waste compactors were performed by EPA. The results of these tests are now included in the revised Background Document. These tests, which were conducted by EPA in accordance with the noise emission test procedure given in the regulation, confirm EPA's original findings.

A-3.5.3 Noise Level of Standard

Local governments, citizens groups, and private citizens (A-2.5.15, A-2.6.4, A-2.7.12, A-2.7.19, A-2.5.18, and A-2.5.4) were all concerned that the noise level selected for the standard was too high (not sufficiently stringent). Most of the above commenters came to this conclusion through familiarity with local ordinances that appeared to be more stringent than the proposed Federal standard. Others cited cases of individual truck-mounted solid waste compactors that were considerably quieter than the proposed standard. One local government (A-2.5.11), objected to the proposed standards as being too stringent. They indicated that many of their garbage trucks would have difficulty meeting the proposed standard, particularly those which do not have any limits on the maximum engine speed.

Response: The sound level selected for the standard is based on the optimal benefits achievable within the constraints of the best technology available for quieting the noise source. The costs of the noise control features required to meet the standard are also carefully weighed in the determination of the final regulatory standard. EPA's selection of the final standard indicated that the 79 dBA level (which is further reduced to 76 dBA two years later) will optimize the health and welfare benefits while minimizing the economic impact of the regulation.

During the EPA studies of the noise emissions of truck-mounted solid waste compactors, several advanced technologies for quieting compactor trucks were investigated. These technologies ranged from the exclusive use of electric vehicles to requiring special auxiliary motors for powering the compactors. Since none of these more advanced quieting methodologies had achieved any widespread use in the United States, the EPA determined that, at this time, the economic impact of a noise regulation requiring technological changes this extensive would be too severe.

EPA also noted that at least one locality (New York City) had issued standards that appeared to be more stringent than the EPA standard. Further investigation by EPA found that the full benefit of such standards were not fully realized for a variety of reasons. It is costly to purchase compactor trucks meeting such stringent standards, and sometimes difficult to obtain bids from qualified suppliers. If the delivered units do not quite meet the noise specifications, they may be accepted anyhow, in order to meet urgent needs for refuse collection. After the effective date of the Federal regulation, all newly manufactured truck-mounted solid waste compactors are expected to meet the Federal standard. In addition, any purchasers desiring compactor vehicles quieter than the Federal standard may include lower noise emission levels in the purchase specifications for such vehicles.

Suppliers of compactor vehicles will now have to incorporate noise control features on their trucks as a routine matter to comply with the Federal standard.

With respect to the inability of existing refuse collection vehicles to meet the Federal standard, the regulation provides that the standard applies only to vehicles manufactured after the effective date of the standard. The regulation does not require retrofit of existing in-use vehicles.

A-3.5.4 Categorization of Loaders

Two compactor manufacturers (A-2.1.3 and A-2.1.4) commented that it did not seem appropriate to group all types of compactors under one standard when each type is distinctly different and has different end use applications.

Response: Although the different types of compactors may have different end uses, (i.e., the front loader is used primarily for commercial collection), EPA studies indicate that all three types of compactors are found in environments where noise impacts occur. For example, the front loader is frequently found in high density residential neighborhoods collecting refuse either from neighboring commercial establishments or from high rise apartment dwellings. Therefore, it can have significant environmental noise impact in such areas.

The EPA analysis did show that there were variations in the baseline noise levels for the three types of compactors. However, in its testing of compactors with quieting features incorporated, EPA found that all types could be quieted to meet the proposed standard.

Therefore, the Agency believes that technology is available to permit all three types of compactor vehicles to comply with the regulation. From EPA's health and welfare analysis, the standard is set at close to an optimal level. Setting a lower standard, especially for only part of the vehicle population, would not significantly increase the health and welfare benefits of the regulation and thus would not justify the additional complexity and attendant cost.

A-3.5.5 Containers

The noise emitted by the containers utilized for refuse collection concerned many commenters. Two city officials (A-2.5.7 and A-2.5.21), one private citizen (A-2.7.13), and a representative of a citizens group (A-2.6.2) commented that some regulation of containers was important to the overall effectiveness of the regulation. However, three compactor manufacturers (A-2.1.1, A-2.1.2 and A-2.1.4), a trade association (A-2.4.1), and a truck manufacturer (A-2.2.1) all objected to the inclusion in the regulation of containers which are mechanically hoisted by the truck. One reason given for excluding containers was that testing was impractical due to many different types and materials of containers. Another was that potential higher noise levels emitted with containers attached were not given full consideration in EPA noise tests and were therefore absent from the data base supporting the proposed standards.

Response: This regulation does not apply to containers as such. While container noise may contribute to trash collection noise, the presence or absence of a container does not lessen the beneficial effects of quieting the noise of the vehicle during the entire loading and compaction process. In addition, the regulation of container noise is not considered to be feasible since it would be difficult (if not impossible) to set performance standards for containers. The difficulty is that most of the noise generated by container arises primarily from the handling of the containers by collection personnel. The Agency's view is that the noise emitted by containers in use can be controlled more effectively by local regulatory and enforcement action than by Federal regulation. The success of many local governments in reducing trash collection noise by encouraging such practices as the use of plastic trash containers testifies to the validity of this view. The comments that follow are intended to provide background information for the guidance of local officials in planning possible action to abate container noise.

Two general classes of containers are used. One is a relatively small capacity container such as a garbage can, used by individual households. The other is substantially larger in capacity, frequently used by multiple-family residential buildings and commercial and industrial firms.

The first type usually is dumped by hand into the hopper of the trash vehicle (rear loader or side loader). Traditionally, this container has been of galvanized steel construction. In recent years containers made of plastic, either cans or bags, have increasingly come into use, largely as a result of local efforts to reduce the noise associated with trash collection.

The large commercial trash container, with capacity up to eight cubic yards, must be manipulated by container-handling machinery built into the compactor vehicle. This equipment engages the container, lifts, rotates and dumps it, then returns it to the ground.

Impact noises occur due to contact between the container and the handling mechanism, truck hopper surfaces, and the ground. For the large containers with lids, banging of the lid against the hopper surfaces and the container body is one of the most prevalent causes of impact noise.

Although individual household containers made of plastic are practical, large commercial containers must be made of durable structural material; glass fiber-reinforced plastic units are available. The application of suitable damping materials or the use of damped sandwich panels, especially for lids, can substantially reduce the sounds of container lids hitting container bodies or vehicle hopper surfaces. Reductions of 15 dB or greater in impact noise are achievable by suitable application of sound damping materials to steel panels.

EPA strongly recommends that compactor manufacturers supply elastomeric materials, such as rubber or polyurethane pads, to those portions of the hopper where impacts with containers and container lids are apt to occur. EPA also recommends that municipalities require the use of such materials in their communities where noise from this source continues to be a problem.

A-3.5.6 Definition of "Newly Manufactured"

Two commenters (A-2.5.5 and A-2.4.1) noted that the regulation needed clarification as to the applicability of the standard to newly manufactured compactor bodies which are mounted on used chassis or new chassis that are one or two years old and do not meet the medium and heavy truck noise standards for 1978. Another commenter (A-2.5.23) recommended that the regulation include refurbished truck-mounted solid waste compactors.

Response: The EPA has clarified its definition of "newly manufactured" in §205.200 of the regulation. Only truck-mounted solid waste compactors that consist of chassis and compactor bodies manufactured after the effective date of the regulation are subject to regulation. Previously used compactor bodies or chassis that are refurbished for further use are not subject to regulation. Likewise, for the second stage of the regulation, only chassis and compactor bodies manufactured after the second effective date of this regulation are subject to the second-stage standard.

A-3.5.7 Diesel Truck Usage

A trade association (A-2.4.1) indicated that the proposed regulation would discourage the use of the more energy efficient diesel engines because the diesel trucks are noisier than the gasoline trucks.

Response: Information received by EPA from large users of truck-mounted solid waste compactors indicate that the diesel trucks operate very well under the proposed noise control technology, mainly because such engines can operate reliably and steadily at low speeds while developing enough torque and horsepower to operate the compaction mechanism. Some manufacturers of compactor bodies have indicated that they will continue to use diesel trucks because they are believed to be easier to quiet, even though the noise control technology is more costly. Nevertheless, New York's experience has shown that it is also feasible to manufacture quieted refuse collection vehicles with gasoline engines.

As evidenced by the current market structure, a large number of purchasers believe the trade-off for a higher priced diesel truck is justified because of the energy efficiency characteristics of diesel trucks. Since both gasoline and diesel-powered vehicles can be manufactured to meet the standard, it does not appear that the noise emission regulation will significantly alter the current situation.

A-3.5.8 Route Trailers

A truck manufacturer (A-2.2.1) noted that route trailers are excluded from consideration for regulation in the Background Document but are included in §205.201 of the proposed regulation. The commenter recommended that route trailers be excluded from the regulation.

Response: The statement in the Background Document did not exclude route trailers from regulation. It merely pointed out that route trailers were excluded from consideration in the economic impact analysis because of the small number of such vehicles manufactured.

Compactors which are mounted on truck trailers (route trailers) are subject to the noise emission standards for truck-mounted solid waste compactors. Route trailers do not differ significantly in design or operational aspects from compactors mounted on trucks. Although there are only a few route trailers in use and current production is small, an exemption for route trailers, aside from being inconsistent with the purpose of the regulation, could result in increased demand for this type of compactor vehicle, increasing the potential noise impact. This would represent unfair competition for the manufacturers of compactors subject to the regulation.

A-3.5.9 Acoustical Assurance Period

A-3.5.9.1 Length of Acoustical Assurance Period (AAP)

Four commenters (A-2.5.7, A-2.5.15, A-2.7.17 and A-2.6.4) indicated that the length of the Acoustical Assurance Period should be as long as the useful life of the truck-mounted solid waste compactor.

Response: The length of the Acoustical Assurance Period is based upon the time the product is expected to operate without major maintenance action other than routine periodic maintenance. It is related to the maximum warranty period that reasonably could be achieved. If a high quality product is well maintained, significant degradation should not occur over the useful economic life of the product. However, EPA does not consider it reasonable to hold the manufacturer responsible after the expected time of the first major overhaul. At this point, it should be the responsibility of the owner to ensure that the noise does not increase due to inadequate maintenance or non-performance of unrepaired parts.

States and localities may also help in ensuring that significant noise degradation does not occur over the useful life of the product by promulgating complementary in-use standards for truck-mounted solid waste compactors in their jurisdiction.

A-3.5.9.2 Computation of Sound Level Degradation Factor (SLDF)

Two compactor manufacturers (A-2.1.1 and A-2.1.4), two trade associations (A-2.4.1 and A-2.4.2), and a truck manufacturer (A-2.2.1) commented that there is not data available for computing the SLDF [now known as Noise Level Degradation Factor (NLDF)].

Another three commenters (A-2.6.4, A-2.7.9 and A-2.7.34) indicated that the most appropriate method for determining noise level degradation would be long term durability tests or periodic monitoring by EPA after sale.

Response: The NLDF should represent the best estimate of the manufacturer. It is expected that during the first few years of effectiveness of the regulation, manufacturers will rely heavily on engineering judgments in determining the NLDF of their products. As more experience is gained and test data is gathered, the estimation of the NLDF will become less dependent on judgment alone. Manufacturers may be more conservative in their estimates during the first few years and experience will show the way to a more knowledgeable estimate.

Developing and implementing long term durability testing could move back the effective date of the regulation by several years. The cost of such a program as well as the substantial delay in achieving benefits from the regulation does not, in the EPA's opinion, constitute a cost effective approach to minimizing noise level degradation of regulated products.

Periodic monitoring of regulated equipment is one area where state and local governments can assist the Federal government in ensuring that the full benefits of the regulation are being realized. It would be impractical for the EPA to undertake monitoring of products except on a limited basis. However, State and local governments with monitoring programs can notify EPA of specific situations where there appears to be non-compliance.

A-3.5.9.3 Cost of the Acoustical Assurance Period (AAP)

One compactor manufacturer (A-2.1.4) remarked that the costs of the AAP were not included in the economic analysis. Another commenter (A-2.7.34) was concerned that the AAP will create exceptionally high costs for the consumer.

Response: It is assumed that one of the primary goals of most manufacturers is to design and build a high quality product. The manufacturers in this industry maintain that they indeed build a high quality product. The AAP merely ensures that these same goals are applied to the quieting features of the product.

Consequently, the AAP is not expected to create additional costs for the consumer. The AAP should benefit the consumer by providing an additional incentive for manufacturers to provide high quality, durable quieted products.

A-3.5.9.4 Compliance with the Acoustical Assurance Period (AAP)

Three compactor manufacturers (A-2.1.2, A-2.1.3, and A-2.1.4) and a trade association (A-2.4.1) commented that it was impossible to comply with the AAP for the total vehicle, since the medium and heavy truck regulation does not have an AAP. One of the above commenters indicated that even if the truck regulation had an AAP it would still be impossible to comply since the noise test for trucks is a pass-by test while the test for compactor trucks is a stationary noise test. Another of the above commenters indicated that compactor vehicles are sometimes used for snowplowing or other functions unrelated to the collection of solid waste and that the impact of these secondary uses on compliance with the AAP was not considered in the proposed regulation.

Response: Experience with trucks included in the DOT Quiet Truck program showed no significant noise level degradation after being in operation over 100,000 miles. Consequently, the Agency expects that the truck chassis used for compactor vehicles will show no significant degradation in the two-year period of the AAP, which generally entails less than 50,000 miles of operation for a refuse collection vehicle.

The difference between the regulatory test procedures for the medium and heavy truck regulation and the compactor regulation should not be an important factor relative to the AAP. The noise control components for the truck chassis perform the same function in either type of test, and the quality and durability of the components is not relevant to the type of noise measurement involved.

The secondary uses of products should not affect manufacturers' compliance with the AAP. If the manufacturer has recommended operating instructions indicating that the potential secondary uses involve improper operating procedures, then any lack of compliance with the AAP due to misuse of the product would be the responsibility of the owner who has misused the product.

A-3.5.9.5 Legal Authority for Establishing the Acoustical Assurance Period

A truck manufacturer (A-2.2.1) and a trade association (A-2.4.1) commented that the Noise Control Act provides no authority for EPA to promulgate an Acoustical Assurance Period (AAP) and NLDF. The trade association asserted that the AAP was in direct conflict with the Act by reading "the time-of-sale" language out of the Act.

Response: EPA maintains that the AAP provision is required to adequately protect the public health and welfare. Without this provision the benefits of the regulation could be severely reduced. If the noise control features of a product are not designed to be durable over time and the noise characteristics of regulated products degrade significantly after the sale of the product, no substantial health and welfare benefits can result from the regulation.

EPA considers the authority for promulgating the AAP to be implicit in the Noise Control Act. In order to meet the requirements of the Act it is necessary to ensure that real and lasting benefits result from each regulation.

The AAP is an important and necessary provision of any noise emission regulation for achieving such lasting benefits.

A-3.6 ENFORCEMENT

A-3.6.1 Legal Authority

A truck manufacturer (A-2.2.1) and a trade association (A-2.4.1) objected to the authority claimed by the EPA to conduct searches, to recall products, and to issue cease-to-distribute orders. The trade association commented that these provisions appear to exceed the authorities granted in the Noise Control Act.

Response: Since the EPA production verification system leaves the manufacturer in control of many aspects of the compliance program, it is essential that EPA Enforcement Officers have access to manufacturers' plants and records in order to determine whether the requirements of the regulation are being followed and whether conforming vehicles are being distributed in commerce. Thus, EPA has prescribed inspection and monitoring regulations (40 CFR §205.4) to permit duly designated EPA Enforcement Officers to have access to a manufacturer's facility. This was done so that the Administrator may satisfy himself that required records are being kept, that products which will be tested are selected and prepared for testing in accordance with the regulatory requirements, that tests are properly conducted, and that the manufactured product is one which conforms to the applicable noise emission standard. This is all part of the testing procedures promulgated under §6(c) and §13(a), and the records obtained are information which the manufacturer is required to maintain under §13(a).

The EPA inspection and monitoring regulation is narrowly structured. The EPA Enforcement Officer is limited to inspecting only facilities where: (1) products to be distributed in commerce are manufactured, assembled or stored; (2) noise tests are performed, (3) test products are present, or (4) records, reports, or documentary information required to be maintained or provided to the Administrator are located.

Examination of the limited inspection authority in the EPA regulation, its reasonableness, and the reasons for the requirements, make clear that the regulation is fully authorized by §6(c)(1) and §13(a) of the Noise Control Act. §13(a) specifically authorizes EPA to require such tests as are necessary to assure compliance with the promulgated standard and to have access to the results of such tests and other records that the manufacturers are required to maintain under §205.203 of the regulation.

The recent U.S. Supreme Court decision in the case of Marshall vs. Barlow's Inc., 46 USLW 4483, has prompted EPA to promulgate changes to §205.4 of Subpart A, General Provisions, of 40 CFR Part 205, Noise Emission Standards for Surface Transportation Equipment. Those changes were published in the Federal Register. The changes incorporate the spirit of Barlow's decision and clarify that EPA Enforcement Officers may not inspect a manufacturer's property unless (1) the manufacturer consents or (2) the officers have obtained a warrant. For the text of the revised §205.4, interested parties are referred to 43 FR 27988.

With respect to recall and cease-to-distribute orders, the Administrator is given the authority to issue remedial orders under §11(d) of the Noise Control Act. Remedial orders supplement the criminal penalties of §11(a) and will be issued only after notice and opportunity for a hearing. Recall and cease-to-distribute are examples of orders the Administrator could find appropriate in certain circumstances. Different circumstances may necessitate remedial orders different than those described in the regulation. The Administrator is given the power to fashion remedial orders in such situations to protect the public health and welfare.

A-3.6.2 Selective Enforcement Auditing (SEA)

A trade association (A-2.4.1) commented that the SEA procedure is totally inappropriate for the compactor manufacturing industry. A later submission to the docket indicated that the association was concerned about the lack of "batches" that could be samples as set forth in the regulation under the SEA procedures.

Response: After reviewing the comments, the Agency recognizes that the SEA procedures outlined in the proposed regulation might not be suitable for use in certain cases where very small batches are manufactured. Consequently, the Agency is developing improved procedures, and the relevant sections of the regulation have been reserved for later incorporation of these improved procedures.

A-3.6.3 Tampering

One commenter (A-2.7.9) indicated that penalties were needed for tampering with the equipment. A manufacturer (A-2.1.3) noted that it would be necessary to alter the chassis to achieve noise control for the total compactor vehicle. This would be considered tampering under the truck regulation and would require the compactor manufacturer to retest the chassis under the noise emission standards for medium and heavy trucks.

Response: There are no predetermined penalties for the tampering violations specified in the Noise Control Act. Appropriate penalties will be determined for each individual case.

Only those modifications which would result in an increase in noise emissions to a level above the standard are considered tampering. The manufacturer specifies the list of components which constitute the noise control system. Modification of any of these components is presumed to be tampering. While some acts are presumed to be tampering, they may be shown not to be tampering, if, after the modification, the product is tested and shown to be in compliance according to the Federal test procedure. On the other hand, modification of a component not on the tampering list is not presumed to be tampering. However, if modification of such a component resulted in an increase in noise emissions above the compliance level, that modification would be judged to be tampering.

Altering the truck chassis, for example, by moving the exhaust system might be an act of tampering, but it is not a presumed act of tampering on present models, because the exhaust system is not on the list of noise-control components. However, if testing showed that the noise level was increased above the compliance level by this act, then it would be considered tampering.

A-3.6.4 Local Enforcement

Several commenters were concerned about the impact of the Federal regulation on local governments. Three commenters (A-2.5.9, A-2.7.28, and A-2.7.23) remarked that local laws that were more stringent should not be preempted. Two other commenters (A-2.5.15 and A-2.5.5) were concerned that local communities would be unable to enforce the regulation due to the proposed test procedure.

One commenter (A-2.5.10) suggested that EPA allow the manufacture of both quieted and non-quieted trucks. Communities without curfews should then order the quieted trucks.

Response: When the Federal standards for compactors are effective, state and local governments will be pre-empted from enacting and enforcing time-of-sale standards which are not identical to the Federal standards, and all compactor manufacturers will be required to meet the Federal standards. Congress, through the Noise Control Act, mandated this result; the EPA does not have the power to change the Noise Control Act. Two of the reasons for the Congressional mandate of uniformity of treatment were: (1) to relieve manufacturers of products identified as major noise sources from the necessity of building different products solely to comply with differing state and local time of sale standards and (2) to assure that all new products identified as major noise sources would be required to meet the noise standard.

State and local governments can still exercise control over compactor noise. For instance, a state or local government can elect to purchase quieter vehicles for state or municipal use. Also, a state or local government can adopt and enforce a standard identical to the Federal standard. In the latter case, the enforcement procedures may call for preliminary screening of noise while the vehicle is actually being used in the customary manner, place and time. Measurements could be made with one microphone on one side of the vehicle at 7 meters. If a vehicle measured in this way produces noise over the state and local standard, the owner may be requested to take the vehicle to another site more suitable for conducting the Federal test procedure. There, a strict noise measurement using the Federal test procedure could take place.

Finally, a state or locality has the option of adopting an in-use (as opposed to time-of-sale) control on compactor operations such as a curfew on time of operation.

A-3.6.5 Batch Acceptance

One State (A-2.5.12) indicated that a better quality assurance method was needed. The proposed batch acceptance would allow 10% of the product to be in non-compliance which was considered high. Development of a method that would prevent the sale of any product in non-compliance was suggested.

Response: The Act and the regulations require that all products distributed in commerce be in compliance with the noise emission standard. The 10% AQL is utilized only during SEA testing requested by the Administrator. The AQL was established to account for testing and production variations. The 10% AQL does not permit 10% of the products produced to be in non-compliance, but is merely the level of non-compliance found in an SEA above which the Agency will likely take remedial administrative action. Any product tested and found to be in non-compliance must be brought into compliance and retested prior to distribution into commerce. For example, if a manufacturer tests a product as part of an internal quality control program and that product is found to be non-complying, the manufacturer must correct the non-compliance and retest to assure compliance prior to distribution. Any distribution in commerce of a product which is not in compliance is a violation of the Noise Control Act and is subject to remedial orders under Section 11(d). Shipment of a product known to be non-complying is a willful and knowing violation of the Act and is potentially subject to the criminal penalties of section 11(a) of the Act.

A-3.7 SEPARATION OF SOURCES FOR REGULATION

A-3.7.1 Separate Standards for Each Component

Seven distributors of truck-mounted solid waste compactors (A-2.3.3, A-2.3.4, A-2.3.6, A-2.3.8, A-2.3.9, A-2.3.10, and A-2.3.11), three manufacturers (A-2.1.1, A-2.1.2, and A-2.1.4), and a trade association (A-2.4.1) favored separate noise standards for major components of the garbage truck. Most of the above indicated that separate standards should be developed for the compactor body and the chassis, which is one of the major sources of noise of a refuse vehicle. One manufacturer (A-2.1.4) suggested separate tests for the chassis, compactor bodies, and hydraulic drives.

Response: EPA believes that the noise problem must be viewed in the context of the total compactor vehicle system, comprising the compactor body, hydraulic power systems, engine power take-off unit accessories, and the chassis-cab unit. EPA's study of the noise control technology for garbage trucks showed that the most effective way of reducing overall compaction cycle noise is to design the compactor vehicle system to operate at low engine speed during the waste-handling and compacting cycle. Since the compactor body manufacturer has control of the overall system design, and it is only through proper design that the compactor can operate effectively at low engine speed, the Agency believes that responsibility for meeting the noise requirement reasonably rests on the compactor body manufacturer.

All new truck chassis which typically are used for refuse truck applications are already required to meet a Federal noise emission standard. Based on field tests, the Agency believes that most diesel engines operating at speeds below 1200 rpm and gasoline engines operating at speeds below 1500 rpm will not exceed a noise level of 72 dBA. Allowing an equal contribution from compactor related noise sources, a body manufacturer could work toward a design target of 75 dBA. This would provide a substantial margin for variability in conforming with the proposed 79 dBA standard.

It is within the capability of the body manufacturer to design the compactor vehicle system to operate effectively with engine speeds not exceeding those stated above. This design function is under the control of the body manufacturer and no one else. Consequently, if the responsibility for the noise of the total vehicle is to be assigned, it must be assigned to the body manufacturer.

EPA believes that promulgation of the regulation will set into motion a market mechanism that will result in the acquisition of chassis noise data by compactor body manufacturers. At present, a number of the customers for compactor bodies specify or provide a chassis of their own selection on which the compactor body is to be mounted by the body manufacturer or the distributor. After the effective date of the regulation, the customer may be limited in his selection of truck chassis suitable for a given compactor body. The chassis selected must be one which the body manufacturer is assured has satisfactory noise emission characteristics (at appropriate engine speeds) to permit compliance with the standard. This means that, in order to be competitive for refuse vehicle applications, the chassis manufacturer will not only have to supply the necessary noise emissions data, he will also have to provide a warranty or similar document to assure the body manufacturer of the acoustic performance of the chassis.

Although the market for refuse truck chassis is relatively small compared to the total market for trucks, the EPA believes that it is of sufficient magnitude to attract an adequate supply of chassis with suitable accompanying noise emission data and warranted characteristics; this has been confirmed by several chassis manufacturers. The EPA intends to encourage the chassis manufacturers to develop and provide the necessary data. Inquiries addressed to chassis manufacturers by the EPA have elicited noise data on a number of chassis which show that the chassis are suitable for quieted refuse vehicle applications.

If the market forces do not operate as effectively as EPA expects in making available chassis with satisfactory and warranted noise characteristics, the Agency will seriously consider promulgation of supplemental regulations to require chassis manufacturers to provide the needed noise data with appropriate warranties or certifications. The authority for such action is Section 8 (noise labeling) of the Noise Control Act.

A-3.7.2 Noise Emission Tests for Components

Two manufacturers (A-2.1.1 and A-2.1.4), a trade association (A-2.4.1), and a truck manufacturer (A-2.2.1) indicated concern over testing the chassis under the compactor regulation. Reasons for concern were related to the differences in the noise emission tests for medium and heavy trucks and the compaction vehicle. Commenters believed that no correlation had been developed between the two tests, particularly when the truck has a load comparable to a compactor. Compactor manufacturers were concerned that the chassis generates more noise than the compactor body and that they have no control over the chassis noise.

One compactor manufacturer (A-2.1.3) indicated that truck noise will not necessarily be reduced at lower engine speeds.

Response: EPA analysis has shown that any truck engine used in a truck chassis meeting the EPA noise standard for 83 dBA during a passby test at 50 feet for medium and heavy trucks will be able to meet the EPA noise regulation for compactors if the maximum engine speed during the compaction cycle is controlled to a reasonable level. Several truck manufacturers have submitted data to EPA indicating that trucks meeting the 1978 medium and heavy truck regulation of 83 dBA at maximum engine speed have sufficiently low noise levels at reduced engine speeds to be suitable for use in assembling compactor vehicles that conform to the standard. For gasoline engines, significant reductions in sound levels were obtained with engine speed reduced to below 2000 rpm. Diesel engines appear to require lower engine speeds; at engine speeds below 1300 rpm sound level reductions ranged from approximately 10 dB to 15 dB below the regulated level of 83 dBA, according to data submitted by truck manufacturers. The compactor manufacturer has final control over the speed at which the engine operates during the compaction cycle, and therefore does have ultimate control over the noise emitted by the chassis during the compaction cycle.

A-3.7.3 Production Verification Testing

A trade association (A-2.4.1), three compactor manufacturers (A-2.1.2, A-2.1.3, and A-2.1.4), and a truck manufacturer (A-2.2.1) commented that when the total vehicle is tested, under the proposed production verification configurations, most of their production line would consist of one-of-a-kind units or very small batches. This would result in PV testing from 75% to 90%

of all units produced. All of the above, except the truck manufacturer, indicated that separate standards for chassis and body would alleviate this large testing burden.

Response: The final regulation incorporates several changes from the proposed rule, with the objective of clarifying the Agency's intent and reducing the amount of testing required. The number of parameters defining a configuration has been reduced, in order to reduce the potential number of configurations to be tested. Further, the regulation offers the manufacturer the option of grouping configurations into categories, which are characterized by only three major factors - engine type, compactor type, and compactor power system. The manufacturer may identify the noisiest configuration within each category and production verify only that noisiest configuration.

By virtue of these changes, the Agency believes that a relatively small percentage - probably less than 10 percent - of units would have to be tested.

A-3.7.4 Liability

A trade assocation commented that the liability for warranty costs should be placed on the party responsible for the noise emission characteristics of the product. The compactor body manufacturer should not have to be responsible for compliance and liability of the chassis and other components manufactured elsewhere which produce noise.

Response: As discussed previously in Section A-3.7.1, it is the compactor body manufacturer's responsibility to design an overall system for the compactor vehicle which will be able to meet the standard. The design process must take into account the noise characteristics of the chassis. If the compactor manufacturer fails to select appropriate components and a feasible design for this system, that should be the compactor manufacturer's responsibility, not the components manufacturer's responsiblity.

The compactor manufacturer may wish to elicit some type of assurance from his suppliers that the components he purchases meet certain specifications that he deems to be necessary for meeting the noise emission standard. The assurance can be in the form of contractual commitments or purchase specifications that include specific requirements regarding the noise emissions of the components under conditions appropriate to the compaction cycle operation of the vehicle.

A-3.7.5 Responsibility for Compliance

Nine distributors* of truck-mounted solid waste compactors objected to the responsiblity for compliance being placed on the assembler of the total vehicle. The distributors mount many of the garbage trucks that they sell and indicate that they would be unable to assume the costs of testing and therefore would have to give up mounting of compactor bodies on chassis. A truck manufacturer (A-2.2.1) indicated that the responsibility for compliance should be placed upon the manufacturer of the complete vehicle as was done in the proposed regulation.

Response: EPA has carefully reviewed this issue with potentially affected parties. Under §3(6) of the Act, a "manufacturer means any person engaged in the manufacturing or assembling of new products, or the importing of new products for resale, or who acts for, and is controlled by, any such person in

*(A-2.3.1, A-2.3.2, A-2.3.4, A-2.3.5, A-2.3.7, A-2.3.8, A-2.3.9, A-2.3.10, and A-2.3.11)

connection with the distribution of such products". EPA believes that the broad definition encompasses a distributor that mounts a body and attendant power take off equipment on a chassis and is the last person to have control of the completed unit before it enters the stream of commerce. Although the distributor does not have control over the system design, he could produce a non-complying unit by selecting an unusually noisy combination of components (chassis-cab, PTO and body) or by improperly mounting or assembling the components or by altering any of the components.

Nevertheless, EPA recognizes the potential burden imposed by placing total responsibility for compliance upon the distributor. §205.205-1(d) was added to the regulation to reflect this concern. This section of the regulation is intended to relieve distributors (and any other manufacturer who only assembles compactor vehicles) of the requirements to perform Production Verification tests of the vehicles they assemble. The rationale for this provision is outlined below.

The distributor, in assembling a vehicle, follows the detailed installation instructions provided by the compactor body manufacturer. When an unusual configuration is encountered, the distributor generally consults with the body manufacturer who assumes and maintains continual engineering overview of the distributor's work. It is recognized that this type of manufacturer-distributor relationship helps to maintain a competitive situation in the industry.

EPA's intent is to optimize the distributor's ability to function effectively by shifting certain duties and responsibilities to others in the chain of the manufacturing of the complete vehicle. The revised regulation §205.205-1(d) now allows a distributor to rely in good faith for compliance upon installation instructions of the compactor body manufacturer, provided that such instructions are accompanied by statements that assure that the vehicle will conform to the standard if assembled in accordance with those instructions. If a distributor fails to follow the instructions given to him, by acts of either omission or commission, then the responsibility for compliance with the standard is shifted back to him.

A-3.8 GENERAL ISSUES

A-3.8.1 Regulatory Process

Five commenters (A-2.1.4, A-2.1.1, A-2.4.1, A-2.7.1, and A-2.7.12) requested an extension of the regulatory timetable to allow for further evaluation of the proposed rule. Three of the four commenters would like to have a joint EPA-industry group formed to conduct this evaluation. One commenter (A-2.7.1) indicated that the regulation should go into effect sooner.

Another manufacturer (A-2.1.3) suggested that the effective date of the regulation should be the date of manufacture, not the date of delivery.

Response: In the Noise Control Act of 1972, Congress provided guidelines for obtaining and reviewing all comments pertaining to the regulation. EPA has followed these guidelines through provision of a well publicized public comment period after publication of the proposed regulation, and through public hearings held at diverse geographical locations. The Agency and its representatives held many meetings and discussions with the industry trade associations as well as with officials of a number of firms in various segments of the industry. The information obtained in these contacts was reviewed thoroughly, together with information and data obtained independently by EPA from other sources, including other Federal agencies, state and local governments, environmental organizations and the general public. The conclusions reflected in the regulation and accompanying documents represent, in the Agency's view, a fair and objective synthesis of the information obtained. EPA considers the time frame and process established for this regulation to be adequate for receiving comments from the public, and for reviewing and evaluating these comments before issuing a final regulation. In view of the extensive public participation as outlined, formation of a joint EPA industry group to evaluate the rule as suggested, would be an unnecessary and redundant process.

The effective date of the regulation relates to the date of manufacture. Any truck-mounted solid waste compactor (i.e., both the compactor body and the truck chassis) manufactured after the effective date is subject to regulation.

A-3.8.2 Occupational Safety and Health Administration

One commenter (A-2.5.3) opposed EPA's involvement in the regulation of noise, indicating that noise regulations should be for the protection of workers rather than residents and therefore should be handled by the Occupational Safety and Health Administration (OSHA).

Response: In the Noise Control Act of 1972, the Congress declared: "It is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health and welfare." While OSHA regulates for the protection of workers, EPA is concerned with the effect of noise on the general population. Although the regulation for compactors does benefit the vehicle operators, its primary intent is to protect the public affected by the noise of the compactor.

A-3.8.3 Regulation of Other Aspects of Solid Waste Collection

Five commenters (A-2.7.13, A-2.6.2, A-2.7.14, A-2.7.18, and A-2.7.20) requested that EPA regulate hours of collection as well as equipment noise. Another commenter (A-2.7.33) recommended that EPA consider the use of sound absorbing materials and barriers to control noise for certain situations.

Response: In the Noise Control Act, the Congress declared 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. Section 6 of the Act authorizes EPA to regulate noise emissions of newly manufactured products distributed in commerce. The Act restricts EPA to setting performance standards (under Section 6) or labeling regulations (under Section 8) for these products. Therefore, the EPA is not authorized to regulate other aspects of environmental noise, which are amenable to local control, such as use of sound barriers, zoning controls, licensing or use restrictions. States and localities may regulate hours of collection or any other aspect of solid waste collection services, not regulated by the Federal government, that is deemed necessary in their jurisdictions.

A-3.8.4 Public Education

Two commenters (A-2.5.21 and A-2.6.4) indicated that the proposed regulation should be accompanied by a public education program designed to inform purchasers and end users about quieted products. The education program should be conducted in conjunction with a labeling program and focus on the need for quieter products, the noise impact of the products purchased, and how to effectively maintain the products' noise control characteristics. The fact that more noise does not necessarily mean more power should also be emphasized.

Response: EPA concurs with these commenters. EPA's entire public hearing process and accompanying publicity was designed to promote public awareness of noise pollution problems related to products distributed in commerce. In addition, the EPA Office of Noise Abatement and Control has been developing, and expects to implement, in the near future, both a public awareness program on noise, and a regulatory program (under Section 8 of the Noise Control Act) for labeling of both noisy products and products sold for the purpose of reducing noise.

A-3.8.5 Favorable Comments

Seventeen submissions* to the docket consisted of comments that were favorable to the proposed regulation of truck-mounted solid waste compactors. These submissions did not take issue with any provisions of the proposed regulation nor suggest additional items that should be addressed by the EPA in regard to the proposed regulation. Some of the submissions elaborated on situations that illustrated the need for the proposed regulation of truck-mounted solid waste compactor noise.

No specific response is required.

*(A-2.5.1, A-2.5.2, A-2.5.17, A-2.5.19, A-2.6.1, A-2.7.2, A-2.7.5, A-2.7.7, A-2.7.8, A-2.7.11, A-2.7.22, A-2.7.24, A-2.7.25, A-2.7.26, A-2.7.27, A-2.7.30, and A-2.7.36).

Appendix B

FRACTIONAL IMPACT PROCEDURE

Adapted, in part, from Goldstein, J., "Assessing the Impact of Transportation Noise: Human Response Measures," Proceedings of the 1977 National Conference on Noise Control Engineering, G. C. Maling (ed.), NASA Langley Research Center, Hampton, Virginia 17-19 October 1977, pp. 79-98.

FRACTIONAL IMPACT PROCEDURE

An integral element of an environmental noise assessment is to determine or estimate the distribution of the exposed population to given levels of noise for given lengths of time. Thus, before implementing a project or action, one should first characterize the existing noise exposure distribution of the population in the area affected by estimating the number of people exposed to different magnitudes of noise as described by metrics such as the Day-Night Average Sound Level (L_{dn}). Next, the distribution of people who may be exposed to noise anticipated as a result of adopting various projected alternatives should be predicted or estimated. We can judge the environmental impact by simply comparing these successive population distributions. This concept is illustrated in Figure B-1 which compares the estimated distribution of the population prior to inception of a hypothetical project (Curve A) with the population distribution after implementation of the project (Curve B). For each statistical distribution, numbers of people are simply plotted against noise exposure where L_i represents a specific exposure in decibels to an arbitrary unit of noise. A measure of noise impact is ascertained by examining the lessened project related noise. Such comparisons of population distributions allow us to determine the extent of noise impact in terms of changes in the number of people exposed to different levels of noise.

The intensity or severity of a noise exposure may be evaluated by the use of suitable noise effects criteria, which exist in the form of dose-response or cause-effect relationships. Using these criteria, the probability or magnitude of an anticipated effect can be statistically predicted from knowledge of the noise exposure incurred. Illustrative examples of the different forms of noise effects criteria are graphically displayed in Figure B-2. In general, dose-response functions are statistically derived from noise effects information and exhibited as linear or curvilinear relationships, or combinations thereof. Although these relationships generally represent a statistical "average" response, they may also be defined for any given population percentile. The statistical probability or anticipated magnitude of an effect at a given noise exposure can be estimated using the appropriate function. For example, as shown in Figure B-2 using the linear function, if it is established that a number of people are exposed to a value of L_j, the incidence of a specific response occurring within that population would be statistically predicted at 50 percent.

A more comprehensive assessment of environmental noise may be performed by cross-tabulating both indices of extent (number of people exposed) and intensity (severity) of impact. To perform such an assessment we must first statistically estimate the anticipated magnitude of impact upon each individual exposed at each given level, L_i, by applying suitable noise effects criteria. At each level, L_i, the impact upon all people so exposed is then obtained by simply comparing the number of people exposed with the magnitude or probability of the anticipated response. As illustrated in Figure B-1, the extent of a noise impact is functionally described as a distribution of exposures. Thus, the total impact of all exposures is a distribution of people who are affected to varying degrees. This may be expressed by using an array or matrix in which the severity of impact at each L_i is plotted against the number of people exposed at that level. Table B-1 presents a hypothetical example of such an array.

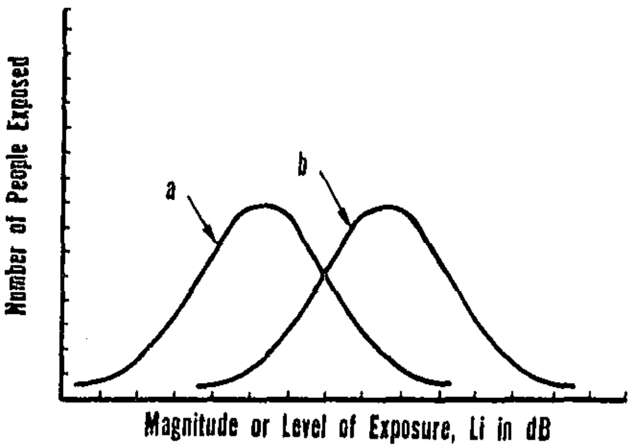

FIGURE B-1

EXAMPLE ILLUSTRATION OF THE NOISE DISTRIBUTION OF POPULATION AS A FUNCTION OF NOISE EXPOSURE

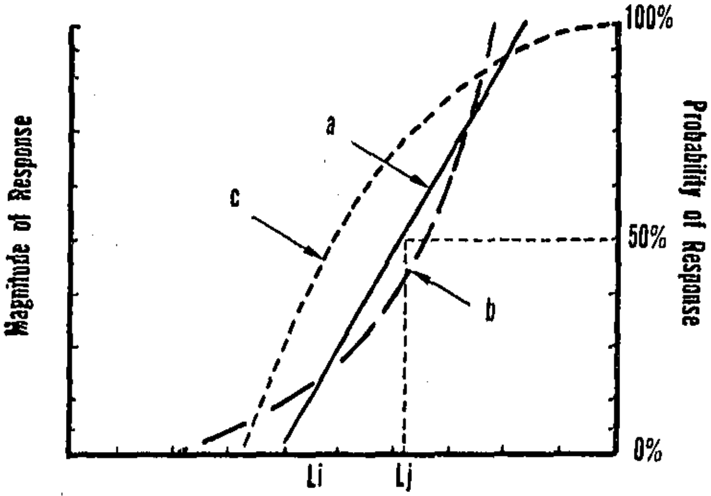

FIGURE B-2

EXAMPLE OF FORMS OF NOISE EFFECTS CRITERIA
(a) LINEAR, (b) POWER, (c) LOGARITHMIC

TABLE B-1

EXAMPLE OF IMPACT MATRIX FOR A HYPOTHETICAL SITUATION

Exposure	Number of People	Magnitude or Probability of Response in Percent
L_i	1,200,000	4
L_{i+1}	900,000	10
L_{i+2}	200,000	25
L_{i+3}	50,000	50
...		
L_{i+n}	2,000	85

An environmental noise assessment usually involves analysis, evaluation and comparison of many different planning alternatives. Obviously, comparing multiple arrays of population impact information is quite cumbersome, and subsequently evaluating the relative effectiveness of each of the alternatives generally tends to become rather complex and confusing. These comparisons can be simplified by resorting to a single number interpretation or descriptor of the noise environment which incorporates both attributes of extent and intensity of impact. Accordingly, the National Academy of Sciences, Committee on Bioacoustics and Biomechanics (CHABA) has recommended a procedure for assessing environmental noise impact which mathematically takes into account both extent and intensity of impact (Ref. B-1). This procedure, the fractional impact method, computes total noise impact by simply counting the number of people exposed to noise at different levels and statistically weighting each person by the intensity of response to the noise exposure. The result is a single number value which represents the overall magnitude of the impact.

The purpose of the fractional impact analysis method is to quantitatively define the impact of noise upon the population exposed. This, in turn, facilitates trade-off studies and comparisons of the impact between different projects or alternative solutions. To accomplish an objective, comparative environmental analysis, the fractional impact method defines a series of "partial noise impacts" within a number of neighborhoods or groups, each of which is exposed to a different level of noise. The partial noise impact of each neighborhood is determined by multiplying the number of people residing within the neighborhood by the "fractional impact" of that neighborhood, i.e., the statistical probability or magnitude of an anticipated response as functionally derived from relevant noise effects criteria. The total community impact is then determined by simply summing the partial impacts of all neighborhoods (Ref. B-1).

It is quite possible, and in some cases very probable, that much of the noise impact may be found in subneighborhoods exposed to noise levels of only moderate value. Although people living in proximity to a noise source are generally more severely impacted than those people living further away, this does not imply that the latter should be totally excluded from an assessment where the purpose is to evaluate the magnitude of a noise impact. People exposed to lower levels of noise may still experience an adverse impact, even though that impact may be small in magnitude. The fractional impact method considers the total impact upon all people exposed to noise recognizing that some individuals incur a significantly greater noise exposure than others. The procedure duly ascribes more importance to the more severely affected population.

As discussed previously, any procedure which evaluates the impact of noise upon people or the environment, as well as the health and behavioral consequences of noise exposure and resultant community reactions, must encompass two basic elements of that impact assessment. The impact of noise may be intensive (i.e., it may severely affect a few people) or extensive (i.e., it may affect a larger population less severely). Implicit in the fractionalization concept is that the magnitude of human response varies commensurately with the degree of noise exposure, i.e., the greater the exposure, the more significant the response. Another major assumption is that a moderate noise exposure for a large population has approximately the same noise impact upon the entire community as would a greater noise exposure upon a smaller number of people. Although this may be conceptually envisioned as a trade-off between the intensity and extent of noise impact, it would be a misapplication of the procedure to disregard those persons severely impacted by noise in order to enhance the environment of a significantly larger number of people who are affected to a lesser extent. The fact remains, however, that exposing many people to noise of a lower level would have roughly the same impact as exposing a fewer number of people to a greater level of noise when considering the impact upon the community or population as a whole. Thus, information regarding the distribution of the population as a function of noise exposure should always be developed and presented in conjunction with use of the fractional impact method.

Because noise is an extremely pervasive pollutant, it may adversely affect people in a number of different ways. Certain effects are well documented. Noise can:

- o cause damage to the ear resulting in permanent hearing loss.
- o interfere with spoken communication.
- o disrupt or prevent sleep.
- o be a source of annoyance.

Other effects of noise are less well documented but may become increasingly important as more information is gathered. They include the nonauditory health aspects as well as performance and learning effects.

It is important to note, however, that quantitatively documented cause-effect relationships which functionally characterize any of these noise effects may be applied within a fractionalization procedure. The function for weighting the intensity of noise impact with respect to general adverse reaction (annoyance) is displayed in Figure B-3 (Ref. B-1). The nonlinear weighting function is arbitrarily normalized to unity at L_{dn} = 75 dB. For convenience of calculation, the weighting function may be expressed as representing percentages of impact in accordance with the following equation:

$$W(L_{dn}) = \frac{[3.364 \times 10^{-6}]\ [10^{0.103\ L_{dn}}]}{[0.2]\ [10^{0.03\ L_{dn}}] + [1.43 \times 10^{-4}]\ [10^{0.08\ L_{dn}}]} \qquad (1)$$

A simple linear approximation that can be used with reasonable accuracy in cases where day-night sound levels range between 55 and 80 dB is shown as the dashed line in Figure B-3, and is defined as:

$$W(L_{dn}) = \begin{cases} 0.05\ (L_{dn} - 55) & \text{for } L_{dn} \geq 55 \\ 0 & \text{for } L_{dn} < 55 \end{cases} \qquad (2)$$

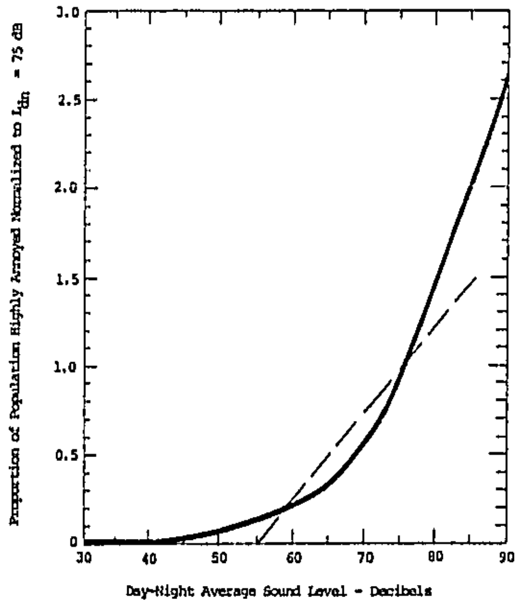

FIGURE B-3

WEIGHTING FUNCTION FOR ASSESSING THE
GENERAL ADVERSE RESPONSE TO NOISE

Using the fractional impact concept, an index referred to as the Level-Weighted Population (LWP)* may be derived by multiplying the number of people exposed to a given level of traffic noise by the fractional or weighted impact associated with that level as follows:

$$LWP_i = W(L_{dn}{}^i) \times P_i \qquad (3)$$

where LWP_i is the magnitude of the impact on the population exposed at $L_{dn}{}^i$, $W(L_{dn}{}^i)$ is the fractional weighting associated with a noise exposure of $L_{dn}{}^i$, and P_i is the number of people exposed to $L_{dn}{}^i$.

*Terms such as Equivalent Population (P_{eq}), and Equivalent Noise Impact (ENI), have often been used interchangeably with LWP. The other indices are conceptually identical to the LWP notation.

Because the extent of noise impact is characterized by a distribution of people all exposed to different levels of noise, the magnitude of the total impact may be computed by determining the partial impact at each level and summing over each of the levels. This may be expressed as:

$$LWP = \sum_i LWP_i = \sum_i W(L_{dn}{}^i) \times P_i \qquad (4)$$

The average severity of impact over the entire population may be derived from the Noise Impact Index (NII) as follows:

$$NII = \frac{LWP}{P_{total}} \qquad (5)$$

In this case, NII represents the normalized percentage of the total population who describe themselves as highly annoyed. Another concept, the Relative Change in Impact (RCI) is useful for comparing the relative difference between two alternatives. This concept takes the form expressed as a percent change in impact:

$$RCI = \frac{LWP_i - LWP_j}{LWP_i} \qquad (6)$$

where LWP_i and LWP_j are the calculated impacts under two different conditions.

An example of the fractional impact calculation procedure is presented in Table B-2.

Similarly, using relevant criteria, the fractional impact procedure may be utilized to calculate relative changes in hearing damage risk, sleep disruption, and speech interference.

TABLE B-2

EXAMPLE OF FRACTIONAL IMPACT CALCULATION FOR GENERAL ADVERSE RESPONSE

(1) Exposure Range (L_{dn})	(2) Exposure Range (L_{dn})	(3) P_i	(4) $W(L_{dn})$ (Curvilinear)	(5) $W(L_{dn})$ (Linear approx.)	(6) LWP_i (Curvilinear) (Column (3) X (4))	(7) LWP_i (Linear) (Column (3) X (5))
55-60	57.5	1,200,000	0.173	0.125	207,600	150,000
60-65	62.5	900,000	0.314	0.375	282,600	337,500
65-70	67.5	200,000	0.528	0.625	105,600	125,000
70-75	72.5	50,000	0.822	0.875	41,100	43,750
75-80	77.5	10,000	1.202	1.125	12,020	11,250
		2,360,000			648,920	667,500

LWP (Curvilinear) = 648,920
LWP (Linear) = 667,500
NII (Curvilinear) = 648,920 ÷ 2,360,000 = 0.27
NII (Linear) = 667,500 ÷ 2,360,000 = 0.28

REFERENCES
Appendix B

B-1. Guidelines for Preparing Environmental Impact Statements on Noise. National Academy of Sciences, Committee on Bioacoustics and Biomechanics Working Group Number 69, February 1977.

Appendix C

LISTING OF ORGANIZATIONS AND INDIVIDUALS

CONTACTED IN THE DEVELOPMENT OF THE REGULATION

LISTING OF ORGANIZATIONS AND INDIVIDUALS
CONTACTED IN THE DEVELOPMENT OF THE REGULATION

The list below details those organizations and individuals with which EPA had contact concerning the development of the noise emission standards for truck-mounted solid waste compactors. These contacts have provided the opportunity for the public to participate fully in the rulemaking process, and to have their interests and concerns known, and, where appropriate, included in the regulation. The entries on the list are grouped together to show the various sectors of the public with which EPA had contact. The grouping headed MEDIA includes media organizations with which the Agency was in contact and those which independently carried stories concerning noise from truck-mounted solid waste compactors.

The contacts with the public have been of several different types: by mail, by telephone, at meetings, through briefings, and through the media. In addition, an important aspect of the Agency's public participation program has been the Public Docket which was a formal 90 day period during which public comment on the regulation (as proposed) was solicited. Comments were gathered during that period through accepting written submissions to the Docket and by holding two public hearings. Organizations and individuals who commented during the period are listed in Appendix A to this document. The lists from Appendices A and C, when combined, detail the public that was contacted and that participated in the development of the noise emission standards for truck-mounted solid waste compactors.

Trade and Manufacturing Associations

National Solid Wastes Management Association; Waste Equipment Manufacturers Institute

American Public Works Association; Institute for Solid Wastes

Truck Equipment Body Distributors Association (now National Truck Equipment Association)

Truck Body and Equipment Association

Truck Manufacturers

Master Truck

White Motor Corporation

Oshkosh Truck Corporation

Chrysler Corporation

Mack Truck, Inc.

Volvo of America Corporation

General Motors Corporation

Ford Motor Company

Crane Carrier Company

Paccar, Inc.

Freightliner Corporation

International Harvester

FWD Corporation

Mercedes-Benz of North America, Inc.

Hendrickson Manufacturing Company

Diamond Reo Trucks, Inc.

Dodge Division, Chrysler Corporation

Chevrolet Motors Division, General Motors

Compactor Manufacturers

Pak-Mor Manufacturing Company

Perfection Cobey Company

Wayne Engineering Corporation

Maxon Industries, Inc.

Truxmore Industries, Inc.

City Tank Corporation

Elgin Leach Corporation

Heil Company

Dempster Dumpster Systems

Peabody Solid Wastes Management

Carrier Corporation

Combustion Engineering, Inc.

Fruehauf Corporation

Neway Division

Sargent Industries

Trailer Body Builders

Whittaker Corporation

Ebeling Manufacturing Corporation

McClain Industries

Orbital Collection Systems, Inc.

Hesston Corporation

Union Corporation

Helix Corporation

LoDal, Inc.

Sanitary Controls, Inc.

Compactor Distributors

Connecticut Truck and Trailer Service Company

Stephenson Equipment, Inc.

MacQueen Equipment, Inc.

Capital Equipment Company, Inc.

GranTurk Sanitation Equipment Company, Inc.

Truck Equipment

Bell Equipment Company

C.N. Woods Company, Inc.

Theodore J. Burke and Son, Inc.

Sanitation Equipment Corporation

General Equipment, Inc.

Elgin Leach Corporation

Compactor Users (Private Industry)

Browning Ferris Industries, Inc.

Golden Gate Disposal Company

Sunset Scavenger Company

Chicago and Suburban Refuse Disposal Association

State and Local Governments

San Francisco, CA City Administrator

San Francisco, CA Department of Public Health

Chicago, IL Department of Environmental Control

Cook County, IL Department of Environmental Control

Salt Lake City-County, UT Health Department

Salt Lake City, UT Corporation

California Department of Health

Health Systems Agency of New York City, NY

City of Chicago, IL

San Diego, CA City Manager's Office

Arlington, VA Noise Control Office

Charlotte, NC Department of Public Works

Upper San Juan, CO Regional Planning Commission

San Leandro, CA Office of Public Works

Boulder, CO Office of Environmental Protection

Kissimmee, FL Office of the City Engineer

DeKalb County, GA Board of Commissioners

City of Portland, OR Department of Public Works

Oklahoma City, OK Office of the City Manager

New Rochelle, NY Department of Public Works

Alexandria, VA Department of Health

Oregon Department of Environmental Quality

Denver, CO

Illinios Environmental Protection Agency

Memphis, TN Sanitation Department

Memphis, TN Division of Public Works

New York City, NY Department of Air Resources

New York Department of Sanitation

New York City, NY Bureau of Noise Abatement

New York State Department of Environmental Conservation

National Association of Counties Research Foundation

Metropolitan Washington, D.C. Council of Governments

Tallahassee, FL Department of Environmental Regulation

Town/Village of Harrison, NY

Montgomery County, MD County Government

Syracuse, NY Department of Public Works

Colorado Springs, CO Noise Control Administrator

City of Beverly Hills, CA

City of West Palm Beach, FL

Fort Worth, TX Public Works Department

Office of Noise Control, Colorado State Department of Health

City of Sioux City, IA Public Service Department

Provo City, UT Corporation

Provo City, UT Sanitation Department

Utah State Division of Health

Ogden City, UT Sanitation Department

County of Sarasota, FL Department of Environmental Services

City of Chicago, IL City Council Committee on Environmental Services

City of Beverly Hills, CA Superintendent of Sanitation

Santa Clara County, CA Environmental Health Services

Tuscon, AR

Los Angeles, CA Bureau of Street Maintenance

San Diego, CA Equipment Division

Industry and Organizations

Hackney Brothers Body Company

Conservation Industries, Inc.

Motor Coach Industries, Inc.

Sperry Vickers

Waterous Company

Koehring Company

VIC Equipment Sales Company

Aetna Freight Lines, Inc.

IRC and D Motor Freight, Inc.

Ramcon Environmental Corporation

Stone and Webster Engineering Corporation

Feeco International, Inc.

Dana Corporation

Donohue and Associates, Inc.

Society of Automotive Engineers

Washington Researchers

Automation Industries, Inc.

AIA AIP

Onan Corporation

INA Associates

Mull Bell and Associates

Acoustical Engineers, Inc.

Cladouhos and Brashares

Information Planning Associates, Inc.

Theta Systems, Inc.

Stephen A. Estrin, Inc.

VIPAC Partners P/L

Acoustical Society of America

Institute of Noise Control Engineering

Prefecture de Paris

American Institute of Certified Public Accountants

Embasssy of Spain

New South Wales, Australia State Pollution Control Commission

Canada Ministry of Transport

Association Francaise

University of London

Institute Fuer Operations Research

CW Post College

Westinghouse Electric Corporation

University of New South Wales

Thermo King Corporation

Bishop and Harmsen

American Rental Association

University of Utah

University of Montana

Georgia Institute of Technology

Hawaii University

California University

North Carolina State University

Center for Study of Noise in Society

American National Standards Institute

Charles M. Salter Associates, Inc.

University of New Hampshire

Congress

Koch, E.I., U.S. House of Representatives

Natcher, W.H., U.S. House of Representatives

Scott, W.L., U.S. Senate

Proxmire, W., U.S. Senate

Nelson, G., U.S. Senate

Heinz, H.J., U.S. Senate

Humphrey, H.H., U.S. Senate

Stevenson, A.E., U.S. Senate

Percy, C.H., U.S. Senate

Cederberg, E.A., U.S. House of Representatives

Wydler, J., U.S. House of Representatives

Ireland, A., U.S. House of Representatives

Weicker, L.P., U.S. Senate

Stone, R., U.S. Senate

Byrd, H.F., U.S. Senate

Vento, B.F., U.S. House of Representatives

Huddleston, W.D., U.S. Senate

Talmadge, H., U.S. Senate

Schweiker, R.S., U.S. Senate

Florio, J., U.S. House of Representatives

Winn, L., U.S. House of Representatives

Yatron, G., U.S. House of Representatives

Other Federal Agencies

Occupational Safety and Health Administration

National Bureau of Standards

Department of Agriculture, U.S. Forest Service

Army Environmental Hygiene Agency

Department of Commerce

Army Construction Engineering Research Laboratory

Individuals and Citizens Groups

Kamhi, V.

Pistocco, C.

De La Houssaye, Jr. R.E.

Kornelsen, V.D.

Bartlett, V.

Fay, T.H.

Reinison, H.R.

Mastriana, F.R.

Poirot, D.E.

Pfeffer, E.

Mellinger, J.W.

Homas, B.

Vandenengel, Y.

McWhorter, C.K.

Bixler, D.W.

Fuchs, W.F.

Lackner, Jr. F.A.

Hawley, M.E.

Bratcher, J.

Cook, R.T.

Esslen, R.

Weisberg, R.

Mathieu, M.

Ledwozon, M.

Mercogliano, E.

Bundy, S.

Hoover, P.K.

White, L.D.

Gewiitz, M.

Graf, G.

Williamson, J.B.

Fields, W.

Ansberry, D.

Randolph, M.M.

Sadagopan, B.

Donofrio, F.

Oatley, F.

Bradley, L.

Blewer, R.R.

Hahn, R.F.

Bodine, S.T.

Gordon, H.

Arenander, N.L.

Eisenberg, J.

Rhein, A.

Renneberg, H.F.

Price, G.

Goodman, M.

Horowitz, B.

Horowitz, D.

Kline, H.A.

Breitman, P.

Perlstadt, H.

Evarts, Jr. W.M.

Martin, K.

Wilson, D.G.

Wale, D.

Moore, D.

Bogan, R.F.

Washington Square Village Tenants Association

Citizens Against Noise

Citizens for a Quieter City

Federation of West Side Block Associations

<u>MEDIA</u>

WNEW

WNBC TV

WINS

WOR TV

CBS News

KTVX

KABC TV

KNX FM Radio

Noise Regulation Reporter

Noise Control Reporter

Environmental Impact News

Montreal Canada Oracle

Toronto Canada Globe and Mail

London United Kingdom Sunday Times

Oakland CA Montclarion

Oakland CA Piedmonter

Newsworld

New Yorker Magazine

New York NY Post

Poughkeepsie NY Journal

Commercial Car Journal

Waste Age

Journal of Environmental Health

Greenwood SC Index Journal

Wappinger Falls NY News

Bristol United Kingdom Evening Post

Noise and Vibration Bulletin

Washington DC Post

Artesia CA News

Birmingham AL News

Maplewood NJ News Record

Scranton PA Times

Montgomery County MD Sentinel

Anaheim CA Bulletin

Somerville NJ Messenger Gazette

Manville NJ News

Manchester NH Union Leader

Conservation News

Denver CO Post

Springfield MA News

Government Product News

Chicago IL Tribune

Detroit MI Free Press

Indianapolis IN Star

Mt Pleasant MI Morning Sun

Sturgis MI Journal

Kansas City MO Times

Alpena MI News

Philadelphia PA Bulletin

Christian Science Monitor

Fair Lawn NJ Shopper

Waco TX Tribune Herald

Little Falls NY Evening Times

Three Rivers MI Commercial

Elmira NY Star Gazette and Telegram

Birmingham AL Post Herald

Knoxville TN News Sentinel

Wilmington DE Evening Journal

New York NY Times

Wall Street Journal

Survey of Current Business

Solid Waste Report

Grand Rapids MI Press

Walnut Creek CA Contra Costa Times

Syracuse NY Herald Journal

Lomita CA News and Progress

Somerville NJ Courier-News

New York NY Westsider

Commerce Business Daily

Changing Times

Sacramento CA Bee

American City and County

Automotive News

Fleet Owner

Pontiac MI Oakland Press

Dunkirk NY Observer

San Diego CA San Diego Union

Heavy Duty Trucking

Transport Topics

Beverly Hills CA Courier

Passaic NJ Herald News

Solid Waste Management/Refuse Removal Journal

Honolulu HI Star Bulletin

St Petersburg FL Times

Denver CO Rocky Mountain News

Pasadena CA Star News

Las Vegas NV Sun

Birmingham AL Times

Phoenix AZ Arizona Republic

Campbell CA Press

Bloomington IN Herald Telephone

Sound and Vibration

Pollution Engineering

Noise News

New York NY News

Washington DC Star

Garden City NY Newsday

Dover NJ Advance

Bethesda MD Montgomery Journal

Savannah GA Press

Salt Lake City UT Sunset News

Forbes Magazine

Salt Lake City UT Desert News

Easton MD Star Democrat

Jersey City NJ Journal

Baltimore MD Sun

Owasso MI Argus Press

Construction Digest

Dayton OH Daily News

Ironwood MI Daily Globe

Goldsboro NC News Argus

Rocky Mount NC Telegram

Hopkinsville KY New Era

Escanaba MI Daily Press

Atlanta GA Journal

Oklahoma City OK Journal

Appendix D

LISTING OF ORGANIZATIONS AND INDIVIDUALS TO BE CONTACTED IN INFORMING THE PUBLIC OF THE BENEFITS AND IMPACTS OF THE REGULATION

LISTING OF ORGANIZATIONS AND INDIVIDUALS
TO BE CONTACTED IN INFORMING THE PUBLIC OF
THE BENEFITS AND IMPACTS OF THE REGULATION

As another step in the Agency's continuing public participation program, an extensive effort is underway to inform the public of the benefits and impacts of the noise emission standards for truck-mounted solid waste compactors. This effort will include direct mailings of information packets to the major groups affected by the regulation and briefings to selected groups. The list below outlines the groups that are to be contacted in this informative public participation effort.

- Congress
  - Senate
  - House of Representatives
  - Concerned Congressional Committees and Offices
- Interested Federal Agencies
- State and Local Governments
  - State Governors
  - State Attorneys General
  - State Noise/Environmental Offices
  - State and Local Environmental Agency Public Information Directors
  - Major Cities
  - State and Local Government Associations
- Truck Chassis Manufacturers
- Compactor Body Manufacturers

Compactor Distributors/Dealers

Refuse Industry Trade and Manufacturing Associations

Refuse Haulers

- Private Refuse Haulers
- Municipal Refuse Haulers

Media

- Major Media
- Environmental Media
- Trade Media
- State and Local Government Media
- Noise Media

Labor Organizations

- Refuse Hauler Employee Unions
- Manufacturing Employee Unions

Commenters to Docket and Public Hearings

Noise/Environmental/Citizens Organizations

Interested Citizens and Organizations
from EPA/ONAC Mailing List

EPA Regional Offices

Libraries

- Major Public Libraries
- State University Libraries

TECHNICAL REPORT DATA

1. REPORT NO. EPA 550/9-79-257	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Noise Emission Standards for Surface Transportation Equipment - Regulatory Analysis of the Noise Emission Regulations for Truck-Mounted Solid Waste Compactors		5. REPORT DATE August 1979 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT NO. EPA 550/9-79-257
9. PERFORMING ORGANIZATION NAME AND ADDRESS Environmental Protection Agency Office of Noise Abatement and Control (ANR-490) Washington, D.C. 20460		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency Office of Noise Abatement and Control Washington, D.C. 20460		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE EPA/200/02
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

This document presents the technical data and analysis used by EPA in developing the Noise Emission Regulations for Truck-Mounted Solid Waste Compactors. The information presented includes a detailed description of the truck-mounted solid waste compactor industry and the product; baseline noise levels for current compactors; a description of the measurement methodology; an analysis of the health and welfare impacts and potential benefits of regulation; the noise control technology available; an analysis of the costs and potential economic effects of regulation; the enforcement procedures; existing local, state, and foreign regulations applicable to compactor noise emissions; an analysis of comments to the public docket; and a description of the participation of the public throughout the development of the regulation.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Truck-mounted solid waste compactors, noise emission regulations, docket analysis, economics, health and welfare analysis, noise control technology, refuse collection vehicles, garbage trucks	Enforcement, measurement methodology, public participation	

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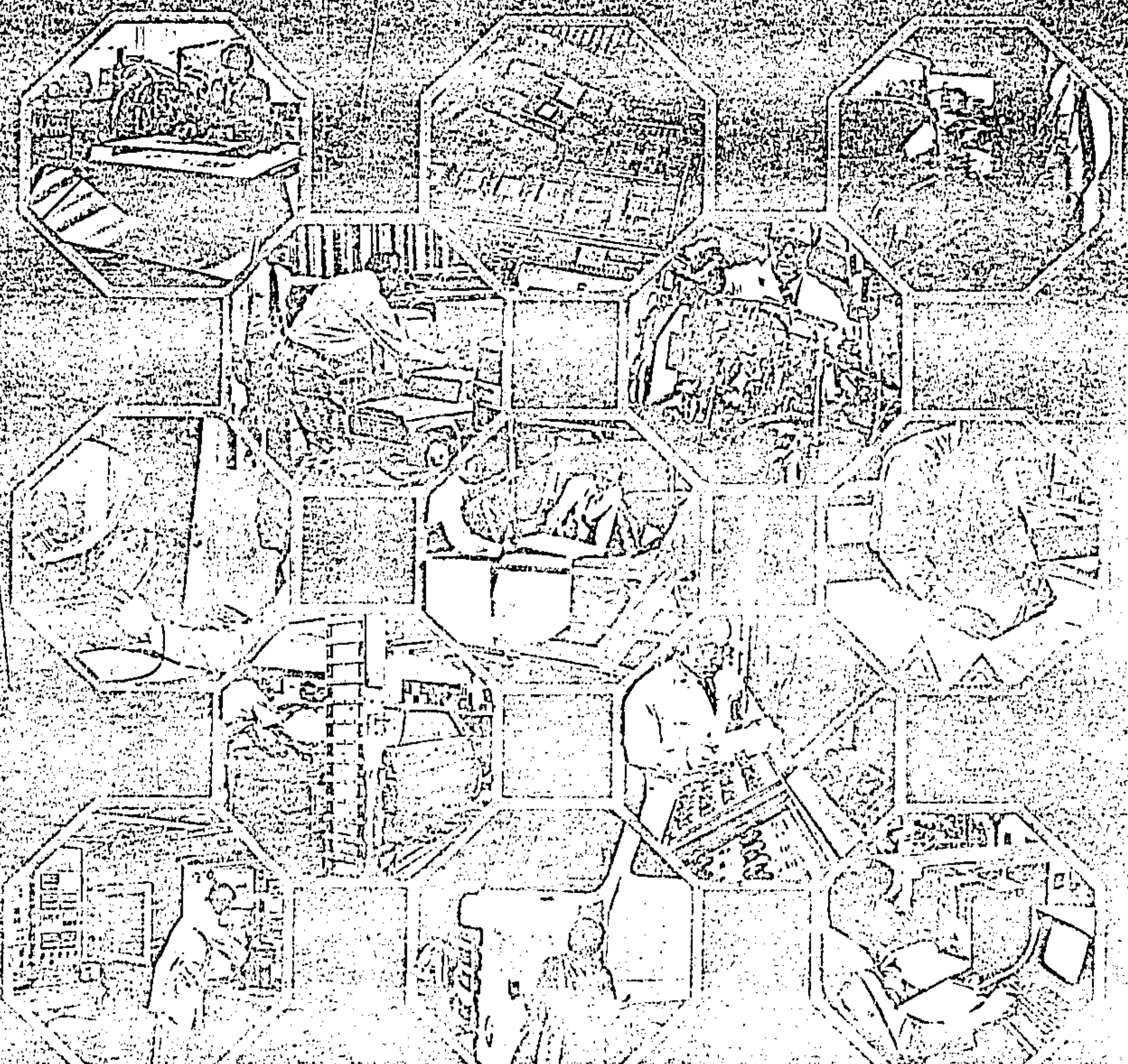
#4

MVMA MOTOR VEHICLE FACTS AND FIGURES '80

SHIFTING GEARS FOR NEW MARKET DEMANDS



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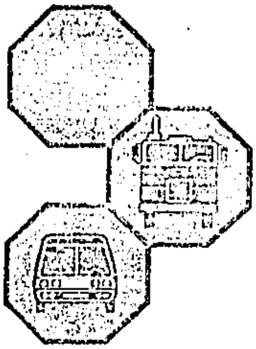


Factory Truck Sales Top 3 Million Mark Again

Though factory sales of trucks slipped in 1979, the volume topped the 3 million plateau for the third consecutive year. Light-duty vehicles (14,000 pounds Gross Vehicle Weight or less) accounted for more than 2.6 million of 1979 sales but also were responsible for most of the decline from 1978, the best year ever.

Heavy-duty trucks (over 26,000 pounds GVW) were on the upside by more than 20,000 units. Factory sales of all trucks had been rising at a spectacular rate since the recession of 1975.

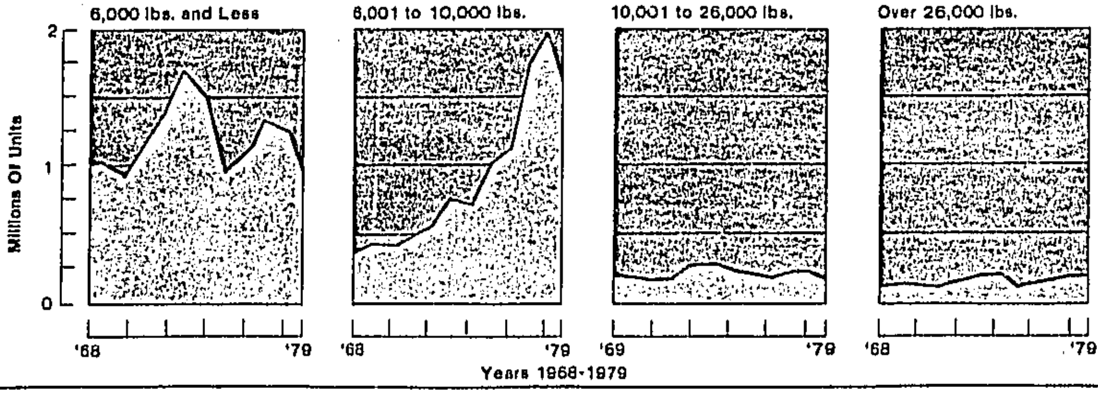
Bus

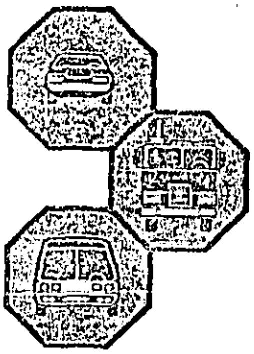
FACTORY SALES OF TRUCKS AND BUSES BY GROSS VEHICLE WEIGHT, POUNDS

	6,000 & Less	6,001-10,000	10,001-14,000	14,001-16,000	16,001-19,500	19,501-26,000	26,001-33,000	33,001 & Over	TOTAL
TOTAL				4	5	6	7	8	
1979	1,014,016	1,594,060	19,163	2,399	4,611	163,304	46,264	192,889	3,036,706
1978	1,231,559	1,990,547	74,938	5,989	5,476	178,992	41,151	177,587	3,706,239
1977	1,326,132	1,723,426	20,288	1,221	7,888	174,256	30,602	157,708	3,441,521
1976	1,248,034	1,389,707	22,444	70	11,416	164,796	24,961	118,048	2,979,476
1975	982,511	962,987	14,342	1,129	10,516	174,284	27,310	99,081	2,272,160
1974	1,536,778	731,529	9,094	4,318	13,071	224,499	34,432	173,592	2,727,313
1973	1,735,645	761,481	44,724	7,477	18,941	203,300	42,200	165,920	2,979,688
1972	1,414,551	584,612	44,221	9,945	28,080	182,058	42,213	141,127	2,446,807
1971	1,196,544	486,388	17,928	14,871	58,042	132,197	36,441	110,735	2,053,146
1970	950,252	401,592	7,353	9,979	59,205	124,554	38,451	101,054	1,692,440
1969	1,121,222	405,108	7,161	13,491	78,105	147,405	33,304	117,383	1,923,179
1968	1,136,059	385,803	4,646	17,495	79,436	141,264	41,814	89,561	1,896,078
DOMESTIC									
1979	961,345	1,413,229	17,366	2,361	3,140	135,189	42,393	166,058	2,741,081
1978	1,160,609	1,826,323	72,756	5,959	3,736	150,412	37,386	158,467	3,415,648
1977	1,253,835	1,580,898	20,015	1,221	4,950	149,027	27,205	141,869	3,179,020
1976	1,181,906	1,267,518	21,942	67	7,982	135,202	19,947	99,533	2,734,097
1975	897,292	853,310	13,914	917	5,652	139,835	21,555	70,283	2,002,758
1974	1,409,586	660,312	8,911	3,220	10,271	197,450	29,091	150,785	2,469,626
1973	1,639,663	713,210	44,272	6,443	15,543	180,345	37,834	149,503	2,786,813
1972	1,339,226	549,523	43,898	8,661	24,826	163,266	37,727	127,244	2,294,371
1971	1,133,911	453,981	17,796	12,602	52,038	110,587	32,795	100,598	1,914,308
1970	895,238	373,595	6,510	8,357	52,466	103,318	34,751	91,434	1,565,669
1969	1,052,057	379,492	6,525	11,272	68,617	125,910	30,858	106,446	1,781,177
1968	1,069,422	365,785	4,338	14,690	67,381	123,059	37,882	82,534	1,765,091

NOTE: Diesel trucks and buses are included in data.
SOURCE: Motor Vehicle Manufacturers Association of the U.S., Inc.

ANNUAL TRUCK AND BUS FACTORY SALES BY GROSS VEHICLE WEIGHT





Heavy-Duty Diesels Continue Sales Climb

The diesel engine was a major engineering story of the Seventies and is slated to become an even greater factor in the motor vehicle industry during the Eighties. The diesel passenger car and light truck are starting to make their mark but that husky but efficient power plant has been identified with heavy-duty trucks for many years.

Factory sales of the big diesel-powered trucks generally have been growing annually since the early 1960's except for recession and strike years. It has just been in the last two years that they have become important in the light-duty market.

U.S. FACTORY SALES OF DIESEL TRUCKS BY GROSS VEHICLE WEIGHT, POUNDS

	6,000 & Less	6,001-10,000	10,001-14,000	14,001-16,000	16,001-19,500	19,501-26,000	26,001-33,000	33,001 & Over	Total
TOTAL			3	4	5	6	7	8	
1979	33,019	950	–	–	–	17,268	25,152	182,139	258,528
1978	35,019	990	–	–	–	15,561	24,978	167,300	243,848
1977	2,392	1,128	–	–	–	14,575	17,363	149,839	185,297
1976	–	1,596	–	–	–	7,708	11,509	108,263	129,076
1975	–	1	–	–	159	5,651	11,819	84,878	102,508
1974	–	–	–	–	41	4,192	12,597	150,429	167,259
1973	–	–	–	296	20	4,896	17,194	145,983	168,389
1972	–	–	–	215	41	4,789	13,563	124,481	143,089
1971	–	85	–	416	10	5,077	11,269	96,295	113,152
1970	8	417	–	168	26	7,875	11,932	85,288	105,714
1969	4	549	–	459	392	8,447	11,551	93,468	114,870
1968	84	903	12	155	1,272	7,587	14,401	69,405	93,819
1965	323	566	146	207	3,739	9,864	16,208	51,098	82,151
DOMESTIC									
1979	31,894	653	–	–	–	14,404	23,121	157,762	227,834
1978	34,751	840	–	–	–	12,229	22,597	149,498	219,915
1977	2,386	975	–	–	–	11,142	15,695	135,361	165,559
1976	–	1,498	–	–	–	5,045	9,053	91,620	107,216
1975	–	1	–	–	159	3,517	8,992	59,936	72,605
1974	–	–	–	–	41	2,704	10,333	131,624	144,702
1973	–	–	–	296	6	3,197	15,164	133,496	152,159
1972	–	–	–	215	5	3,196	11,922	114,290	129,628
1971	–	81	–	412	–	3,011	9,499	88,485	101,488
1970	–	268	–	165	–	3,158	10,245	77,965	91,801
1969	–	512	–	459	245	4,391	10,505	85,591	101,703
1968	33	788	4	155	341	4,242	13,045	64,815	83,423
1965	59	509	123	160	2,715	6,206	14,749	47,836	72,357

ANNUAL MOTOR VEHICLE FACTORY SALES FROM U.S. AND CANADIAN PLANTS

	PLANTS IN THE UNITED STATES				PLANTS IN CANADA			
Year	U.S. Total	Exports to Canada	Other Exports	U.S. Domestic	Canada Total	Exports to U.S.	Other Exports	Canada Domestic
PASSENGER CARS								
1979	8,419,226	582,097	158,991	7,678,138	973,174	582,386	92,728	298,060
1978	9,165,190	541,552	130,075	8,493,563	1,127,573	764,835	107,037	255,701
1977	9,200,849	586,073	102,308	8,512,468	1,155,701	831,994	87,148	236,559
1976	8,500,305	562,635	97,167	7,840,503	1,134,644	808,788	75,331	250,525
1975	6,712,852	549,353	90,199	6 073,300	1,043,245	713,407	58,149	271,689
1970	6,546,817	245,746	113,753	6,187,318	919,232	681,872	30,427	206,933
1965	9,305,561	46,540	158,334	9,100,687	750,777	33,862	39,771	677,144
TRUCKS AND BUSES								
1979	3,036,706	158,394	137,231	2,741,081	633,075	348,231	43,861	240,983
1978	3,706,239	138,970	151,621	3,415,648	662,299	396,935	51,195	214,169
1977	3,441,521	135,078	127,423	3,179,020	605,484	347,592	47,278	210,614
1976	2,979,476	128,524	116,855	2,734,097	497,914	265,623	44,065	188,226
1975	2,272,160	133,701	135,701	2,002,758	390,065	181,165	47,742	161,158
1970	1,692,440	53,646	73,125	1,565,669	252,079	157,532	32,429	62,118
1965	1,751,805	9,550	126,311	1,615,944	151,214	7,001	15,525	128,688

SOURCE: Motor Vehicle Manufacturers Association of the U.S., Inc.

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DATA RESOURCES LONG TERM REVIEW, FALL 1980

PAGES 11.16 THROUGH 11.19

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Table 5
Consumer Expenditures for Motor Vehicles and Parts

TRENDLONG2005	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
	Millions of Units - SAAR												
Retail Sales of New Passenger Cars.....	8.9	9.5	10.6	11.1	11.6	11.6	11.5	11.4	11.4	11.4	11.2	11.1	11.3
Domestic..........................	6.5	7.0	7.9	8.5	9.0	9.2	9.1	9.0	9.0	8.9	8.7	8.5	8.6
Imported..........................	2.3	2.5	2.7	2.7	2.5	2.4	2.4	2.4	2.4	2.5	2.6	2.6	2.7
Import Share (%).................	26.3	26.0	25.8	23.9	21.7	20.7	20.8	21.0	20.9	21.6	22.8	23.4	23.5
Dealer Deliveries of Trucks............	2.44	2.48	2.98	3.29	3.55	3.69	3.73	3.79	3.88	3.98	3.99	4.02	4.17
Heavy & Medium Trucks..............	0.26	0.27	0.28	0.30	0.31	0.32	0.33	0.33	0.33	0.34	0.34	0.34	0.33
Light.............................	2.18	2.22	2.70	2.99	3.24	3.36	3.40	3.46	3.54	3.64	3.65	3.68	3.84
Total: Cars and Light Trucks...........	11.05	11.68	13.31	14.13	14.79	14.97	14.87	14.85	14.93	15.05	14.87	14.77	15.12
Total: Cars and Trucks.................	11.31	11.95	13.60	14.43	15.10	15.29	15.20	15.17	15.26	15.39	15.21	15.10	15.45
Consumption of Motor Vehicles & Parts													
Billions of Current Dollars.........	81.8	96.4	118.7	136.9	155.7	171.8	187.0	204.6	224.9	247.3	266.9	291.4	324.4
Billions of 1972 Dollars............	48.7	51.9	58.6	62.6	66.4	68.4	69.4	70.7	72.4	74.3	74.9	76.3	79.6
Annual Rate of Change............	-17.0	6.7	12.9	6.8	6.2	3.0	1.4	1.8	2.5	2.6	0.8	1.8	4.4
Factors Affecting Automobile Expenditures													
Unit Car Sales as a Percent of:													
Each $100,000 of Real Disp. Income..	8.97	9.54	10.32	10.46	10.42	10.17	9.73	9.41	9.15	8.95	8.61	8.33	8.27
Stock of Registered Cars............	8.44	8.92	9.85	10.18	10.31	10.12	9.79	9.54	9.37	9.24	8.94	8.71	8.74
Driving Age Population..............	5.26	5.54	6.15	6.39	6.56	6.53	6.39	6.28	6.23	6.20	6.05	5.95	6.02
Average Miles per Gallon Achieved by New Models.......................	17.4	19.1	20.7	21.8	22.8	23.6	24.1	24.6	25.1	25.6	26.1	26.6	27.1
	Household Economic Position												
Real Disposable Income (%Ch)...........	-0.7	0.3	3.8	3.6	4.0	3.0	3.3	2.6	2.9	2.4	2.2	2.1	2.5
Real Permanent Disp. Income (%Ch)......	2.4	1.4	2.0	2.5	3.0	3.1	3.1	3.1	3.0	2.8	2.7	2.5	2.5
Real HH. Financial Assets (%Ch)........	1.0	-0.9	-4.0	2.5	1.9	0.8	0.4	2.3	3.5	2.5	1.0	1.0	0.8
HH. Debt Service as % of Disp. Income..	8.0	7.8	8.1	8.1	8.1	8.0	7.9	7.9	7.8	7.7	7.7	7.7	7.5
Credit Liquidations As % of Income.....	16.5	15.7	15.5	15.5	15.7	16.2	16.4	16.5	16.6	16.8	16.8	16.8	16.8
Unemployment Rate (%)..................	7.5	8.6	7.9	7.2	6.9	6.4	6.1	6.1	6.0	5.9	6.0	6.1	6.3
Employment (HH Survey, %Ch)............	0.0	0.5	2.9	2.5	1.9	1.8	1.6	1.4	1.4	1.2	1.0	0.7	0.7
Consumer Sentiment Index (1966/I=100.0)	55.9	58.0	65.9	70.4	74.7	75.3	76.5	77.3	78.8	79.0	76.2	77.7	78.2
Stock of Registered Cars (Mil. Units)..	105.4	107.1	108.8	111.0	113.7	116.3	118.6	120.7	122.8	124.8	126.6	128.3	130.1
Scrappage Rate for Cars (%)............	8.1	7.4	8.3	8.2	8.0	8.0	7.9	7.8	7.7	7.7	7.5	7.4	7.4
	Prices & Interest Rates - Annual Rates of Change												
Index of Car Costs.....................	26.6	5.5	11.5	11.2	9.6	8.9	9.3	9.2	8.6	8.4	8.6	8.8	8.7
Price Deflator - Autos & Parts......	7.7	10.2	9.2	8.0	7.1	7.1	7.4	7.4	7.3	7.1	7.1	7.2	6.7
Price Deflator - Gasoline...........	42.4	19.4	17.6	11.5	10.5	11.3	12.2	11.6	11.4	11.2	11.0	10.6	10.4
Gasoline Tax (Cents per Gallon)..	12.9	13.5	15.7	17.3	18.3	19.4	20.6	21.8	23.2	24.6	26.2	27.9	29.6
Federal.......................	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
State & Local.................	8.9	9.5	11.7	13.3	14.3	15.4	16.6	17.8	19.2	20.6	22.2	23.9	25.6
Auto Installment Loan Rate (%)......	14.19	11.61	11.24	11.77	12.11	12.11	12.01	11.97	11.76	11.52	11.38	11.36	11.42
Cost of Car Ownership Relative to All Consumer Prices (1972=1.000)....	1.338	1.282	1.307	1.345	1.373	1.391	1.413	1.436	1.452	1.467	1.483	1.506	1.534

Table 5 (continued)

TRENDLONG2005	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Millions of Units - SAAR													
Retail Sales of New Passenger Cars.....	11.3	11.5	11.7	11.8	11.8	11.8	11.8	11.8	11.9	11.9	12.0	12.1	12.1
Domestic............................	8.6	8.8	8.9	9.0	9.0	9.0	9.0	9.1	9.1	9.1	9.1	9.2	9.2
Imported............................	2.7	2.7	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.9	2.9	2.9
Import Share (%).................	23.8	23.7	23.7	23.7	23.7	23.5	23.6	23.5	23.6	23.7	23.8	23.8	23.9
Dealer Deliveries of Trucks............	4.26	4.41	4.57	4.69	4.77	4.86	4.92	5.01	5.10	5.19	5.27	5.38	5.47
Heavy & Medium Trucks...............	0.33	0.34	0.36	0.38	0.39	0.40	0.41	0.41	0.42	0.43	0.43	0.44	0.44
Light...............................	3.93	4.07	4.21	4.32	4.38	4.46	4.52	4.59	4.68	4.77	4.84	4.94	5.03
Total: Cars and Light Trucks...........	15.24	15.56	15.87	16.09	16.17	16.29	16.32	16.43	16.56	16.71	16.82	17.01	17.14
Total: Cars and Trucks.................	15.57	15.90	16.23	16.46	16.56	16.69	16.73	16.84	16.98	17.14	17.25	17.45	17.58
Consumption of Motor Vehicles & Parts													
Billions of Current Dollars.........	355.4	392.3	431.6	471.9	512.1	556.9	602.7	654.3	710.4	772.0	836.7	910.5	987.9
Billions of 1972 Dollars............	82.1	85.4	88.6	91.5	93.8	96.5	98.7	101.5	104.3	107.3	110.2	113.5	116.6
Annual Rate of Change............	3.0	4.0	3.8	3.3	2.6	2.8	2.4	2.8	2.8	2.9	2.6	3.0	2.7
Factors Affecting Automobile Expenditures													
Unit Car Sales as a Percent of:													
Each $100,000 of Real Disp. Income..	8.15	8.08	8.05	7.93	7.80	7.64	7.49	7.33	7.22	7.09	6.97	6.85	6.74
Stock of Registered Cars............	8.65	8.66	8.68	8.64	8.54	8.46	8.35	8.27	8.21	8.16	8.09	8.06	8.01
Driving Age Population..............	6.00	6.05	6.10	6.11	6.07	6.04	5.97	5.94	5.91	5.89	5.86	5.85	5.83
Average Miles per Gallon Achieved by New Models........................	27.7	28.2	28.8	29.3	29.9	30.5	31.1	31.7	32.3	32.9	33.5	34.2	34.9
Household Economic Position													
Real Disposable Income (%Ch)...........	1.8	2.3	1.9	2.4	1.9	2.4	1.8	2.4	1.9	2.5	2.0	2.5	2.0
Real Permanent Disp. Income (%Ch)......	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.1	2.2	2.2	2.2	2.2
Real HH. Financial Assets (%Ch)........	2.9	3.8	2.8	2.2	2.4	2.2	2.2	2.7	2.5	2.2	2.5	2.4	2.0
HH. Debt Service as % of Disp. Income..	7.5	7.4	7.3	7.2	7.2	7.0	7.0	6.9	6.9	6.9	6.9	6.9	6.9
Credit Liquidations As % of Income.....	16.8	16.8	16.9	17.0	17.1	17.1	17.1	17.0	17.0	17.0	17.0	16.9	16.9
Unemployment Rate (%)..................	6.5	6.4	6.1	5.9	5.8	5.8	5.9	5.9	5.9	5.9	5.9	5.8	5.8
Employment (HH Survey, %Ch)............	0.6	0.9	1.2	1.2	1.0	0.9	0.9	0.9	1.0	1.0	0.9	0.9	0.9
Consumer Sentiment Index (1966/I=100.0)	78.4	80.6	81.8	82.4	82.2	82.2	81.7	82.0	82.2	82.3	82.4	82.8	82.7
Stock of Registered Cars (Mil. Units)..	131.9	133.7	135.5	137.3	139.1	140.8	142.5	144.1	145.8	147.4	149.0	150.7	152.3
Scrappage Rate for Cars (%)............	7.3	7.3	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.0	7.0	7.0
Prices & Interest Rates - Annual Rates of Change													
Index of Car Costs.....................	8.1	7.6	7.6	7.8	7.8	7.7	7.8	7.8	7.8	7.8	7.9	7.0	7.8
Price Deflator - Autos & Parts......	6.3	6.1	6.0	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.6	5.6	5.6
Price Deflator - Gasoline...........	10.2	10.0	9.8	9.7	9.6	9.5	9.4	9.2	9.2	9.1	9.0	9.0	8.9
Gasoline Tax (Cents per Gallon)..	31.3	33.0	34.7	36.6	38.5	40.6	42.8	45.1	47.6	50.2	53.0	55.9	59.1
Federal.......................	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
State & Local.................	27.3	29.0	30.7	32.6	34.5	36.6	38.8	41.1	43.6	46.2	49.0	51.9	55.1
Auto Installment Loan Rate (%)......	11.33	11.11	10.93	10.85	10.79	10.72	10.70	10.71	10.73	10.79	10.86	10.90	10.97
Cost of Car Ownership Relative to All Consumer Prices (1972=1.000)....	1.556	1.575	1.597	1.623	1.650	1.678	1.707	1.739	1.771	1.806	1.841	1.876	1.913

Table 5 (continued)

CYCLELONG2005	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Millions of Units - SAAR													
Retail Sales of New Passenger Cars	11.4	11.8	10.9	10.6	11.3	11.8	10.8	10.5	11.2	11.8	10.9	10.7	11.5
Domestic	8.9	9.2	8.1	7.9	8.7	9.1	8.1	7.8	8.5	9.0	8.0	8.0	8.8
Imported	2.5	2.7	2.7	2.7	2.6	2.7	2.8	2.7	2.7	2.7	2.8	2.8	2.7
Import Share (%)	22.3	22.5	25.0	25.1	23.4	22.9	25.5	25.7	23.9	23.4	26.2	25.8	23.8
Dealer Deliveries of Trucks	3.93	4.17	3.76	3.66	4.08	4.35	3.91	3.76	4.17	4.48	4.04	3.98	4.45
Heavy & Medium Trucks	0.31	0.33	0.34	0.34	0.35	0.37	0.38	0.36	0.37	0.39	0.39	0.38	0.39
Light	3.63	3.84	3.42	3.32	3.73	3.98	3.54	3.39	3.80	4.09	3.65	3.59	4.07
Total: Cars and Light Trucks	15.06	15.67	14.28	13.89	15.04	15.78	14.37	13.88	15.00	15.84	14.51	14.31	15.58
Total: Cars and Trucks	15.37	16.00	14.62	14.24	15.40	16.15	14.75	14.24	15.37	16.23	14.91	14.69	15.96
Consumption of Motor Vehicles & Parts													
Billions of Current Dollars	404.6	454.5	464.3	505.1	588.6	661.4	672.6	725.1	838.1	940.2	958.1	1044.2	1206.3
Billions of 1972 Dollars	80.8	85.0	80.5	81.1	88.4	93.3	88.6	88.8	96.3	102.0	97.4	99.1	107.7
Annual Rate of Change	10.4	5.2	-5.2	0.7	9.0	5.6	-5.1	0.2	8.5	5.9	-4.5	1.7	8.7
Factors Affecting Automobile Expenditures													
Unit Car Sales as a Percent of:													
Each $100,000 of Real Disp. Income	8.46	8.53	7.69	7.43	7.78	7.91	7.14	6.87	7.18	7.32	6.65	6.50	6.81
Stock of Registered Cars	9.30	9.51	8.65	8.30	8.76	9.06	8.27	7.92	8.38	8.75	8.06	7.88	8.38
Driving Age Population	6.06	6.23	5.68	5.49	5.83	6.02	5.48	5.26	5.57	5.79	5.31	5.20	5.54
Average Miles per Gallon Achieved by New Models	27.7	28.2	28.8	29.3	29.9	30.5	31.1	31.7	32.3	32.9	33.5	34.2	34.9
Household Economic Position													
Real Disposable Income (%Ch)	2.8	2.7	1.8	0.9	2.1	2.6	1.7	0.6	2.2	2.9	1.9	0.8	2.5
Real Permanent Disp. Income (%Ch)	2.2	2.4	2.3	1.9	1.8	2.1	2.1	1.7	1.7	2.0	2.1	1.8	1.8
Real HH. Financial Assets (%Ch)	3.2	-3.8	0.9	8.0	3.4	-5.1	2.0	8.5	3.5	-5.1	3.0	8.4	2.9
Hh. Debt Service as % of Disp. Income	7.4	7.4	7.4	7.3	7.2	7.2	7.2	7.2	7.1	7.1	7.2	7.2	7.0
Credit Liquidations As % of Income	16.7	16.8	16.8	16.9	16.9	17.0	16.9	16.9	16.9	16.9	16.8	16.8	16.9
Unemployment Rate (%)	6.8	6.1	6.0	7.0	6.7	5.9	5.9	7.2	7.0	6.1	6.0	7.1	6.9
Employment (HH Survey, %Ch)	1.3	1.7	1.1	-0.2	1.1	1.9	1.0	-0.4	1.0	2.0	1.0	-0.3	1.1
Consumer Sentiment Index (1966/I=100.0)	80.7	78.6	66.3	70.0	78.7	79.1	65.9	69.2	78.2	78.5	66.1	71.4	80.4
Stock of Registered Cars (Mil. Units)	123.9	125.1	126.6	128.6	129.9	130.6	131.8	133.3	134.2	134.5	135.4	136.9	137.8
Scrappage Rate for Cars (%)	8.1	8.6	7.4	6.8	7.8	8.5	7.4	6.8	7.7	8.5	7.4	6.8	7.7
Prices & Interest Rates - Annual Rates of Change													
Index of Car Costs	6.4	9.7	13.0	7.2	6.7	9.4	14.1	6.9	6.3	8.9	13.5	6.3	5.6
Price Deflator - Autos & Parts	7.0	6.8	7.9	7.9	6.9	6.5	7.2	7.4	6.5	6.0	6.7	7.0	6.3
Price Deflator - Gasoline	7.7	9.7	16.6	8.4	7.2	10.1	18.9	8.1	6.7	9.5	17.5	7.3	5.8
Gasoline Tax (Cents per Gallon)	31.3	33.0	34.7	36.6	38.5	40.6	42.8	45.1	47.6	50.2	53.0	55.9	59.1
Federal	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
State & Local	27.3	29.0	30.7	32.6	34.5	36.6	38.8	41.1	43.6	46.2	49.0	51.9	55.1
Auto Installment Loan Rate (%)	10.63	11.14	11.36	10.95	10.79	11.16	11.36	10.95	10.79	11.16	11.36	10.95	10.79
Cost of Car Ownership Relative to All Consumer Prices (1972=1.000)	1.550	1.588	1.697	1.656	1.656	1.697	1.793	1.794	1.794	1.837	1.939	1.936	1.928

Table 5 (continued)

CYCLELONG2005	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Millions of Units - SAAR													
Retail Sales of New Passenger Cars.....	8.9	9.7	10.3	10.7	11.6	11.6	9.8	10.0	10.8	11.3	10.5	9.5	10.5
Domestic..........................	6.6	7.1	7.4	8.0	9.0	8.8	7.3	7.6	8.5	8.8	7.9	7.0	8.0
Imported..........................	2.3	2.6	2.8	2.7	2.7	2.9	2.6	2.4	2.3	2.4	2.6	2.4	2.5
Import Share (%)................	25.8	26.3	27.8	25.4	23.0	24.2	26.1	23.9	21.5	21.6	24.5	25.8	24.0
Dealer Deliveries of Trucks............	2.47	2.56	2.80	3.06	3.52	3.59	2.89	3.00	3.44	3.69	3.40	2.98	3.47
Heavy & Medium Trucks..............	0.26	0.27	0.27	0.28	0.29	0.30	0.29	0.28	0.29	0.31	0.32	0.31	0.30
Light..............................	2.21	2.29	2.53	2.78	3.23	3.28	2.60	2.72	3.14	3.38	3.08	2.67	3.17
Total: Cars and Light Trucks...........	11.15	11.98	12.79	13.47	14.87	14.88	12.41	12.68	13.98	14.65	13.55	12.15	13.68
Total: Cars and Trucks.................	11.40	12.26	13.06	13.75	15.16	15.19	12.70	12.96	14.27	14.96	13.87	12.46	13.98
Consumption of Motor Vehicles & Parts													
Billions of Current Dollars.........	82.4	99.1	116.3	135.0	162.6	180.2	173.5	197.5	234.7	265.4	272.2	279.7	342.4
Billions of 1972 Dollars............	49.0	53.1	56.6	60.2	66.9	68.0	59.6	62.3	68.8	72.5	68.9	64.6	73.2
Annual Rate of Change............	-16.4	8.3	6.6	6.3	11.1	1.7	-12.4	4.5	10.4	5.5	-5.1	-6.2	13.2
Factors Affecting Automobile Expenditures													
Unit Car Sales as a Percent of:													
Each $100,000 of Real Disp. Income..	9.01	9.69	9.98	10.08	10.59	10.27	8.59	8.56	9.00	9.06	8.21	7.33	8.00
Stock of Registered Cars............	8.50	9.13	9.50	9.75	10.42	10.21	8.51	8.53	9.17	9.45	8.74	7.89	8.66
Driving Age Population..............	5.30	5.68	5.94	6.13	6.61	6.52	5.46	5.49	5.92	6.12	5.65	5.09	5.61
Average Miles per Gallon Achieved by New Models......................	17.4	19.1	20.7	21.8	22.8	23.6	24.1	24.6	25.1	25.6	26.1	26.6	27.1
Household Economic Position													
Real Disposable Income (%Ch)...........	-0.3	1.0	2.7	3.1	3.7	2.7	1.1	1.9	3.4	3.5	2.4	1.4	1.6
Real Permanent Disp. Income (%Ch)......	2.4	1.7	2.0	2.3	2.7	2.9	2.5	2.0	2.4	2.8	2.8	2.5	2.1
Real HH. Financial Assets (%Ch)........	2.1	-5.7	-4.2	5.0	-1.6	-6.4	7.7	8.9	4.5	-1.0	-7.2	7.2	5.6
HH. Debt Service as % of Disp. Income..	8.0	7.9	8.2	8.2	8.3	8.3	8.4	8.1	7.9	7.8	7.8	7.8	7.6
Credit Liquidations As % of Income.....	16.5	15.8	15.6	15.3	15.5	15.9	16.0	16.0	16.3	16.5	16.6	16.5	16.5
Unemployment Rate (%)..................	7.5	8.1	7.9	7.7	7.1	6.4	7.0	7.8	7.1	6.2	5.8	6.6	7.3
Employment (HH Survey, %Ch)............	0.0	1.0	2.4	1.9	2.1	2.1	0.7	0.3	2.1	2.2	1.5	0.1	0.1
Consumer Sentiment Index (1966/I=100.0)	57.9	58.4	59.9	64.9	71.8	61.1	59.5	69.4	78.9	77.9	63.2	63.4	72.7
Stock of Registered Cars (Mil. Units)..	105.5	107.4	108.8	110.9	112.9	114.7	116.3	117.6	118.9	119.7	119.9	120.8	122.4
Scrappage Rate for Cars (%)............	8.1	7.4	8.2	7.9	8.7	8.6	7.2	7.4	8.1	8.8	9.6	7.2	7.4
Prices & Interest Rates - Annual Rates of Change													
Index of Car Costs.....................	26.6	7.2	13.1	12.7	11.3	13.7	9.6	6.7	7.0	9.2	14.1	9.9	6.1
Price Deflator - Autos & Parts......	7.7	10.8	10.1	9.1	8.4	9.1	9.9	8.8	7.7	7.2	8.1	9.4	8.1
Price Deflator - Gasoline...........	42.4	19.6	18.1	12.7	11.6	18.4	14.1	9.3	9.2	9.3	17.5	13.2	7.9
Gasoline Tax (Cents per Gallon)..	12.9	13.5	15.7	17.3	18.3	19.4	20.6	21.8	23.2	24.6	26.2	27.9	29.6
Federal......................	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
State & Local................	8.9	9.5	11.7	13.3	14.3	15.4	16.6	17.8	19.2	20.6	22.2	23.9	25.6
Auto Installment Loan Rate (%)......	14.19	12.03	11.96	12.60	13.14	13.38	12.62	11.80	11.31	11.66	12.19	11.69	10.98
Cost of Car Ownership Relative to All Consumer Prices (1972=1.000)....	1.339	1.300	1.337	1.384	1.423	1.479	1.481	1.465	1.459	1.485	1.558	1.574	1.557

4e.

REGULATORY ANALYSIS AND ENVIRONMENTAL IMPACT OF FINAL EMISSION REGULATIONS FOR 1984 AND LATER MODEL YEAR HEAVY DUTY ENGINES.

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REGULATORY ANALYSIS AND ENVIRONMENTAL IMPACT OF FINAL EMISSION REGULATIONS FOR 1984 AND LATER MODEL YEAR HEAVY DUTY ENGINES

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF MOBILE SOURCE AIR POLLUTION CONTROL

DECEMBER 1979

To remain competitive with alternative means of transport, intercity carriers work on a small margin over costs. Costs for drivers are about 30% of the total. Costs of equipment account for another 9.0% of the total and operating costs (fuel/maintenance) about 11%. In 1974 there were approximately 2,800 Class I and II motor carriers. Finally, employment in the trucking industry amounted to 9,052,000 people in 1973 (ATA estimate).

Heavy-duty engine exhaust emission regulations will, of course, also apply to buses. As an example of how this segment of the vehicle population is made up, in 1977 there were about 20,000 buses being operated in the U.S. by 1050 intercity transit bus companies, employing about 44,000 people. There were also 48,700 buses being operated by local transit companies. Most of these transit buses are equipped with diesel engines. School buses, however, account for the overwhelming number of buses on the roads. In 1977 over 298,800 publicly- and privately-owned school buses were in operation. They accounted for over 80 percent of all buses on the road and were nearly all gasoline-powered.5/

E. The Future of Heavy-Duty Vehicles

The next decade is sure to bring changes in the heavy-duty vehicle industry. Changes in GNP and weight and length restrictions may tend to slow the rate of growth of the heavy-duty vehicle fleet. Increasing real fuel costs will certainly lead to further development and utilization of the efficient diesel engines. Although precise predictions are impossible, the discussion which follows addresses some of the major factors which will affect the size and composition of the heavy-duty vehicle fleet in the next decade.

The GNP growth rate is expected to slow in the next decade as compared to the 1970's in which it slowed as compared to the 1960's. The main reason is the energy problem. A corollary of a declining rate of growth in GNP is a declining rate of growth in commercial freight and therefore, a lesser growth rate in sales of heavy-duty vehicles to move that freight.

Another area of change which will affect the sales of heavy-duty vehicles in the next decade is deregulation of the trucking industry. Spurred by the trucking industry, the Federal Government, and the fuel crisis, states should continue to move towards uniform weight and length limitations. This will decrease the number of miles that trucks have to travel since many unnecessary miles are due to the differences in state regulations.7/ Trucks today go around states where regulations are more restrictive since that is cheaper than making two trips through the state to meet weight restrictions or having to reload into a shorter trailer to meet length restrictions.

Along with uniform regulations, less strict weight and length limits may be implemented. Double and triple-trailer rigs can substantially reduce the gallons of fuel used per ton-mile traveled. It is estimated that doubling of gross combination weight results in more than a doubling in fuel efficiency as measured by ton-miles per gallon of fuel. Of course these weight and length restriction changes will continue to be debated in view of safety and environmental concerns.

Restrictions on return trip loads should be eased. This will reduce the number of empty backhauling trips and therefore increase fuel efficiency.

All of the above regulation changes will tend to decrease the rate of growth of the heavy-duty vehicle fleet. Trucks will carry more freight per trip from both a weight and a volume viewpoint. Also, the number of miles per trip should decrease due to less bypassing of overly restrictive states. On the other side of the future heavy-duty vehicle sales equation is the fact that heavy-duty vehicle lifetimes may tend to diminish somewhat since they will be doing more work per hour and per mile. This will place more stress on engines and drivetrains resulting in increased wear and tear. Durability will become increasingly important.

The fuel crisis, while being an underlying cause of all of the above changes, will be a direct cause of the shift from gasoline-fueled engines to diesel engines. As mentioned previously in this chapter, diesel engines are more fuel efficient than gasoline-fueled engines. Coupled with the greater durability of diesels, the fuel efficiency advantage should continue to increase the diesel's market share.

The switch to diesels will not be as fast as the mechanical advantages of diesels would predict. Environmental, social, and economic concerns will prevent the extremely rapid rate of dieselization predicted in some studies.4/,8/ Concern over future particulate and NOx regulations will prevent manufacturers from fully committng to diesel production until they are confident that such regulations can be met without adversely affecting the economic advantage of the diesel. As more diesels are put into use, the diesel fuel shortages may increase to a greater degree than gasoline fuel shortages. This was demonstrated with the fuel shortages in the spring of 1979. The specter of diesel fuel shortages may dampen demand. Basic economics predicts that as diesel fuel demand increases, its price will increase, which will also remove some of the diesel advantage. Finally, lack of confidence in diesel cold-start capability and maintenance availability is still a concern with many prospective owners.

EPA is projecting that the current growth in heavy-duty vehicle sales will decrease slightly in the mid-eighties. The major change expected is a shift to diesels in the heavier weight classes.

To project total heavy-duty vehicle sales by weight class EPA used several steps.

First, the total heavy-duty vehicle sales by domestic manufacturers for the years 1967-1978 were determined from MVMA data. A linear regression through this data gave a sales growth of 10,903 per year.

The next step in this process was to account for imports, primarily Canadian. The data available to EPA indicated that on a year to year basis, Canadian imports were mathematically about 10 percent of domestic sales by U.S. manufacturers. So the growth rate was increased by 10 percent to about 12,000 per year.

To apportion the sales across the weight classes, historical percentages from the period 1974-1978 were used. These percentages, as shown below, are percentages of total sales in each weight class and have been assumed not to change in the mid-1980's.

Class IIB	8,501 - 10,000#	28.3%
Class III	10,001 - 14,000#	5.3%
Class IV	14,001 - 16,000#	0.9%
Class V	16,001 - 19,500#	2.2%
Class VI	19,501 - 26,000#	32.2%
Class VII	26,001 - 33,000#	5.9%
Class VIII	33,001 and over	25.2%

Table III-M contains the total projected haevy-duty vehicle sales for the period 1984-1988.

To determine how the total heavy-duty sales in each weight class will be divided between gasoline-fueled engines and diesel engines, EPA used several input sources and in a few cases best judgment. This methodology will be discussed on a per class basis in the following paragraphs.

<u>Classes IIB, III, IV, V</u> - Based on data submitted in the light-duty diesel particulate rulemaking action it appears that dieselization in lighter gross vehicle weight will not be as great as in the heavier weight classes. This slower dieselization rate will be caused in part by the larger initial purchase price of the diesel, slightly poorer performance of diesels, and less availability of maintenance for diesels. Based on the light-duty diesel summary and analysis of comments, our projections will allow 20 percent of the sales in each of these classes to be diesel by 1990 9/ and the percentage of diesel sales to grow at a steady 2 percent per year for the period 1984-1988 (see Table III-N).

Excludes Bus

Table III-M

Estimated HDV Sales for
1984 through 1988 by GVWR (pounds)

Year	8,501-10,000	10,001-14,000	14,001-16,000	16,001-19,500	19,501-26,000	26,001-33,000	33,001 and over	All HD Vehicles
1988	192,760	36,100 5,776	6,130 981	14,985 2398	219,324 89,923	40,187 40,187	171,645 171,645	681,131
1987	189,366	35,464 4,965	6,022 343	14,721 2061	215,462 81,376	39,479 37,900	168,623 168,623	669,137
1986	185,971	34,829 4,179	5,915 710	14,457 1,735	211,600 71,944	38,771 35,669	165,600 165,600	657,142
1985	182,577	34,193 3,419	5,806 551	14,193 1,419	207,738 64,[illegible]	38,064 33,[illegible]	162,578 162,578	645,149
1984	179,183	33,557 2,[illegible]	5,698 456	13,929 1,114	203,876 57,035	37,356 31,753	159,555 159,555	633,154

	TOT MEDIUM	MEDIUM DIESEL	%
1988	276,539	99,078	35.83
1987	271,669	89,745	33.03
1986	266,[illegible]	78,563	29.45
1985	261,930	69,[illegible]	26.86
1984	257,060	61,340	23.86
:			:
[illegible]			7.3
1978			6.[illegible]
1977			5.6
1976			3.1
1975			2.6
1974			1.[illegible]
1973			1.[illegible]
1972			1.[illegible]

GROWTH RATE
① 12,000 units/year
② Distribution by class based on historical [illegible]

1989 38.[illegible]%
1990 41.41

Table III-N

Estimated Diesel Sales as a Percentage of Heavy-Duty Sales for 1984 through 1988 by GVWR (pounds)

Year	8,501-10,000	10,001-14,000	14,001-16,000	16,001-19,500	19,501-26,000	26,001-33,000	33,001 and over	All HD Vehicles
1988	16%	16%	16%	16%	41%	100%	100%	50%
1987	14%	14%	14%	14%	38%	96%	100%	48%
1986	12%	12%	12%	12%	34%	92%	100%	46%
1985	10%	10%	10%	10%	31%	89%	100%	44%
1984	8%	8%	8%	8%	28%	85%	100%	42%

MED

	5.3%	0.9%	2.2%	32.2%	5.9%	25.2%	
YEAR	10-14,999	14-16,999	16-19,999	19,5-26,999	26-33,999	>33	ALL
1991	36,736	6,238	15,249	223,137	40,394	174,662	693,126
1990	37,371	6,346	15,513	227,049	41,602	177,610	705,121
1991	18%	18%	18%	45	100	100	
1990	20	20	20	50	100	100	
	5.3	6.9	2.2	32.2	5.9	25.2	

32.2% 6.4%

Class VI - This class is comprised primarily of "medium-duty" trucks and school buses. Historically, school buses are about 18 percent of the sales each year. In an article published in "Fleet Specialist" magazine, several manufacturers estimated Class VI diesel/truck sales in the mid-eighties. The manufacturers estimated that in 1985 between 35 and 50 percent of Class VI truck sales would be diesel.10/ Currently only about 10 percent are diesel. Our analysis will conversatively use the 35 percent figure. Dieselization in school buses is difficult to estimate. Significant growth in school bus sales is not expected due to declining school enrollments and the almost complete implementation of "court ordered busing." Most school buses do not accumulate enough mileage on a daily basis, and thus enough fuel savings, to fully justify the increased initial cost of a diesel engine. Lacking a more specific estimate, best judgment dictates that by 1990 about 10 percent of all school bus sales will have diesel engines.

Class VII - In 1978 Class VII sales were more than 61 percent diesel with dieselization in this class increasing rapidly over the past five years. Sales in this weight class are expected to become mostly diesel in the mid-eighties. Based on historical ratios, this class should be almost all diesel by 1988.

Class VIII - Sales in Class VIII were over 96 percent diesel in 1978. Based on the recent history in this class, these sales will all be diesel by 1984 or earlier. It is reasonable that by 1984 all Class VIII sales will be diesel.

Using the data in Table III-M, and the criteria in the discussions above, Tables III-O and III-P contain the estimated sales split by weight class between gasoline and diesel engines for the period 1984-1988.

Based on this analysis, the major changes expected give an overall heavy-duty sales growth of about 1.8% per year over the 5 year period (1984-1988). The increased dieselization in all classes will actually lead to a decrease of about 2 percent per year in gasoline-fueled engine sales and an increase of about 6.4 percent per year in diesel engine sales over the 5-year period.

Table III-O

Estimated Diesel Usage in Heavy-Duty Vehicles for 1984 through 1988 by GVWR (pounds)

Year	8,501-10,000	10,001-14,000	14,001-16,000	16,001-19,500	19,501-26,000	26,001-33,000	33,001 and over	All HD Vehicles
1988	30,841	5,776	981	2,398	89,755	40,187	171,645	341,583
1987	26,511	4,965	843	2,061	80,984	37,979	168,623	321,966
1986	22,316	4,179	710	1,735	72,490	35,824	165,600	302,854
1985	18,258	3,419	581	1,419	64,275	33,725	162,578	284,255
1984	14,335	2,685	456	1,114	56,338	31,678	159,555	266,161

Table III-P

Estimated Gasoline-Fueled Usage in Heavy-Duty Vehicles for 1984 through 1988 by GVWR (pounds)

Year	8,501-10,000	10,001-14,000	14,001-16,000	16,001-19,500	19,501-26,000	26,001-33,000	33,001 and over	All HD Vehicles
1988	161,918	30,324	5,149	12,587	129,569	0	0	339,547
1987	162,855	30,499	5,179	12,660	134,478	1,500	0	347,171
1986	163,654	30,650	5,204	12,722	139,110	2,947	0	354,287
1985	164,313	30,774	5,225	12,774	143,463	4,339	0	360,888
1984	164,848	30,872	5,242	12,815	147,536	5,678	0	366,991

Table III-Q

1978 Vehicle and Engine Manufacturer Information

Company	Total Sales ($)	Net Income ($)	No. of Employees
American Motors	2,585,430,000	36,690,000	27,517
Caterpillar	7,219,200,000	566,300,000	84,004
Chrysler	16,340,700,000	-204,600,000	157,958
Cummins Engine	1,520,750,000	64,400,000	23,298
Ford Motor	42,784,100,000	1,588,900,000	506,531
General Motors	63,221,100,000	3,508,000,000	839,000
International Harvester	6,664,350,000	186,680,000	95,450
Mack Trucks	1,640,010,000	68,800,000	17,100
White Motor	1,095,710,000	330,000	9,232

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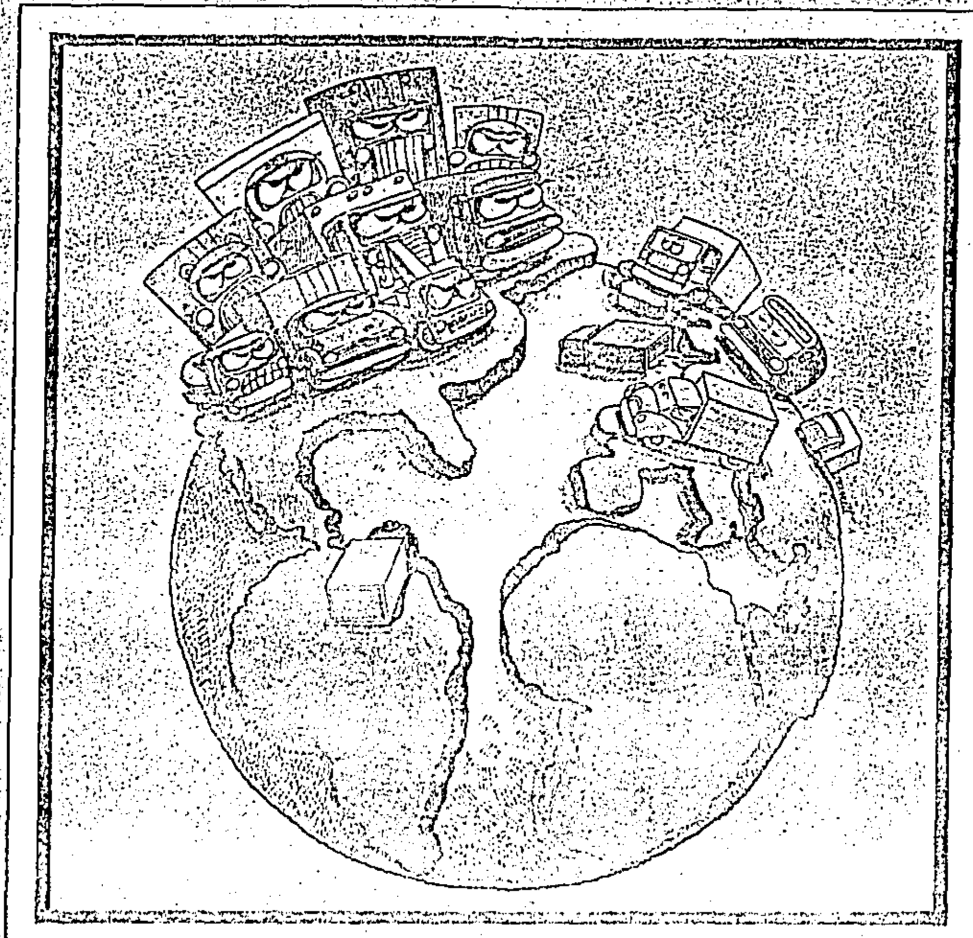
"ON WHAT'S AVAILABLE IN MID-RANGE DIESAL TRUCKS", PAGES 74-97, COMMERCIAL CAR JOURNAL, JAN. 80.



BATTLE OF THE '80s

A CCJ Special Report On What's Available In Mid-Range Diesel Trucks

This special CCJ report on mid-range diesel trucks, engines and components was written and edited by the following staff editors: JAMES WINSOR, *Editor-In-Chief;* BRIAN TAYLOR and RICHARD CROSS, *Feature Editors*; and DAVE RITCHIE, *Technical Editor*. The design work was by staff artist JACK TAYLOR and editing by CARL GLINES, *Managing Editor*

■ A generation ago, a popular advertising slogan proclaimed: "There's a Ford in your future." As we enter the '80s, that slogan will probably read: "There's a diesel in your future."

For fleets operating trucks and school buses in the 18,500- to 33,000-lb GVW weight ranges (classes 6 and 7), your next vehicle may be a diesel, even if your company has been 100% gasoline. One reason is that every 5¢ increase in fuel price makes diesel power that much more attractive.

Furthermore, economics dictate that the higher the gross weight, the more likely it will be diesel.

Translated to numbers, truck manufacturers are making huge financial commitments to develop vehicles for the '80s that will switch the gasoline-diesel mix from 1978's estimated 190,000 mid-range gas and 62,000 diesels to something close to 100,000 gas and 130,000 mid-range diesels annually by 1985. That's a significant turnaround.

The swing to diesel affects far more than the engine. In most cases, you'll be buying a bigger clutch, transmission, driveline and axle to handle the increased torque. Records also show that many fleets going diesel also go "automatic" at the same time.

Chances are you'll also be getting a much bigger battery and starter to crank that diesel and a higher capacity alternator to charge the battery. These are some of the reasons for the higher price tag that goes along with diesel power.

The economics of diesel power

Why do forecasters say so many of you will be going diesel? The answer is simple economics. For years, the premium price to "go mid-range diesel" required 50,000 to 70,000 miles per year to justify the cost. Now, with both diesel and gasoline fuel at $1 and more per gallon, the economics have changed rapidly (see accompanying box).

With a typical medium-duty diesel getting twice as many miles per gallon as gas, it doesn't take long to pay off the added investment.

The race is on

There's no question the battle of the '80s pits the four offshore manufacturers against four U.S. truck giants—Ford, GMC, Chevrolet and International Harvester, and big-name engine companies, Caterpillar, Cummins and Detroit Diesel.

The big question is whether the imports which are substantially different than those of the U.S. manufacturers will be accepted. Or will the U.S. manufacturers, who just now are turning on the heat with new trucks, new engines and volume manufacturing capacity, swamp the "invaders"?

In addition, there are substantial savings to be had in maintenance costs and, based on current used truck prices, it appears the used diesel-powered truck will command *at least* a $2500 premium and perhaps as much as $5000, according to an October 1979 analysis by Caterpillar.

In Europe, where fuel prices are double U.S. prices, diesel power has been a way of life for 20 years. In fact, gas power isn't even offered in trucks much over 10,000-lb GVW!

European manufacturers have a 20-year advantage in developing diesel power. Their know-how is the main reason Mercedes, Volvo, Iveco/Magirus and Mack/Renault are competing today in the U.S. marketplace.

Basic difference to look for

The typical 19,500- to 33,000-lb GVW vehicle is powered by a diesel engine from 150 to 210 hp. Horsepower, of course, isn't the whole story. Vehicle use—percent of time loaded, percent of time operated at expressway speeds, percent of time in stop/start, city vs sustained open-road speeds, tractor vs straight truck service—is the key in deciding what *type* (and possibly what make) you should buy.

Off-shore manufacturers offer a high-quality product with minimum options. As a rule, they offer engine options to meet power requirements and axle options to meet payload needs. Beyond that, options are mainly limited to in-cab features, fuel tank size, tire sizes, etc.

Heavy-duty premium engine features are common in all imports. For example, Mercedes, Iveco/Magirus, Mack/Renault and Volvo all have replaceable cylinder liners. At overhaul time, engines can be rebuilt to original specs.

Each off-shore manufacturer furnishes his own engine. Optional powerplants from independent engine companies are not offered. Also, since these same off-shore OEMs determine most components, there are few, if any restrictions on vehicle application. Generally, these units are equally suited to in-town or over-the-road with lots of idling or sustained turnpike speed operation.

Mercedes, granddaddy of the off-shore manufacturers, imports its vehicles from Brazil. Sales in 1978 were 3700 conventional cab units, a record for M-B.

By contrast, Magirus, Mack's MidLiner and Volvo trucks are all cab-overs—and basically the same cab at that! This arrangement is part of their "Club-Of-Four" consortium. They all stress driver comfort—seating, ride, visibility, low noise.

U.S. manufacturers pour it on

This year will be the first year for "big numbers" in the mid-range diesel from Ford, GMC, Chevrolet and International Harvester. Clearly, they are not going to give away the U.S. truck market.

These four OEMs are now offering a full line of mid-range diesel trucks—both cab-over and conventional—and with a variety of engine options. The fleet buyer will have the same flexibility and choice in spec'ing as he has had in bigger, heavy-duty trucks and tractors.

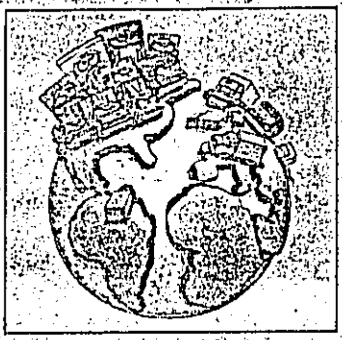
Credit for being the first with mid-range diesel power goes to Caterpillar with its family of 1100 series of V-8 diesels, now the 3208 family.

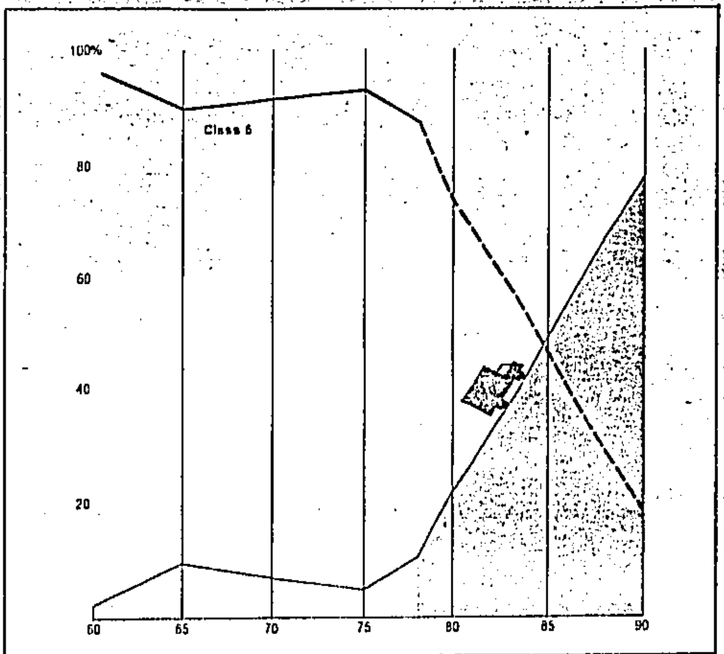
Detroit Diesel, with its family of 53 series two-cycle engines has provided heavy-duty diesel features in a lower, 135 to 195 hp, market.

International Harvester, while offering Cat, Cummins and DDA

Continued

Mid-Range Diesels





power, has been successful in developing two engine families of its own: the DT-466, far and away the firm's most popular engine with 25,000 engine sales in 1979 alone; and the new 9-liter diesel V-8 introduced last September. Recent IH studies indicate this engine offers economic payback for diesel power at as little as 10,000 miles per year.

Cummins, temporarily on the sidelines of the medium-duty engine market, is back with its VT-225, successor to the "triple nickel" V-555.

But the biggest impact on the mid-range market has yet to happen because the much-heralded new Detroit Diesel 8.2-liter (500-cu in.) family of four-cycle V-8s went into production just this month. Reportedly, DDA has invested $200 million in this engine and highly-automated plant which has the capacity to produce 75,000 engines annually!

The 8.2 engine will be heavily touted by Ford this spring in its all new F-model family of conventionals and in Chevrolet's and GMC's mid-size models.

Mid-range diesel price war?

The battle of the '80s may well become a dollar-and-cents battle, too. U.S. manufacturers' capacity to provide mid-range diesel power has more than doubled. In addition, Mack is now writing orders for its Mid-Liner; Mercedes is building an assembly plant in Hampton, Va. with a 4000-vehicle annual capacity; Magirus is in high gear nationally, importing trucks through Philadelphia, Oakland and, later this year, Houston; The Freightliner-Volvo marriage is a year old. Volvo for the first time is now available nationally.

In short, the year is starting out as a buyers' market.

Heavy-duty vs light duty

What will it cost to buy diesel power? Answer: $3000 to $6000 more than for comparable gasoline power. Included in the higher cost are mandatory powertrain options required for diesel power.

The additional $3000 will get you a minimum-spec mid-range vehicle in the 19,500-lb GVW category. The $6000 premium gets you something in the 25,000- to 26,000-lb GVW range with a number of extras, plus a lot of heavy-duty features.

For the buyer, what it ultimately boils down to is: How is the truck to be used? Heavy duty and/or high mileage? Light duty and/or low mileage? Obviously, users will have to spec accordingly and buy accordingly.

What lies ahead?

The Class 6 and 7 diesel market is really two-tiered: light-duty and heavy-duty with engines slotted for each. The challenge for fleets is to spec the best combination which will give the lowest total cost over the life of the vehicle.

Cummins engineering and marketing experts clearly segment the engine business by type of engine service and recommend engine application accordingly. "Heavy-duty" is high mileage, high speed, heavy loads requiring big-bore top-priced large displacement engines. CCJ translation: Cummins' NTC series; Detroit's 71 and 92 series; Cat's 3400 series; Mack's ENDT-675-76-77 and ETAZ engines.

"Medium-duty" means mostly Class 7 and 8 heavy vehicles but not in heavy-duty service. Typically: less than 50,000 miles per year and less than 200-mile range. Typical vehicle is a two-axle tractor or 6 x 4 straight truck. GCW for tractors is 60,000 lb with average GCW of 40,000 lb; straight trucks are less. Typical en-

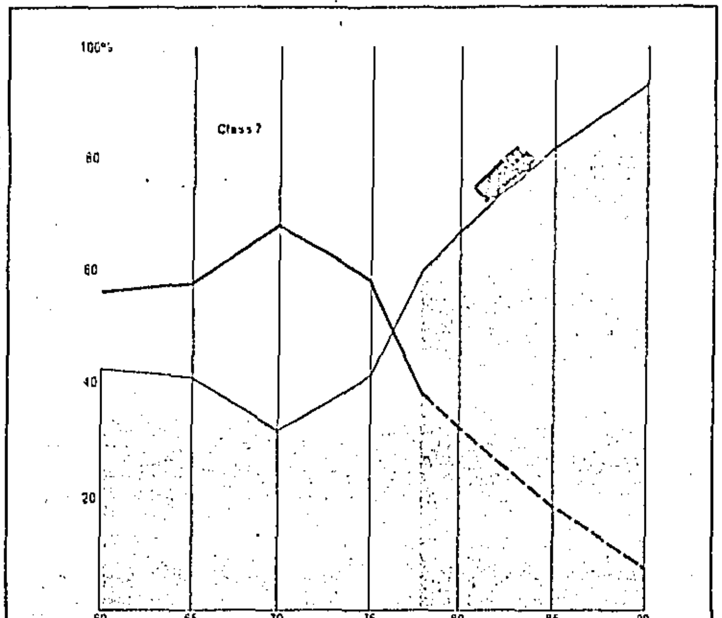
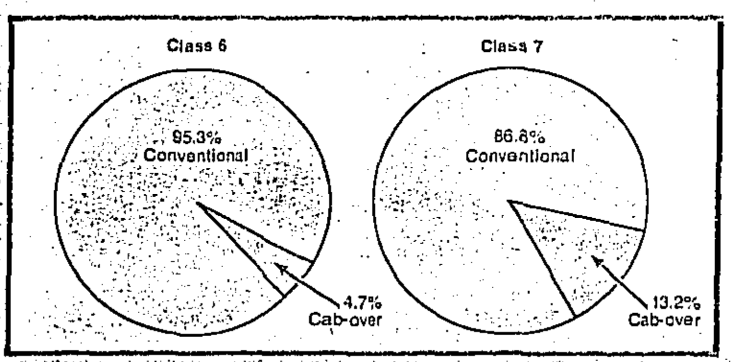


Fig. 5

Class 6 chart (far left) reflects decline in gasoline-powered vehicles over the next decade. Chart shows that by 1985, distribution between gasoline and diesel power in this particular category of mid-range vehicles should be about 50-50. The same situation holds true for Class 7 vehicles (left) except the breakeven point has already occured.



Pie chart shows development of Class 6 and 7. Historically, Class 6 has been dominated —95.3%—by conventional models, according to 1977 figures, while in Class 7 factory sales of conventional models accounted for 86.8%. These figures will change as more cabover models are introduced into the market place.

gine: 210-hp range. CCJ translation: these are the next engine family, a step down from the big-bore heavy duties: Cummins VT-225, Cat 3208, IH DT-466, Detroit 53 series, all sleeved engines used in imported trucks.

"Light-duty," according to Cummins, means vehicles in Classes 4 to 6 usually operated over a range less than 50 miles and less then 20,000 miles per year. Engine load factor is 30% to 35% with engine life to first overhaul either 100,000 miles or vehicle trade-in time. Typical straight truck application in whole-sale/retail delivery service (which includes school bus) is: 13,000 average annual mileage; 26,000-lb max GVW; 16- to 18,000-lb average GVW; CCJ translation: these are the Detroit 8.2-liter V-8 and IH 9-liter V-8.

Other factors to consider

Finally, in weighing gas vs diesel power there are other factors that should be considered:

- **Mechanic training.** If your fleet presently has no diesels, you must start a mechanic training and driver education program. There are also less service locations qualified for diesels if you farm out work.
- **Parts costs and availability.** This is a common complaint today—for both domestic and imported trucks. So-called "captive" parts for offshore trucks are a key consideration because of one-source-only availability. Other points to consider on imports are: which ones have "Americanized" common replacement items like filters, belts, hoses, lights, mirrors? Which models also offer American driveline components such as clutches, transmissions, U-joints and axles?

What lies ahead?

While the gasoline truck engine certainly isn't dead, it is developing emphysemal.

So . . . the battle of the '80s has begun. At least eight domestic and foreign truck builders are competing for the business. And there may be still more. The Japanese have yet to be heard from.

Today, the fleet buyer has more products from more sources to choose from in the medium-size truck than ever before. The balance of this Special Report gives you technical details and product features you should know as you explore the wonderful world of mid-range diesel power.

Continued

COST ANALYSIS: Diesel versus gasoline powered mid-range trucks

FUEL SAVINGS

This analysis, prepared for IVECO Trucks of North America Inc., is based on a 160-hp, 25,500-lb GVW diesel truck compared with a gasoline-powered truck having similar performance capabilities. It's assumed that each vehicle travels 20,000 miles per year; the diesel averages 9.0 mpg against 4.5 mpg for the "gas job." It's also assumed that both gasoline and diesel fuel cost will rise 10% per year over the five-year period used for purposes of comparison.

During the first year of operation, with fuel for both vehicles at $1 per gallon, the diesel will consume 2222 gal where the gas job burns up 4444 gal. Result: a $2222 savings in fuel cost for the diesel user. Considering 10% annual cost-per-gallon increases, the subsequent four years of operation result in an additional $11,332 fuel savings for the diesel user. *The total fuel-cost advantage for the diesel totals $13,554 over a five-year period.*

MAINTENANCE SAVINGS

Based on data collected by Burlington Fleet Services on maintenance cost for more than 1000 gasoline and diesel straight trucks used for pickup and delivery service by 15 fleets, the following analysis assumes that both the diesel- and gasoline-powered trucks are driven 20,000 miles annually. The analysis was done by *Diesel Equipment Superintendent.*

Gasoline-powered truck

1st year: .0792 ¢/mile = $1584
2nd year: .1260 ¢/mile = $2520
3rd year: .1430 ¢/mile = $2860
4th year: .1625 ¢/mile = $3250
5th year: .1795 ¢/mile = $3590

Diesel-powered truck

1st year: .0547 ¢/mile = $1094
2nd year: .0496 ¢/mile = $ 992
3rd year: .0676 ¢/mile = $1352
4th year: .0740 ¢/mile = $1480
5th year: .1043 ¢/mile = $2086

The cumulative difference between maintenance expense for a diesel truck versus a gasoline-powered truck over this five-year period equates to an advantage of $6800 for the diesel user.

DEPRECIATION COST

Assuming a diesel truck costs about $4000 more than its gasoline-powered counterpart, depreciating the diesel on a straight-line basis (at 15% per year over five years, with a salvage value of 25%) will cost approximately $600 per annum for a total of $3000.

INTEREST SAVINGS

The extra initial cost of a diesel truck incurs additional interest costs over the first two years of ownership. But in the subsequent three years, savings on fuel, maintenance and refueling man-hours actually accumulate interest on the money saved. The assumed interest rate is 12% per year on the extra investment and the accumulated savings in operating costs.

REFUELING SAVINGS

Assuming the diesel truck travels 20,000 miles per year and averages 9 mpg, it'll use 2222 gal of fuel per year. A diesel with a 50-gal tank will have to be refueled about 44 times a year.

Running the same annual mileage, a gasoline-powered truck will use 4444 gal of fuel at 4.5 mpg and have to be refueled approximately 88 times a year.

Making the assumption that filling a tank takes a quarter man-hour, those 44 fewer fuelings required by the diesel truck translate to a savings of 11 man-hours per year. At $10 per man-hour, this saves $110 per year, or $550 over a five-year period.

ADDITIONAL SAVINGS

While not included in the summary of diesel cost advantages, a five-year-old diesel truck may be expected to bring approximately $2000 more than a comparable gasoline-powered truck of the same vintage.

Further, there's "investment tax credit" to consider. Depending on tax bracket, truck owners may be able to deduct 10% of the purchase price to partially offset the extra cost of a diesel. In addition, the higher price of the diesel provides larger income tax deductions for depreciation.

5-YEAR SUMMARY
(Before Tax Considerations)

	FUEL SAVINGS	MAINTENANCE SAVINGS	DEPRECIATION (COST)	INTEREST SAVINGS (COST)	REFUELING MAN-HOURS	TOTALS
FIRST YEAR	$ 2,222	$ 490	$ (600)	$ (480)	$110	$ 1,742
SECOND YEAR	2,444	1,528	(600)	(127)	110	3,355
THIRD YEAR	2,688	1,508	(600)	420	110	4,126
FOURTH YEAR	2,956	1,770	(600)	1,059	110	5,295
FIFTH YEAR	3,244	1,504	(600)	1,838	110	6,096
	$13,554	$ 6,800	$ (3,000)	$ 2,710	$550	$20,614
TOTAL FIVE YEAR SAVINGS						$20,614

Courtesy of IVECO Trucks of North America, Inc.

IH compares specific diesel and gasoline engines

A specific example of diesel cost savings is provided by International Harvester's own analysis comparing annual cost of the following equipment:

- An IH 1724 truck with MV-404, two-barrel, V-8 gasoline engine.
- An IH 1754 truck with 9.0-liter, 165-hp V-8 diesel engine.

Both of these vehicles are assumed to travel 20,000 miles per year. Miles-per-gallon data for both engines are computer-simulated averages for city and suburban use, based on actual tests. Maintenance-cost-per-mile figures are averages established by the American Trucking Associations' Regular Common Carrier Conference. All computations are rounded off to the nearest whole number.

The conclusion of the following analysis is that the diesel pays off the price difference with a gasoline truck in 14 months. The price difference is $3028.75.

FUEL SAVINGS

The diesel may be expected to run at 8.41 mpg, compared with 4.54 mpg for the gasoline-powered IH truck. In 20,000 miles, the diesel consumes 2378 gal of fuel against 4405 gal for the gasoline-powered truck. At the time these calculations were made, diesel fuel was selling for 71¢/gal and gasoline was available at 81¢/gal. Annual fuel savings for the diesel totaled $1880.

MAINTENANCE SAVINGS

Maintenance cost over 20,000 miles for the diesel (at .0201¢/mile) versus that for the gasoline truck (at .0528¢/mile) equates to an annual savings of $654 credited to the diesel.

REFUELING SAVINGS

IH assumes 250 working days per year with the diesel being refueled once every two days against once a day for the gasoline truck. Assuming a quarter man-hour to fill a tank, at $6.07 per man-hour, the 125 less fuel stops required by the diesel translates into an annual savings of $188.

SUMMARY

Combining fuel, maintenance and man-hour savings, the 9.0-liter IH diesel is expected to save $2722 per year in comparison with the IH gasoline engine.

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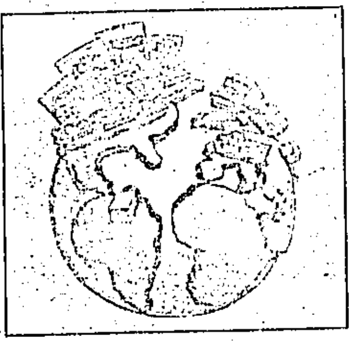
PART 2



Mid-Range TRUCKS

The beginning of the 1980s heralds the start of a race for a share of the mid-range diesel truck market. While some manufacturers have been in this market for years—principally foreign makers who are the mid-range diesel pioneers—1980 marks the first time everything is falling into place. Competitive engines are now available to U.S. truck makers in quantity, and, spurred by skyrocketing gasoline prices, user interest in mid-range diesels is significant.

The following section covers all mid-range diesel trucks available to U.S. buyers. In putting it together, CCJ editors faced a number of complex problems.

First, while there is a separate section titled "Engines," we decided to include in this section "captive" engines along with the vehicles in which only they are available. Therefore, Mercedes-Benz, Magirus/Iveco, Volvo, Mack and International Harvester engines will be covered along with those makers' vehicles.

Next, we had to decide how best to include the various specifications and features. For example, the basic specifications of European-made trucks are relatively straightforward. In most cases, what you see is what you get. There are very few options.

Domestic-made trucks present a different problem. Following the U.S. practice of offering a wide variety of options for almost every component, the domestics make it impossible to list a "basic" set of specifications. While an off-shore manufacturer may offer one or two transmission options, some U.S. models can be had with up to 20 different transmissions to choose from. Further complicating the picture is the fact that all the U.S. models were designed basically as gasoline-powered trucks. They become mid-range diesels only with the spec'ing of diesel engines and components. That means spending considerable time with the data book.

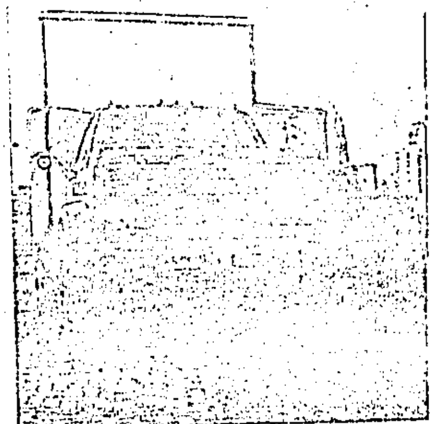
Our solution is to list the specifications of the European models since the specifications are limited. For U.S. makes, we have presented a range of specs, highlighting the more important ones.

CHEVROLET

Engine model	Net Power (hp @ rpm)	Gross Power (hp @ rpm)
DDA4-53T(55)	146 @ 2500	155 @ 2500
DDA4-53T(60)	161 @ 2500	170 @ 2500
DDA 8.2L V8	153 @ 3000	165 @ 3000
DDA 8.2L V8	193 @ 3000	205 @ 3000
CAT 3208	164 @ 2800	175 @ 2800
CAT 3208	199 @ 2800	210 @ 2800

Chevrolet's entries include its C60 and C70 series models. The C60 is in Class 6 with GVWs ranging up to 24,000 lb and is available with two versions of the Detroit Diesel 4-53T engine. The C60 is offered in the single axle 4 x 2 configuration.

Covering both Class 6 and 7 markets is the C70 model with GVWs ranging from 19,200 lb to 33,200 lb. The single axle C70 is available with the DDA 4-53T engine, while tandem axle models offer the DDA 8.2L and Caterpillar 3208 engines. When ordered with the Cat 3208 diesel, the C70 comes fitted with a 92.5-in.



Chevrolet, in foreground with "Cat" hood

BBC cab featuring fiberglass tilt hood, rectangular headlights and new grille. In addition, the 3208 cab is 7-in. higher than the standard version, offering a more commanding view of the road. The C70 is also available with a 92-in. BBC.

A full range of transmissions is available from Clark, Fuller, New Process and Spicer. Automatic transmissions are also offered. One- and two-speed Chevrolet and Eaton axles are available on single rear axle models, while Eaton and Rockwell units are offered with tandem axle vehicles.

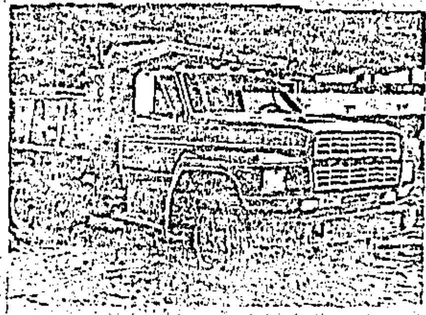
Front suspensions include drop forged steel I-beams working with double acting shocks and multi-leaf, two-stage type springs with tapered rolled ends. Power steering is available on most models.

Braking systems include dual power air/hydraulic brakes or full air brake systems. In addition, Chevrolet offers "Trac Pac" for tractor models which makes available a hydraulically-braked tractor with air controls for pulling air-braked trailers.

Highlighting a long list of options is a new integral air-conditioning system which allows the compressor to cycle on and off as needed. A variety of interiors is also offered.

Continued

Mid-Range/TRUCKS



Ford F-Series

FORD

Engine Model	Net Power (hp @ rpm)	Gross Power (hp @ rpm)
DDA 8.2L V8	NA	165 @ 3000
DDA 8.2L V8	NA	205 @ 3000
CAT 3208	NA	175 @ 2800
CAT 3208 Calif.	NA	200 @ 2800
CAT 3208	NA	210 @ 2800
Cummins VT-225	NA	225 @ 3000

A new truck and a new diesel engine mark Ford's entry into the field. The all new F-series trucks are available with GVWs ranging from 16,500 to 31,000 lb and GCW ratings up to 60,000 lb. BBC is 102 in.

The DDA 8.2L naturally aspirated diesel rated at 165 hp is optional in the F-600, F-700 and F-800 models. The turbocharged version at 205 hp is offered in the F-700 and F-800 models.

The fiberglass front end features *built-in steel reinforcements,* straight frame rails and a front suspension system similar to the Ford L-series. The new chassis features longer front springs than the model it replaces for better ride, while rear spring eyes have rubber bushings on most axles for reduced maintenance.

Greater maneuverability is achieved through a new front axle designed on a wider track which increases wheel turn angle.

Two new rear axles, rated at 17,500 and 18,500 lb, feature induction hardened carbon steel spindles and a pressurized lubrication system. A third rear-axle option is a two-speed planetary axle with a 22,000-lb rating.

A wide variety of transmissions are available, including the Allison AT-540 and MT-643 automatics. Selector controls for these units are column mounted.

Other features include power steering, a new hydraulically powered split braking system which eliminates frame-mounted vacuum boosters and a foot operated parking brake, all standard.

In-cab comfort is improved with an optional high output heater which is available with integral dash mounted air conditioning.

C-Series

For those requiring a low-entry COE, Ford offers its C-Series, with Cat 3208 diesel engine.

The C-700 can be ordered with GVWs ranging from 21,000 to 27,500 lb, while the C-8000 carries a GVW rating ranging from 25,100 to 39,000 lb. Both have a 90.5-in. BBC cab.

Features of the C-Series include power steering as standard along with a split brake system on models fitted with either air or hydraulic brakes.

The Clark 390 V 5-speed transmission is also standard with five other 5-speed models offered as options, along with the 10-speed Fuller RT 610. Additionally, the C-8000 model can also be ordered with the Allison MT-653 automatic.

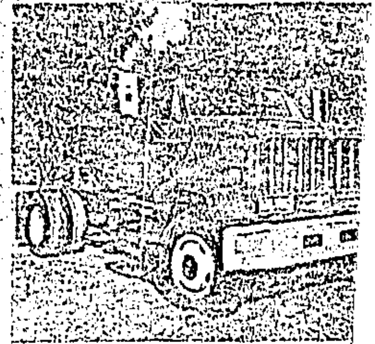
To make servicing easier, the cab tilts 45 degrees. Engine coolant or oil can be added through an access panel behind the passenger seat.

L-Series

Ford's larger line of conventionals, the L-Series, also falls into the medium-duty mid-range diesel market. Engines offered include the Cat 3208 series and Cummins VT-225.

The short cab, 95.3-in. BBC, LN-7000 comes with either standard or custom interior. The front end is steel-reinforced fiberglass. Standard braking is vacuum-hydraulic with optional air brakes. GVW ratings range from 21,000 lb to 27,500 lb.

The L- and LN-8000 models come standard with air brakes with vacuum-hydraulic brakes available as an option. The GVW ratings for these models range from 23,100 lb to 35,000 lb, depending on selected axle options. The L-8000 has a 105.3-in. BBC; the LN-8000, a 93.3-in. BBC.



GMC "Top Kick"

GMC

Engine Model	Net Power (hp @ rpm)	Gross Pow (hp @ rpm
DDA4-53T(55)	146 @ 2500	155 @ 250
DDA4-53T(60)	161 @ 2500	170 @ 250
DDA 8.2L V8	153 @ 3000	165 @ 30
DDA 8.2L V8	193 @ 3000	205 @ 30
CAT 3208 V8	149 @ 2800	160 @ 28
CAT 3208 V8	164 @ 2800	175 @ 28
CAT 3208 V8 Calif.	189 @ 2800	200 @ 28
CAT 3208 V8	199 @ 2800	210 @ 28
Cummins VT-225	212 @ 3000	225 @ 3

A new, diesel-powered " Kick" highlights GMC's entry the mid-range diesel mar Featuring a high cab and 92. BBC, the Top Kick was engine for the Caterpillar 3208 series o gines and the new Cummins VT engine. A lightweight fiber hood tilts for easy engine a while the short BBC will operators to pull a 45-ft trailer.

Other than a wider engine ing, Top Kick models are si to the Chevrolet models al described.

INTERNATIONAL

Engine Model	Net Power (hp @ rpm)	Gross Power (hp @ rpm)
IH 9.0L V8	155 @ 2800	165 @ 2800
IH 9.0L V8	170 @ 2800	180 @ 2800
IH DT-466	169 @ 2600	180 @ 2600
IH DT-466	179 @ 2600	190 @ 2600
IH DT-466	199 @ 2600	210 @ 2600
CAT 3208	164 @ 2800	175 @ 2800
CAT 3208	199 @ 2800	210 @ 2800

International Harvester's mid-range diesels include two basic models: the cab-over Cargostar series and conventional S-Series.

Cargostar

The low-step entry COE Cargostar has an easy access cab with 70-in. BBC. Since the 80-in. wide track front axle is set well back, the vehicle maneuvers easily while offering improved load distribution. Another advantage is the extra cab room. Most models feature a flat floor with no engine doghouse. In addition, the driver's field of view comes within a few inches of the front bumper.

A wide variety of transmissions—manual and automatic—is available. Equally numerous are the front and rear axle offerings which allow the Cargostar to be spec'ed for GVWs covering the full medium-duty range.

Options abound with power steering, oversized fuel tanks, steel disc wheels and a wide selection of tires heading the list.

All tandem axle models are air brake equipped while other models have vacuum-hydraulic brakes as standard with air brakes as an option.

For ease of servicing, the cab tilts 45 degrees with aid of a hydraulic cylinder.

The two Cargostar models which fall into the mid-range diesel category are the CO-1850B with GVWs ranging from 21,700 to 33,200 lb, and the CO-1950B with GVWs from 25,160 to 39,000 lb.

S-Series

International's medium-duty conventional S-series includes a variety of models covering the complete mid-range GVW range.

Lock-on front spring shackles on 9000-lb and larger axles, plus lock-on spring pins give the S-Series durability and strong pin retention.

Components offered with the S-Series include a variety of engines with horsepowers ranging from 155 to 199 net to multi-speed manual and automatic transmissions and various capacity axles.

The standard braking system is a hydraulic power dual split system which features an electric pump backup for reserve braking. Air brakes are also available.

Diesel powered S-Series models include: 1700 and 1800 short conventional trucks, both with single axle, GVW up to 45,000 lb, and 97.5-in. BBC; 1900 single axle 97.5-in. BBC short conventional truck or tractor, or a tandem-axle 100.3-in. BBC conventional truck, GVW up to 65,000 lb; 2100 91.3-in. BBC short conventional tractor, single axle, GVW up to 65,000 lb.

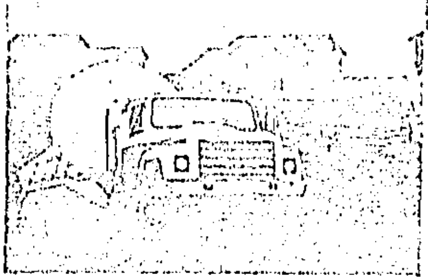
Options for the S-Series include a driver's suspension seat, in-dash heating and air-conditioning system, power steering and adjustable steering column. Power steering is standard on 4 x 4 and 6 x 6 models.

I-H engines

9.0 Liter

A new member of the International family of diesel engines is the 9.0-liter (55.1-cu in.) naturally aspirated four-cycle, valve-in-head, V-8. The 9.0L is available in two gross horsepower ratings, 165 and 180 at 2800 rpm. The 165-hp version delivers 366 lb ft peak torque at 1200 rpm, with 18% torque backup. The 180-hp version produces 401 lb ft peak torque at 1200 rpm, with 19% torque backup.

The 9.0L features an open-chamber, direct injection combustion system with 19.1 to 1 compression ratio and 4.5-in. bore by 4.3-in. stroke. Other features include: conventional three ring design aluminum alloy piston with Ni-Resist top ring insert plus chromed top and oil ring; spin-on throw-away type fuel and lube oil filters; full pressure lubrication; replaceable intake and exhaust valve inserts and guides; positive valve rotators; carbide wafer-faced tappets; gear train with all hardened gears; in-line multiple plunger fuel injection pump with all-speed governor; built-in excess fuel device provides unaided cold starts to 0°F; fully counterbalanced and hardened forged steel crankshaft with torsional vibration damper; constant tension main belt drive system; injection nozzles mounted outside the cylinder head covers for easy servicing; weight of 1270 lb.



International S-Series

DT-466

International's DT-466 in-line six-cylinder four-cycle diesel has a displacement of 466 cu. in. and a dry weight of 1477 lb with standard accessories. There are five different versions available (*all figures are gross ratings*): 160 hp at 2400 rpm with 402 lb ft of torque at 1800 rpm; 180 hp at 2600 rpm with 440 lb ft of torque at 1800 rpm; 190 hp at 2600 rpm with 464 lb ft of torque at 1800 rpm; 210 hp at 2600 rpm with 488 lb ft of torque at 1800 rpm; and 210 hp at 2600 rpm with 488 lb ft of torque at 1800 rpm which is intercooled. All DT-466 engines are tubocharged.

The DT-466 features an open chamber direct injection combustion system with 16.3 to 1 compression ratio. Bore and stroke is 4.30 x 5.35 in.

Standard equipment includes belt driven air compressor; remote mounted air cleaner; 12-volt, 65-amp alternator; two 12-volt, 194-amp hour batteries. Other features are: rebuilt in-chassis ability; replaceable wet sleeves with induction-hardened bores plateau-honed for superior oil control, long life and short break-in time; replaceable valve inserts and valve guides; oil cooled pistons; and regrindable induction hardened crankshaft with hardened fillets.

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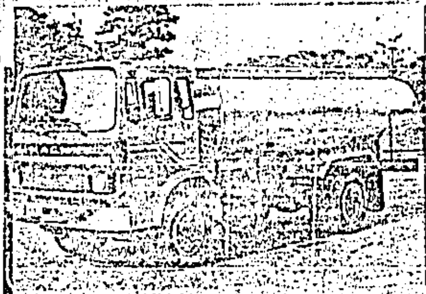
Mid-Range/TRUCKS



Mack Mid-Liner

MACK

Engine Model	Net Power (hp @ rpm)	Gross Power (hp @ rpm)
RVI	NA	175 @ 2800
RVI	NA	210 @ 2400

MACK MID-LINER MS200P
25,000-28,000 GVW Truck

ENGINE(S)	
Model	RVI 175 hp
TRANSMISSION(S)	
Model	Spicer 5052A 5-speed synchro
AXLES	
Front axle capacity (lb)	7500
Rear axle capacity (lb)	17,500
Rear axle ratio	NA
BRAKES	
Service brake	air over hydraulic
Parking brake	sprint/air
Total brake area	NA
WHEELS	
Tires	9.00-22.5 10 PR (6)
Rims	disc (6)
SUSPENSION	
Front	eye and slipper multi-leaf, shock absorbers
Rear	multi-leaf main and helper
ELECTRICAL	
Starter	12 V
Alternator	Motorola 12 V/45 A
Battery	(2) 12 V Delco
WEIGHTS (with driver)	
Front axle (lb)	NA
Rear axle (lb)	NA
Total (lb)	NA
Payload & body allowance (lb)	NA
DIMENSIONS	
Wheelbase (in.)	112-193 in. (133-in. std)
BBC (in.)	69
FUEL TANK	
Capacity (gal)	35

OPTIONS
- Allison AT540 auto. trans.
- 55-gal fuel tank
- 9500-lb front axle
- Power steering
- 20,000-lb rear axle, single reduct.
- Driver suspension seat
- Eaton 18,500-lb rear axle, 2-speed
- Tires, bias, wide selection from 8.25-20 10 PR to 11-22.5 12 PR
- Tires, radial, wide selection from 8.25-20 10 PR to 11.22.5 14 PR
- Alternator, Motorola 70 A

MACK MID-LINER MS300P
29,500-31,500 GVW Truck
Same as above except:

ENGINE(S)	
Model	RVI 210 hp
TRANSMISSION(S)	
Model	RVI 5-speed synchro
AXLES	
Front axle capacity (lb)	9500
Rear axle capacity (lb)	20,000
Rear axle ratio	5.13
BRAKES	
Service brake	
Parking brake	
Total brake area	
WHEELS	
Tires	10.00-22.5 10 PR (6)
Rims	
SUSPENSION	
Front	
Rear	
ELECTRICAL	
Starter	
Alternator	
Battery	(3) 12 V Delco
WEIGHTS (with driver)	
Front axle (lb)	
Rear axle (lb)	
Total (lb)	
Payload & body allowance (lb)	
DIMENSIONS	
Wheelbase (in.)	
BBC (in.)	
FUEL TANK	
Capacity (gal)	

OPTIONS
- Allison MT643 auto. trans.
- RVI 10-speed synchro trans.

MACK MID-LINER MS300T
55,000 GCW Tractor
Same as above except:

ENGINE(S)	
Model	
TRANSMISSION(S)	
Model	
AXLES	
Front axle capacity (lb)	
Rear axle capacity (lb)	
Rear axle ratio	
BRAKES	
Service brake	full air
Parking brake	Anchorlock service chamber/spring brake
Total brake area	NA
WHEELS	
Tires	
Rims	
SUSPENSION	
Front	
Rear	
ELECTRICAL	
Starter	
Alternator	
Battery	
WEIGHTS (with driver)	
Front axle (lb)	
Rear axle (lb)	
Total (lb)	
Payload & body allowance (lb)	
DIMENSIONS	
Wheelbase (in.)	112
BBC (in.)	
FUEL TANK	
Capacity (gal)	

OPTIONS
- Eaton 22,000-lb rear axle, 2-speed
- Vertical exhaust
- Single air horn

Newest entry in the mid-range market is the Mack Mid-Liner, product of a cooperative effort between Mack Trucks and Renault Vehicles of France. While the Mid-Liner has French connections, it was definitely reared in the U.S. as evidenced by the number of American made accessories and components.

While the spec sheet tells the basic story, the Mid-Liner does carry a number of European touches as standard equipment. Full instrumentation and deluxe cab interiors are the most visable signs of the Mid-Liner's European heritage.

Supporting the vehicle, Mack has opened a new parts depot near Baltimore, Md., and anticipates having 300 Mid-Liner dealers by the end of 1980. While the Class 6 MS-200P truck is available now, the Class 7 MS-300P & T truck and tractor will not be available until October.

Engines

The 175-hp RVI engine is both turbocharged and aftercooled. The 210-hp version is turbocharged. The wet-sleeved RVI diesels feature a 12-volt Bosch heavy-duty starter system, provision for cold starting and Mack's spin-on, disposable lube, fuel and water filters. Other engine items include Donaldson dry-type air filters, Garrett AiResearch turbochargers and Robert Bosch in-line type injection systems.

The 175-hp version is 335 cu in. with a bore and stroke of 4.02 x 4.41 in. and is rated at 370 lb ft gross torque at 1800 rpm. The 210-hp engine is 537 cu in. with a bore and stroke of 4.72 x 5.12 in. and is rated at 570 lb ft of gross torque at 1500 rpm.

MAGIRUS

Engine Model	Net Power (hp @ rpm)	Gross Power (hp @ rpm)
FIAT 8360.05	NA	160 @ 2600
FIAT 8220.02	NA	200 @ 2600

MAGIRUS 160A11FL 25,500 GVW Truck

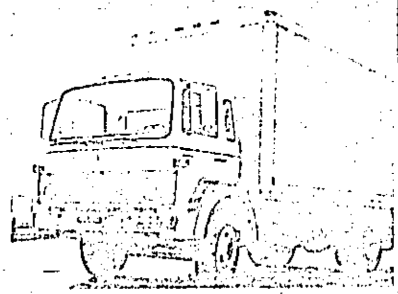
ENGINE(S)	
Model	FIAT 8360.25
TRANSMISSION(S)	
Model	FIAT 1.2860 5-speed, synchro on top 4. Total ratio first gear 6.5
AXLES	
Front axle capacity (lb)	8000
Rear axle capacity (lb)	17,500
Rear axle ratio	4.55 single speed
BRAKES	
Service brake	air assist hydraulic
Parking brake	spring load on rear wheels
Total brake area	503 sq in.
WHEELS	
Tires	8.25-20 10 PR (6)
Rims	6.5-20 disc wheels (6)
SUSPENSION	
Front	progressively acting half-elliptical leaf-springs shock absorbers
Rear	progressively acting half-elliptical leaf-springs rear stabilizer bar
ELECTRICAL	
Starter	12 V/4.3 hp
Alternator	14 V/45 A
Battery	2 x 12 V 110 Ah
WEIGHTS (with driver)	
Front axle (lb)	5633
Rear axle (lb)	2782
Total (lb)	8415
Payload & body allowance (lb)	17,085
DIMENSIONS	
Wheelbase (in.)	110.2-192.9 (165.4 std.)
BBC (in.)	71.3
FUEL TANK	
Capacity (gal)	30 (50 & 70 duals opt.)

OPTIONS
- Automatic transmission
- FIAT 1.2860 5 x 2 sync. transmission
- 9.00 x 20 12 PR tires, 7.0-20 disc wheels
- Tubeless 11:00 x 22.5 12 PR tires, 7.5 x 22.5 wheels
- Power steering
- Air conditioner
- Power Take-off
- Engine shutdown system
- Air horn(s)
- Chrome bumper
- Mud flaps, hangers
- Striping kits
- Tachometer
- Spare tire, rim
- JEB electric engine heater
- Ether starting kit

MAGIRUS 160A13FL 29,800 GVW Truck Same as above except:

ENGINE(S)	
Model	
TRANSMISSION(S)	
Model	
AXLES	
Front axle capacity (lb)	9500
Rear axle capacity (lb)	20,300
Rear axle ratio	
BRAKES	
Service brake	
Parking brake	
Total brake area	655 sq in.
WHEELS	
Tires	9.00-20 12 PR (6)
Rims	7.0-20 disc wheels (6)
SUSPENSION	
Front	
Rear	
ELECTRICAL	
Starter	
Alternator	
Battery	
WEIGHTS (with driver)	
Front axle (lb)	5758
Rear axle (lb)	2998
Total (lb)	8756
Payload & body allowance (lb)	21044
DIMENSIONS	
Wheelbase (in.)	
BBC (in.)	
FUEL TANK	
Capacity (gal)	

OPTIONS
- 2-speed rear (4.88/6.67)
- 10.00 x 20 12 PR tires, 7.5-20 disc wheels
- Tubeless 11-22.5 12 PR tires, 7.5 x 22.5 wheels



Magirus/Iveco

MAGIRUS 200A13FL 29,800 GVW Truck Same as above except:

ENGINE(S)	
Model	FIAT 8220.02
TRANSMISSION(S)	
Model	FIAT 1.2860 5 x 2 synchro transmission first gear 7.01, tenth gear 0.80
AXLES	
Front axle capacity (lb)	
Rear axle capacity (lb)	
Rear axle ratio	4.88 single speed
BRAKES	
Service brake	full air
Parking brake	
Total brake area	
WHEELS	
Tires	
Rims	
SUSPENSION	
Front	
Rear	
ELECTRICAL	
Starter	12 V/4.76 hp
Alternator	14 V/55 A
Battery	
WEIGHTS (with driver)	
Front axle (lb)	6105
Rear axle (lb)	3037
Total (lb)	9142
Payload & body allowance (lb)	20,658
DIMENSIONS	
Wheelbase (in.)	
BBC (in.)	
FUEL TANK	
Capacity (gal)	

OPTIONS
- 23,000-lb rear axle
- Automatic alcohol evaporator
- Automatic water ejector

MAGIRUS 200A13FS 50,000 GCW Tractor Same as above except:

ENGINE(S)	
Model	

Continued

TRANSMISSION(S)

Model	FIAT 1.2860 5-speed, synchro on top 4. Total ratio first gear 6.5

AXLES

Front axle capacity (lb)	
Rear axle capacity (lb)	
Rear axle ratio	4.88/6.67 two-speed

BRAKES

Service brake	
Parking brake	
Total brake area	712 sq in.

WHEELS

• Tires	10:00-20 12 PR (6)
Rims	7.5-20 disc wheels

SUSPENSION

Front	
Rear	

ELECTRICAL

Starter	
Alternator	
Battery	

WEIGHTS (with driver)

Front axle (lb)	6525
Rear axle (lb)	3307
Total (lb)	9832

DIMENSIONS

Wheelbase (in.)	110.24
BBC (in.)	–

FUEL TANK

Capacity (gal)	50

OPTIONS

- 70-gal fuel tank
- 5th wheel

MAGIRUS

ENGINE SPECS

Model	FIAT 8360.05
Displacement	494.33 cu in.
Bore/Stroke	4.53/5.12 in.
Horsepower	160 at 2600 rpm
Maximum torque	376 ft lb at 1600 rpm
Operating cycles	4-stroke
Number of cylinders	6 in-line
Compression ratio	17.5:1

ENGINE EQUIPMENT

Fuel injection system	Robert Bosch
Air compressor	Marolli one cylinder
Clutch	Single disc dry plate, 14 in.
Air cleaner	Dry
Oil filter	Full flow

ENGINE SPECS

Model	FIAT 8220.02
Displacement	584.01 cu in.
Bore/Stroke	4.92/5.12 in.
Horsepower	200 at 2600 rpm
Maximum torque	470 ft lb at 1600 rpm
Operating cycles	4-stroke
Number of cylinders	6 in-line
Compression ratio	17.5:1

ENGINE EQUIPMENT

Fuel injection system	Robert Bosch
Air compressor	Marolli one cylinder
Clutch	Single disc dry plate, 15 in.
Air cleaner	Dry
Oil filter	Full flow

German built, with strong Italian ties, the Magirus truck by Iveco is offered in three models, two trucks and one tractor.

The COE Magirus features a cab that tilts forward 52 degrees for easy engine access. The chassis members are all uncurved, perpendicular and untapered so they can be easily shortened or lengthened. The frames can also be welded. For extended vehicle life, there is polyethylene undercoating in the engine tunnel and under the fenders.

Backing up the dealer's network, Magirus has a parts center outside Philadelphia, Pa., with a $2.5 million inventory. Regional parts and service centers are being planned for Chicago, Ill., Houston, Tex., and Oakland, Calif.

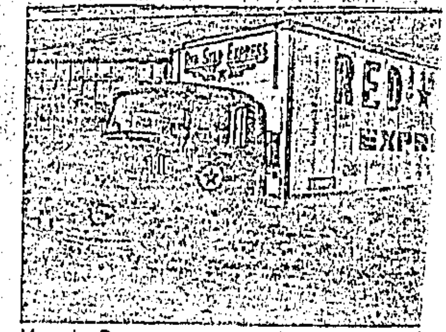
The Magirus warranty covers the entire vehicle for 12 months or 25,000 miles, while the engine, transmission and rear axle are covered for 24 months or 100,000 miles.

Engines

The Magirus Fiat 8360.05 diesel has a displacement of 494.33 cu in. and a bore and stroke of 4.53 x 5.12 in. Rated at 160 hp with a gross torque rating of 376 lb ft at 1600 rpm, the engine is a straight six cylinder design, four-stroke with a 17.5 to 1 compression ratio.

The Fiat 8220.02 diesel features a displacement of 584.01 cu in., bore and stroke of 4.92 x 5.12 in. and also a 17.5 to 1 compression ratio. The 200-hp engine has a gross torque rating of 470 lb ft at 1600 rpm.

Both engines include in their design: wet-sleeve liners; regrindable cranks; replaceable seats and guides for intake and exhaust valves; three-ring forged-aluminum pistons with a cast-iron insert to keep the top ring from flexing and wearing the piston.



Mercedes Benz

MERCEDES-BENZ

Engine Model	Net Power (hp @ rpm)	Gross Power (hp @ rpm)
M-B OM 352	120 @ 2800	130 @ 2800
M-B OM 352/A	145 @ 2800	156 @ 2800
M-B OM 355/5	170 @ 2200	180 @ 2200

MERCEDES-BENZ L1013 22,000 GVW Truck

ENGINE(S)

Model	M-B OM 352

TRANSMISSION(S)

Model	M-B 5-speed, full synchro, total ratio first gear 7.5

AXLES

Front axle capacity (lb)	7500
Rear axle capacity (lb)	14,500
Rear axle ratio	4.875 or 5.714 single speed

BRAKES

Service brake	air assist hydraulic 2 circuit
Parking brake	manual on rear wheels
Total brake area	535.36 sq in.

WHEELS

Tires	8 25-20 12 PR (6)
Rims	7.00-20 (6)

SUSPENSION

Front	telescopic shock absorbers with half-elliptical leaf-springs
Rear	half-elliptical leaf-springs with progressively acting auxilliary springs

ELECTRICAL

Starter	12 V/4 hp
Alternator	14 V/55 A
Battery	172 Ah

WEIGHTS (with driver)

Front axle (lb)	5336
Rear axle (lb)	3042
Total (lb)	8378

Payload & body allowance (lb) 13,622
DIMENSIONS
Wheelbase (in.) 141.7-203.5
BBC (in.) 87
FUEL TANK
Capacity (gal) 53
OPTIONS
- Power takeoff (Power steering std.)

MERCEDES-BENZ L1113
25,000 GVW Truck
Same as above except:

ENGINE(S)
Model
TRANSMISSION(S)
Model
AXLES
Front axle capacity (lb) 8160
Rear axle capacity (lb) 16,840
Rear axle ratio
BRAKES
Service brake
Parking brake
Total brake area
WHEELS
Tires 9.00-20 12 PR (6)
Rims
SUSPENSION
Front
Rear
ELECTRICAL
Starter
Alternator
Battery
WEIGHTS (with driver)
Front axle (lb) 5300
Rear axle (lb) 3244
Total (lb) 8544
Payload & body allowance (lb) 16,456
DIMENSIONS
Wheelbase (in.)
BBC (in.)
FUEL TANK
Capacity (gal)
OPTIONS
- Power steering
- Power takeoff

MERCEDES-BENZ L1116
25,000 GVW Truck
Same as above except:

ENGINE(S)
Model M-B OM 352/A turbo
TRANSMISSION(S)
Model
AXLES
Front axle capacity (lb)
Rear axle capacity (lb)
Rear axle ratio
BRAKES
Service brake
Parking brake
Total brake area
WHEELS
Tires
Rims
SUSPENSION
Front
Rear
ELECTRICAL
Starter
Alternator
Battery
WEIGHTS (with driver)
Front axle (lb) 5351
Rear axle (lb) 3279
Total (lb) 8360
Payload & body allowance (lb) 16,370
DIMENSIONS
Wheelbase (in.)
BBC (in.)
FUEL TANK
Capacity (gal)
OPTIONS

MERCEDES-BENZ L1316
30,000 GVW Truck

ENGINE(S)
Model
TRANSMISSION(S)
Model
AXLES
Front axle capacity (lb) 11,025
Rear axle capacity (lb) 19,404
Rear axle ratio 5.714 or 6.143 single speed
BRAKES
Service brake
Parking brake manual on rear wheels, spring chamber assisted
Total brake area 832 sq in. (2 speed rear axle)
WHEELS
Tires 10.00-20 14 PR (6)
Rims 7.50-20 (6)
SUSPENSION
Front telescopic shock absorbers with half-elliptical leaf-springs and stabilizer
Rear telescopic shock absorbers with half-elliptical leaf-springs and progressively acting auxiliary springs
ELECTRICAL
Starter
Alternator
Battery
WEIGHTS (with driver)
Front axle (lb) 5623
Rear axle (lb) 3994
Total (lb) 9617
Payload & body allowance (lb) 20,183
DIMENSIONS
Wheelbase (in.)
BBC (in.)
FUEL TANK
Capacity (gal)
OPTIONS
- 2-speed rear axle 5.625/7.898

MERCEDES-BENZ L1418
32,225 GVW Truck

ENGINE(S)
Model M-B OM 355/5
TRANSMISSION(S)
Model M-B 5-speed, full synchro, total ratio first gear 6.1
AXLES
Front axle capacity (lb) 11,025
Rear axle capacity (lb) 21,200
Rear axle ratio 4.1
BRAKES
Service brake
Parking brake air release spring chambers acting on both rear wheels
Total brake area 832.74 sq in.
WHEELS
Tires
Rims
SUSPENSION
Front
Rear
ELECTRICAL
Starter 24 V/6 hp
Alternator
Battery 2-88 Ah-12 V
WEIGHTS (with driver)
Front axle (lb) 6843
Rear axle (lb) 4258
Total (lb) 11,101
Payload & body allowance (lb) 21,124
DIMENSIONS
Wheelbase (in.)
BBC (in.)
FUEL TANK
Capacity (gal)
OPTIONS

The German engineered Mercedes-Benz short nose conventional line of trucks covers the full range of Class 6 and 7.

Continued

Mid-Range/TRUCKS

Standard chassis features include rear axles with pressed in carrier tubes dimensioned so their weight is suited to every axle load, separate cab suspension system with a special long leaf spring and two shock absorbers as standard equipment, and a fully synchromesh 5-speed gear box.

The Mercedes-Benz cab includes double steel wall construction, an eight-way adjustable driver's seat, and three electric windshield wiper blades that clear 73% of the glass area.

Mercedes-Benz is the oldest of the off-shore truck manufacturers selling in the U.S. The company's dealer network covers 32 states towards the eastern side of the U.S. with three parts depots located in Chicago, Ill., the New York City area and Jacksonville, Fla. Since many of the parts on all models are interchangeable, parts inventories are simplified.

Engines

The OM 352 and the OM 352/A turbocharged version share the same design features such as: replaceable valve seat rings of chromium alloy steel for exhaust and intake valves; 5-ring pistons with an integrally cast nickel-iron insert for the top compression ring; rubber-type crankshaft vibration damper; heavy-duty injection nozzles surrounded by cooling water jackets for long service life; forged crankshaft of chromium alloy steel with induction hardened pins and journals. Torque ratings of the 346-cu in. in-line six engines are: 240 lb ft at 1700 rpm net and 260 lb ft at 1800 rpm gross for the OM 352; 295 lb ft at 1800 rpm net and 310 lb ft at 2100 rpm gross for the OM 352/A.

The OM 355/5 naturally aspirated 589-cu in. diesel has a net torque rating of 440 lb ft at 1500 rpm and a gross torque rating of 455 lb ft at 1600 rpm. This five-cylinder, in-line engine features dual thermostats, double bolted rod bearings, pressure lubrication supplied to wrist pins and cylinder walls through drilled connecting rods and a four-ring piston design among other features.

All the Mercedes/Benz engines are of 4-stroke design with 16.0 to 1 compression ratios.

VOLVO

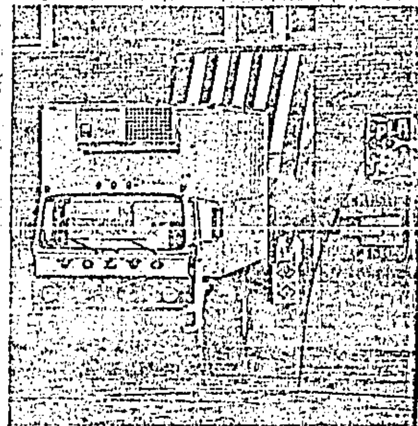
Engine Model	Net Power (hp @ rpm)	Gross Power (hp @ rpm)
Volvo TD 60	NA	170 @ 2800

VOLVO F611
24,500 GVW Truck

ENGINE(S)	
Model	Volvo TD60
TRANSMISSION(S)	
Model	Volvo SS-35 5-speed, synchro on top 4.
AXLES	
Front axle capacity (lb)	9000
Rear axle capacity (lb)	20,000
Rear axle ratio	4.86
BRAKES	
Service brake	air-hydraulic 2 circuit
Parking brake	spring set
Total brake area	640 sq in.
WHEELS	
Tires	8.25R-20 12 PR (6)
Rims	6.5-20 steel disc (6)
SUSPENSION	
Front	8000-lb springs with shock absorbers
Rear	16,500-lb. springs with auxiliary springs and stabilizer bar
ELECTRICAL	
Starter	12 V/4 hp
Alternator	50 A
Battery	(3) 12 V 70AH
WEIGHTS (with driver)	
Front axle (lb)	5277 (172 in. WB)
Rear axle (lb)	2798 (172 in. WB)
Total (lb)	8075 (172 in. WB)
Payload & body allowance (lb)	16,425 (172 in. WB)
DIMENSIONS	
Wheelbase (in.)	134-205 in.
BBC (in.)	60
FUEL TANK	
Capacity (gal)	35
OPTIONS	

VOLVO F613
27,960 GVW Truck
Same as above except:

ENGINE(S)	
Model	
TRANSMISSION(S)	
Model	
AXLES	
Front axle capacity (lb)	
Rear axle capacity (lb)	
Rear axle ratio	



Volvo F6

BRAKES	
Service brake	
Parking brake	
Total brake area	
WHEELS	
Tires	9.00R-20 12 PR (6)
Rims	
SUSPENSION	
Front	9000-lb springs with shock absorbers
Rear	20,000-lb springs with auxiliary springs and stabilizer bar
ELECTRICAL	
Starter	
Alternator	
Battery	
WEIGHTS (with driver)	
Front axle (lb)	5310 (172 in. WB)
Rear axle (lb)	2864 (172 in. WB)
Total (lb)	8174 (172 in. WB)
Payload & body allowance (lb)	19,786 (172 in. WB)
DIMENSIONS	
Wheelbase (in.)	
BBC (in.)	
FUEL TANK	
Capacity (gal)	
OPTIONS	

VOLVO F614
29,000 GVW Truck
Same as above except:

ENGINE(S)	
Model	
TRANSMISSION(S)	
Model	Volvo SS-65 6-speed full synchro
AXLES	
Front axle capacity (lb)	

Rear axle capacity (lb)	
Rear axle ratio	4.88
BRAKES	
Service brake	
Parking brake	
Total brake area	
WHEELS	
Tires	9.00R-20 14 PR (6)
Rims	
SUSPENSION	
Front	
Rear	
ELECTRICAL	
Starter	
Alternator	
Battery	
WEIGHTS (with driver)	
Front axle (lb)	5486 (172 in. WB)
Rear axle (lb)	2996 (172 in. WB)
Total (lb)	8482 (172 in. WB)
Payload & body allowance (lb)	20,518 (172 in. WB)
DIMENSIONS	
Wheelbase (in.)	
BBC (in.)	
FUEL TANK	
Capacity (gal)	
OPTIONS	

The F6 COE Volvo, available in the U.S. through the Freightliner Corp., is not the only Volvo truck sold in the U.S. Volvo of Sweden also produces the F7 model, which is similar in many respects to the F6 and falls in the bottom of the Class 8 category. In addition, Volvo recently announced the N10 conventional tractor for Class 8.

The mid-range F6 cab is made of double steel construction, and the entire underside of the vehicle is covered with a rust inhibitor. The cab tilts forward for servicing and improved stopping capability is provided by a dynamic load sensing valve that automatically adjusts front and rear braking ability. The instrument cluster includes a warning light system that monitors all major truck systems. Driver comfort is enhanced with power steering, power brakes and a short throw shift lever, all standard equipment. Also, Volvo says the seats are orthopedically designed for extra comfort.

Maintenance of the F6 has been made easier with built-in features such as: translucent fluid containers for quick visual inspection; a clearly marked and insulated electrical system on the frame; selfadjusting brakes with visible wear indicators; plus warning lights which indicate a clogged air filter or unlatched tilt-cab lock.

There are slightly more than 200 U.S. Volvo dealers backed up by six regional parts centers. The complete truck is warranted for 12 months or 24,000 miles. The engine warranty is 24 months or 100,000 miles.

Engine

The F6's TD 60 engine is a turbocharged in-line six cylinder diesel that is completely rebuildable. Every engine is test run for two hours over its entire operating range to insure reliability. Engine features include dual cylinder heads and wet cylinder liners, along with an exhaust brake and built-in electrical preheater for intake air.

The 334-cu. in. displacement TD 60 has a gross torque rating of 352 lb ft at 1900 rpm.

Continued

Some observations about non-sleeved diesel engines for mid-range trucks

Non-sleeved diesel engines are designed for less severe applications; ie: not full-rated GVW 100% of the time, nor maximum sustained speeds, nor 100,000 mile per-year mileage.

These engines, regardless of who makes them, cost less than sleeved engines or those with other premium features. These non-sleeved engines—the Cat 3208, Detroit Diesel Allison 8.2 liter or the International 9 liter—have been dubbed "throw-away" engines by competitors and some users. The engine companies vehemently deny the label. They point out that their engines are fully rebuildable if, and when required.

Blocks can be bored out to accommodate oversize pistons and rings. Cat, for instance, says its 3208 can be bored to .020- and .040-in. oversizes and even offers Cat-remanufactured engines in this manner.

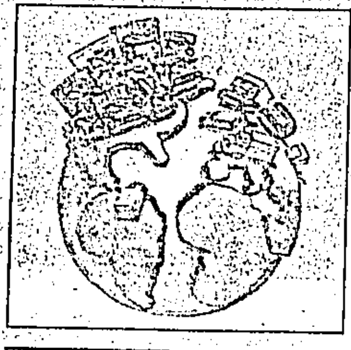
IH and Detroit Diesel with brand new engines for mid-range equipment will not have the volume for some months to justify supplies of factory rebuilt engines. However, they assure CCJ that the 8.2 and 9 liter V-8's can be rebuilt by a fleet or dealer.

The big question is when is rebuilding required? And what is the design life of these engines? In the case of sleeved engines with premium features, 150,000 to 200,000 miles is not unusual before overhaul. That's what experienced fleet operators tell CCJ.

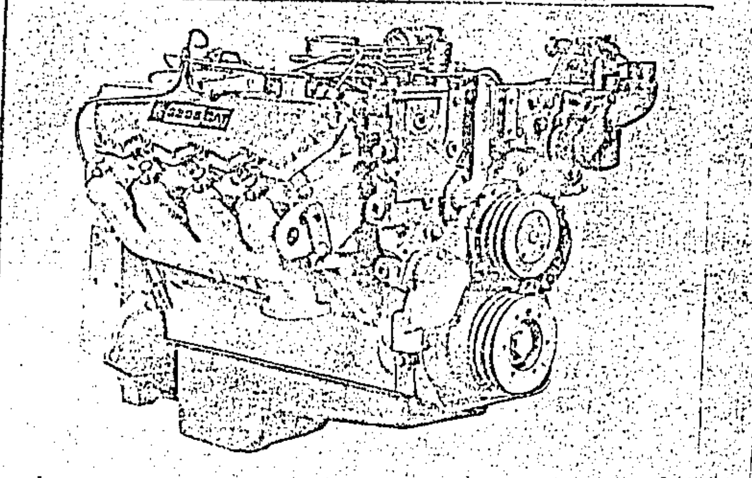
On non-sleeved engines, only time will tell what the acceptable average mileage will be. Engineers say the engines should do as well as, or better than, the gasoline engines they replace. Typically, this means 100,000 to 150,000 miles.

Said another way, manufacturers of non-sleeved engines appear to be engineering their products for applications where engine durability and sheet metal life are about equal. What happens after five-to-seven years? The same as happens now, observers say. Fleet operators must decide whether to invest money in an engine overhaul and sheet metal refurbishing or trade in the vehicle. Only time and experience will tell what the "bottom line" will be on this concept.

PART 3



Mid-Range ENGINES



Largest-selling mid-range diesel today is the Caterpillar 3208, developed from Cat's 1100-series engines first marketed in 1968. Performance tables for this and all engines in this section appear on page 90.

Three U.S. manufacturers, Caterpillar, Cummins and Detroit Diesel Allison, build diesel engines applicable to various truck OEMs' products in the mid-range, medium-duty market. International also manufactures mid-range diesels, but since they are currently available only in International trucks they are covered in the previous "Vehicle" section.

Historically, there have been two engineering philosophies to medium-duty diesel engine design.

One approach is to scale down the big-bore, over-the-road linehaul diesel, incorporating as many heavy-duty engineering features typical of this type engine as possible in the mid-range diesel design. Such features usually, but not always, include replaceable cylinder liners, heavy-duty type pistons (sometimes oil cooled), four valves per cylinder and overall heavy, robust construction.

The other approach starts with a clean slate, so to speak, to make use of linerless engine blocks, relatively lightweight pistons, inexpensive fuel injection equipment and other components, which while not typical of the heavy-duty linehaul engine, nevertheless perform well in their intended applications and offer considerable economy, both from a manufacturing and replacement (users) standpoint.

Somewhere along the line, the products of these two design philosophies came to be regarded by some as "rebuildable" or "non-rebuildable." That is, engines with replaceable cylinder liners and other traditional heavy-duty diesel engine features were thought of as restorable to original specs simply by replacement of standard parts, whereas, linerless engines have to be rebored and fitted with oversize pistons, etc. (necessitating machine shop work) at overhaul time.

Actually, no engine can be called "non-rebuildable" as long as overhaul and replacement parts are available at reasonable cost. Some diesels accused of this so-called failing simply require different overhaul procedures than the standard heavy-duty linehaul engine—techniques which should not be unfamiliar to the gasoline engine user stepping up to a mid-range diesel. In general, manufacturers of mid-range diesels are prepared to offer the user considerable help at overhaul time to get the job done right with minimum fuss.

The following paragraphs present the salient features of each engine family along with tables of performance and weight data. Note that power and torque listings in these tables are gross (bare engine) figures and thus may be higher than the net (installed) ratings given in the vehicle section which reflect parasitic losses of particular installations.

Caterpillar

Caterpillar's entry in the mid-range field is the 3208 V-8 diesel engine. Typical of the "clean-slate" approach to medium-duty diesel design, the 3208 and its forerunners have been in production since 1968. At 636 cu in. (4½ x 5-in. bore and stroke), it offers the largest displacement of all mid-range diesels at relatively lightweight and compact size, thanks to its linerless heat-treated cast iron block.

Pistons are of a two-ring design—unusual in a diesel—that contributes to fuel economy through reduced friction drag. A cast-in nickel-iron band in each piston provides a long wearing groove for the twist-type top compression ring which helps with oil control as well as providing compression seal.

The fuel system incorporates a

no-adjustment vee-type injection pump/governor assembly nestled between the two cylinder banks. The pump feeds individual, relatively inexpensive "pencil" injectors in each cylinder via eight high pressure lines. The injection pump plungers are operated by a camshaft within the pump (separate from the valve train camshaft) which has a centrifugal timing advance mechanism for economical engine operation over the entire speed range.

The 3208 is available in a number of versions with horsepower and torque characteristics tailored to specific applications (see table). In general, the 175-, 200- and 210-hp versions are recommended for local, intra-city service, while the 2600 rpm, 165- and 185-hp variations have been developed for inter-city service. The latest addition to the 3208 family is a 160-hp version intended especially for intra-city operation in Class 6 vehicles (19,500- to 26,000-lb GVW).

Caterpillar has worked out detailed application recommendations for the 3208 series engines which take into account vehicle frontal area, axle configuration, GVW, geared speed and type of service. These should be followed when specifying the 3208 in any fleet vehicle.

At overhaul time, several procedures can be taken advantage of to breathe new life into the 3208. If the engine has been well cared for, an "in-frame" overhaul may be the most economical choice. This is little more than the valve-and-ring job common to gasoline engines, and the cost, according to Cat, is about 20% to 25% of a new engine.

If cylinder wear is more pronounced, an out-of-frame overhaul may be called for. The 3208 is designed to accept two re-bores, and two standard piston oversizes (.020 and .040 in.) are available. The crankshaft is regrindable, and over- and under-size bearings are available. The out-of-frame job runs 25% to 35% of the cost of a new engine, says Caterpillar. In addition, Cat also makes available remanufactured short blocks and complete engines—both with warranties—at less than 65% of new engine cost.

Cummins

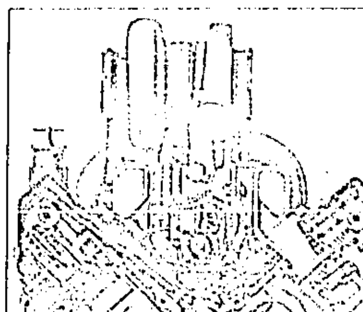
The Cummins VT-225 diesel V-8 represents the heavy-duty design approach to the mid-range engine market. Derived from the company's earlier V-555 mid-range diesel, the VT-225 displaces 555 cu in. (4⅝ x 4⅛-in. bore and stroke). Like most Cummins engines these days it incorporates the added feature of turbocharging as standard equipment.

Though the naturally-aspirated V-555 is still in production, its applications are extremely limited, so the VT-225 can rightfully be considered its successor and Cummins' main effort in the medium-duty field. Nevertheless, the V-555 is included in the table for comparison.

Numerous heavy-duty engine features are carried over into the VT-225. Its replaceable wet-type cylinder liners are very efficient from a cooling standpoint and allow complete in-frame overhauls. The same Cummins PT fuel system used in the big bore engines is employed in the VT-225. Its design ensures equal fuel metering to all cylinders and precise injection timing while permitting changes in engine ratings to optimize equipment performance. The Cummins-designed turbocharger reduces engine smoke and noise and ensures rated engine performance at high altitudes.

The VT-225 has four valves per cylinder—another big engine feature—for increased output and fuel economy. Valves are operated by a valve train employing roller cam followers for long cam and tappet life. The PTD fuel injectors are of the same design as in the larger Cummins engines and are also camshaft operated. Injector fuel supply and return is by drilled passages within the engine block.

The VT-225's crankshaft is a high tensile steel forging, fully counterweighted, with induction hardened journals capable of taking several regrinds. Bearings are steel-backed copper-lead with lead-tin overplate for break-in protection. All oil passages are internally drilled, and a high-pressure gear pump supplies all bearings with cooled oil.



Cummins VT-225 is a turbocharged V-8 exhibiting numerous heavy-duty diesel features such as removable wet liners, four valves per cylinder and rollerized valve train.

Detroit Diesel

Detroit Diesel Allison is fielding a number of offerings in the mid-range diesel market. Two units, the 4-53T and 6V-53T, have been in production in one form or another since the mid-1960s; the other engine, the 8.2 liter, is brand new. Together they represent opposite approaches, engineering-wise, to mid-range diesel design.

The background of the 53 series engines is definitely heavy-duty. Unique among mid-range diesels for their two-cycle mode of operation, they measure 3⅞ x 4½-in. bore and stroke, giving the inline four a displacement of 212 cu in. and the V-6, 318 cu in. Their construction is similar to Detroit Diesel's larger 71-series engines with such features as replaceable wet-type cylinder liners, cast iron multi-ringed pistons, rollerized cam followers, DDA's unit injector fuel system, etc. The "T" suffix in their model designations indicates they're turbocharged.

But the most significant news coming out of Detroit Diesel Allison

Continued

Mid-Range/Engines

these days concerns the new 8.2-liter "Fuel Pincher." This is the long-awaited four-cycle V-8 DDA has been developing and the engine the company is counting on to achieve wide penetration in the medium-duty truck market.

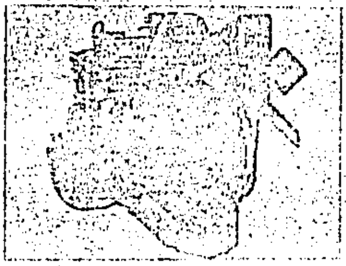
As the table below shows, the 8.2-liter is available in both turbocharged and naturally-aspirated form. Both versions displace 500 cu in. (4¼ x 4¹³/₃₂-in. bore and stroke). Basic to the new engine's construction is its linerless cast iron block, which has several worthy features. The cylinder walls of this block are of what DDA calls a "free-standing" design. That is, they are cast in a manner that allows coolant circulation around and for the entire length, top to bottom, of each cylinder. Besides providing excellent cooling, this design also tends to reduce noise transmission to the outer block walls, which themselves are of a "serpentine" or corrugated design to prevent noise resonance and add strength to the block. The bottom of the block ends at the crankshaft centerline, rather than extending below it as is traditional with almost every other engine design. The reason for this is to eliminate the slab-like crankcase sides, which have been found to be a source noise resonance. Both the deep oil pan and the valve rocker covers are double-wall laminated steel construction to minimize noise radiation as well.

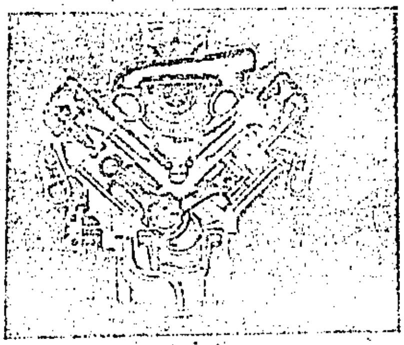
Fuel injectors and valves—two per cylinder—are actuated by the camshaft which is provided with heavy-duty type roller tappets. Another heavy-duty touch is represented by the fuel system which utilizes the same unit injectors found in larger Detroit Diesel engines. Injection fuel supply and return is via internally drilled passages in the cylinder heads.

A helical intake port design imparts optimum air swirl in the combustion chamber for good fuel economy and performance with low emissions. Pistons are aluminum alloy with cup-shaped "swirl supporting combustion chambers" machined in their crowns. The exhaust ports are short and smooth for optimum exhaust gas flow. They are also provided with stainless steel heat shields which reduce exhaust heat loss to the engine coolant, saving it instead to provide additional thermal energy to drive the turbocharger.

The crankshaft has large main and crankpin journals with generous overlap for strength. Four-bolt main bearing caps provide the block with extra strength and rigidity.

The new engine carries a 50,000-mile or 24-month warranty, which is more than double the standard 12-month, 12,000-mile warranty offered on most gasoline truck engines in similar service.





Detroit Diesel offers 4-53T (top) and new 8-Liter Fuel Pincher (above).

CUMMINS

Engine Model	Power (hp @ rpm)	Torque (lb-ft @ rpm)	Torque Rise (%)	Weight (lb)
V-555	202 @ 3000	425 @ 1800	20	1710
VT-225	225 @ 3000	445 @ 1900	13	1740

Engine table

Engine Model	Power (hp @ rpm)	Torque (lb-ft @ rpm)	Torque Rise (%)	Weight (lb)
V8-8.2	165 @ 3000	350 @ 1200	21.2	1108
V8-8.2T	205 @ 3000	430 @ 1700	19.8	1150
4-53T	170 @ 2500	402 @ 1800	12.6	1230
6V-53T	225 @ 2600	550 @ 1800	21.0	1695

CATERPILLAR

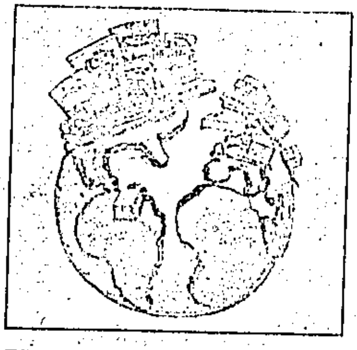
Engine Model	Power (hp @ rpm)	Torque (lb-ft @ rpm)	Torque Rise (%)	Weight (lb)
3208*	160 @ 2800	365 @ 1400	22	1210
3208**	165 @ 2600	398 @ 1300	20	1225
3208	175 @ 2800	405 @ 1400	23	1225
3208***	175 @ 2600	425 @ 1400	29	1250
3208**	185 @ 2600	452 @ 1400	21	1225
3208***	200 @ 2800	490 @ 1400	31	1250
3208	210 @ 2800	500 @ 1400	27	1225

*—Class 6 version for vehicles 19,501- to 26,000-lb GVW only.

**—[illegible] version.

***—California version. Equipped with exhaust gas recirculation.

PART 4



Mid-Range AXLES

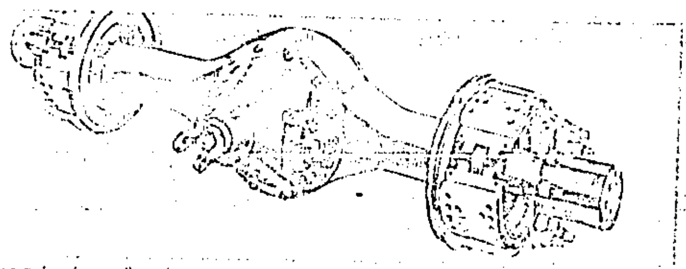
Eaton, Rockwell and Spicer supply drive axles suitable for medium-duty truck applications. All the axles in this range are of the full floating type, and they fall into one of three categories: single reduction, two-speed or double reduction.

Eaton axles employ spiral-bevel ring-and-pinion gearing with planetary secondary gearing on two-speed models. Rockwell and Spicer axles use hypoid primary gearing with additional planetary reduction on the two-speed and double-reduction models.

In general, single speed single reduction axles are used in conjunction with five-speed transmissions for light to average loads in both inter- and intra-city hauling. In hilly areas, or where loads are frequently heavy, two-speed axles give the added flexibility of 10 overall ratios when combined with a five-speed gearbox. For extremely heavy hauling, double reduction models can be specified along with multi-speed transmissions to suit the requirements of dump, grain, refuse or similar service.

When specifying axles for medium-duty mid-range diesel service, particular attention should be paid to getting the right ratio for the job. Otherwise, the result could be a vehicle that can't reach its geared maximum speed (axle ratio numerically too low) or one that wears its engine out prematurely doing so (axle ratio numerically too high).

Because of space limitations, the accompanying tables can only show the highest and lowest ratio for each axle model. Numerous options are available between these extremes which should be carefully checked out with axle suppliers before specifying.



Rear axles for medium-duty use can be either single speed for general use and light load applications; two speed for ratio multiplication; or double reduction for moving heavy loads. Shown above is Eaton's two-speed model 23221.

Continued

ROCKWELL

Axle type & model	Capacity (lb)	Ratio Range Available
Single speed, Single reduction		
D-140	13,000	5.29 thru 7.80
F-106	15,000	5.29 thru 7.80
H-172	17,500	3.73 thru 8.20
L-172	18,500	3.73 thru 8.20
Two speed		
L-600	18,500	4.56/6.36 thru 7.17/10.00

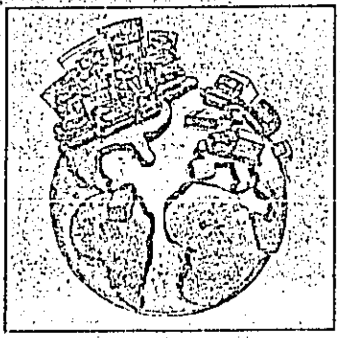
SPICER

Axle type & model	Capacity (lb)	Ratio Range Available
Single speed, double reduction		
G175-D	17,500	6.79 thru 9.97
M165-D	18,500	6.66 thru 9.77
Two speed		
G175-T	17,500	4.89/6.79 thru 7.17/9.97
M185-T	18,500	4.89/6.66 thru 7.17/9.77

EATON

Axle type & model	Capacity (lb)	Ratio Range Available
Single speed, Single reduction		
15101	15,000	4.56 thru 6.33
17121	18,500	3.70 thru 7.17
18121	22,000	3.70 thru 7.17
22121	22,000	3.70 thru 7.17
23121	23,000	3.70 thru 6.67
23421	23,000	3.70 thru 6.67
Two Speed		
15201	15,000	4.56/6.34 thru 6.33/8.81
16244	17,500	4.56/6.34 thru 7.17/9.97
17201	18,500	3.70/5.05 thru 5.57/7.60
17221	18,500	5.57/7.60 thru 7.17/9.77
18201	22,000	3.70/5.05 thru 5.57/7.60
18221	22,000	5.57/7.60 thru 7.17/9.77
22221	22,000	3.90/5.32 thru 7.17/9.77
23221	23,000	3.70/5.04 thru 6.67/9.08

PART 5



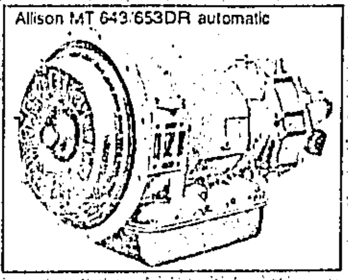
Mid-Range TRANSMISSIONS

If any type of transmission could be considered typical of the medium-duty truck, it would have to be the five-speed manual gearbox. Transmissions of this type are made by Clark and Spicer, and the reasons usually given for their predominance in the field are simplicity, general ruggedness and low cost.

Frequently, however, operating conditions call for a powertrain with more (or sometimes fewer) than five speeds. There are several ways a medium-duty vehicle can be provided with more than five overall ratios: add an auxiliary transmission behind the main gearbox; specify a two-speed rear axle; or opt for a multi-speed transmission such as the Fuller Road Ranger series of units. If a four-speed box is adequate, Warner Gear Division of Borg Warner Corp. has several to choose from.

An alternative to the manual transmission is the automatic. At the present time, Allison has that field all to itself, although at least one other manufacturer is rumored to have an automatic in the planning stages.

The following is a brief discussion of each of these types of transmissions and their outstanding features.

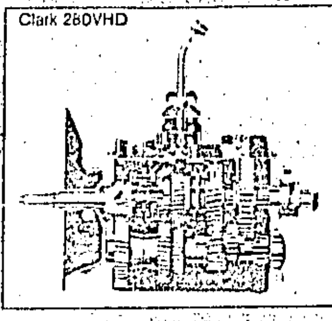


Allison MT 643/653DR automatic

Allison

Allison offers three automatic transmissions applicable to medium-duty truck operation. The Model AT 540 is designed to fill the gap between passenger car derived automatics and heavy-duty truck automatics and is applicable to vehicles up to 36,000-lb GVW and 50,000-lb GCW. The AT 540's torque converter can multiply engine torque up to a ratio of 2 to 1. The total available reduction in any gear range is obtained by multiplying the mechanical ratio by this value. Thus, in low range, the total transmission startability ratio of the AT 540 is 6.90 to 1. The AT 540 will accept up to 235 net input hp at 2400 to 3200 rpm (diesel operation) and a net input torque of 385 lb ft. The transmission weighs 275 lb (dry) and has provision for converter-driven power take-off.

Like the AT 540, the next step up in Allison automatics, the MT 643, is a four-speed unit. It is designed for use with mid-range diesel engines up to 250 hp and 450 lb ft torque. Several torque converter ratios are available, giving overall startability ratios in first gear range of 11.06, 8.70 or 6.66 to 1. The MT 653DR is essentially the same transmission as the MT 643, with the addition of an 8.04 low gear for on/off highway operations. Both transmissions incorporate an automatic lock-up feature on the top two gear ranges for increased fuel economy.



Clark 280VHD

Clark

Clark's "bread and butter" transmission is the 280V series. Primarily a Class 6 vehicle transmission, the 280V and its variants hold a 35% share of the North American Class 6 market and are the largest-selling 5-speed units in the industry, according to Clark. The 280V series has a torque capacity of 330 lb ft (nominal) while the HD versions increase that figure to 350 lb ft.

The 390V series transmissions are intended for Class 7 vehicles. They have a nominal torque capacity of up to 490 lb ft. All Clark transmissions in these two series offer synchronized shifting on 2nd, 3rd, 4th and top gear. They also have provision for right- or left-side power-take-off mounting. The 280V series units weigh 238 lb, while the 290 series tips the scales at 280 lb.

Under development at Clark is a new 5-speed transmission series designated 330V. This series, says Clark, is designed specifically to handle the new mid-range diesels, and eventually will replace the 280V series. The new transmissions will be synchronized on the top four speeds and will offer optional first and reverse gear synchronizing as well. The transmission will be constructed on a "building block" concept which will enable the selection of any combination of available for-

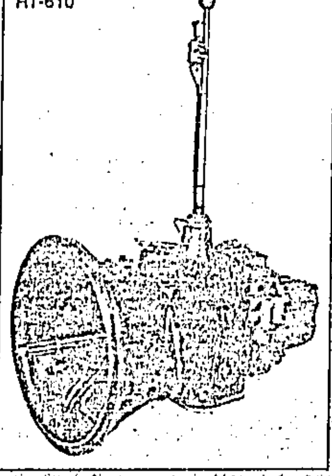
MAKE AND MODEL	No. of Speeds	GEAR RATIOS						Nominal Torque Rating (lb-ft)
		1st	2nd	3rd	4th	5th	Rev.	
ALLISON								
AT540	4	3.45	2.25	1.41	1.00	—	5.02	385
MT643	4	3.58	2.09	1.39	1.00	—	5.67	585
MT653DR	5	8.04	3.58	2.09	1.39	1.00	5.67	535

MAKE AND MODEL	No. of Speeds	GEAR RATIOS 1st	2nd	3rd	4th	5th	Rev.	Nominal Torque Rating (lb-ft)
CLARK 250V	5	7.49	4.36	2.40	1.48	1.00	6.30	330
250VO	5	5.98	3.50	1.86	1.00	.80	5.04	330
282V	5	6.99	4.09	2.17	1.17	1.00	5.89	330
282VHD	5	7.26	4.10	2.18	1.17	1.00	6.00	380
285V	5	6.99	4.09	2.24	1.47	1.00	5.89	330
285VHD	5	7.26	4.10	2.24	1.47	1.00	6.00	380
288V	5	5.98	3.50	1.91	1.37	1.00	5.04	330
289V	5	5.98	3.50	1.91	1.16	1.00	5.04	330
390V	5	7.519	4.353	2.539	1.517	1.00	6.266	490
397V	5	6.816	3.684	1.965	1.167	1.00	5.303	490

ward ratios.

Also under development is a multi-speed transmission designated the 410E. Clark says this unit is intended to replace four- and five-speed gearboxes used in conjunction with two-speed rear axles in the Class 7 market. The company also indicates it is studying new approaches to producing an economical on-highway automatic transmission for medium-duty vehicles.

Fuller Roadranger RT-610



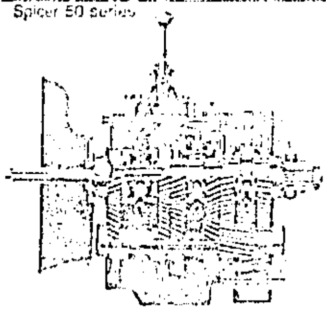
Fuller

When mid-range diesels are used in heavy load or on/off highway operations such as dump, block, mixer, grain or refuse service, a multi-speed transmission such as the Fuller Roadranger RT-610 and RT-613 series units may be the logical choice.

These transmissions consist of a five-speed section and an air-operated two- or three-speed section in one case. With up to 650 lb ft torque capacity, they provide either 10 or 13 evenly spaced ratios to match the pulling power of a mid-range diesel to prevailing load and road (or off-road) conditions.

The RT-610 model offers its 10 forward and two reverse speeds in a package only a little over 28-in. long. The 13-speed (three reverse gear) units measure only slightly longer at 32 ¾ in. Weight of the RT-610 is 425 lb, while that of the RT- and RTO-613 is 622 lb. All three transmissions have right and left side mountings for standard SAE 6-bolt power-take-off units as well as provision for bottom mounting of heavy-duty 8-bolt PTOs. All three transmissions are designed for engines up to 225 hp, but the overdrive RTO-613 is not recommended for use with engines that turn more than 2400 rpm.

Spicer 50 series



Spicer

Spicer's 50 and 60 series transmissions are designed for medium-duty vehicles with engines developing 350 to 725 lb-ft of torque. They feature constant-mesh helical gearing throughout with synchronizers on 2nd, 3rd, 4th and 5th gears. All units in these series have an 8-bolt PTO opening on the right side and a 6-bolt hole on the left. PTO drive gear speeds range from 49% to 75% of engine speed depending on transmission ratio.

The transmissions in the table below can be categorized into several groups as follows:

- Five-speed gathered ratio (1.45 in 4th). This style of transmission is used primarily with single speed axles for straight city truck service or low GVW highway service.
- Five-speed equal step (1.61 in 4th). This type of transmission is best suited for use with supplemental gearing such as a close-step (1.28) two-speed rear axle, or three- or four-speed auxiliary transmission. When used with a two-speed axle,

Continued

MAKE AND MODEL	No. of Speeds	GEAR RANGE	GEAR RATIOS 1st	2nd	3rd	4th	5th	Rev.	Nominal Torque Rating (lb-ft)
FULLER ROAD-RANGERS									
RT610	10	LOW	9.00	7.02	5.48	4.26	3.43	9.50	625
		HIGH	2.62	2.05	1.60	1.24	1.00	2.77	
RT613	13	LOW	18.00	14.04	10.96	—	—	19.00	650
		INTER.	8.64	6.74	5.26	4.09	3.29	9.12	
		HIGH	2.62	2.05	1.60	1.24	1.00	2.77	
RTO-613	13	LOW	14.50	11.31	8.83	—	—	15.30	650
		INTER.	6.96	5.43	4.24	3.29	2.65	7.35	
		HIGH	2.11	1.65	1.29	1.00	.80	2.23	

Mid-Range/TRANSMISSIONS

MAKE AND MODEL	No. of Speeds	GEAR RATIOS 1st	2nd	3rd	4th	5th	Rev.	Nominal Torque Rating (lb-ft)
SPICER 5052-A	5	7.08	3.83	2.36	1.45	1.00	7.08	475-500
5052-B	5	7.08	4.37	2.72	1.62	1.00	7.08	"
5052-C	5	7.08	4.37	2.50	1.45	1.00	7.08	"
5052-D	5	7.08	3.83	2.10	1.28	1.00	7.08	"
5252-A	5	6.50	3.52	1.93	1.18	1.00	6.50	"
6052-A	5	7.28	4.09	2.41	1.44	1.00	7.28	600-725
6052-B	5	7.28	4.38	2.71	1.61	1.00	7.28	"
6052-C	5	6.68	3.52	1.97	1.16	1.00	6.68	"
6052-D	5	7.28	4.09	2.28	1.28	1.00	7.28	"
6252-A	5	5.70	3.20	1.89	1.15	1.00	5.70	"
6253-A	5	5.70	3.00	1.78	1.00	.85	5.70	"
6252-B	5	5.06	3.05	1.78	1.33	1.00	5.06	"
6253-B	5	5.06	3.05	1.78	1.00	.69	5.06	"

10 equal steps are obtained.

- Five-speed short fourth (1.18 in fourth) is intended for use with a 1.37 two-speed rear axle. Such a combination gives 1.37 steps in the lower ranges and 1.18 steps in the top four speeds.
- Overdrive main transmissions. Both the gathered ratio and short fourth style transmissions are available in overdrive configuration (.69 and .85, respectively). Overdrive transmissions are useful in applications that are loaded one way and empty on the return trip. Generally, however, they are not recommended in a five-speed transmission when the vehicle will be pulling its rated load in overdrive.

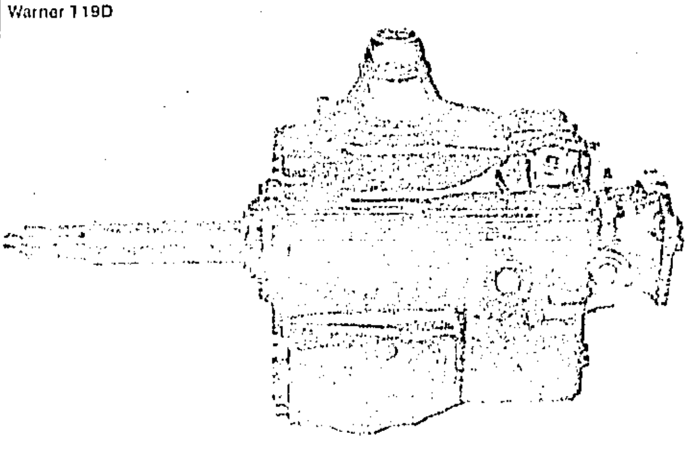
Warner

The "D" version of the T19 transmission by Warner Gear Division of Borg-Warner is the base transmission for the new 1980 Ford medium-duty trucks equipped with Detroit Diesel's 8.2-liter four-stroke diesel engine.

Synchronized in all forward gears, the T19D is the latest version of Warner's four-speed countershaft, helical gear T19 transmission series. Other design features of the T19 include constant mesh low and reverse gears and special heavy-duty strut-type synchronizers that aid shifting and prolong transmission service life. The unit uses tapered roller bearings on the input and output shafts in place of the ball bearings used in lighter duty transmissions.

Other applications of the T19 series transmissions are both diesel- and gasoline-powered school buses, recreational and four-wheel drive vehicles.

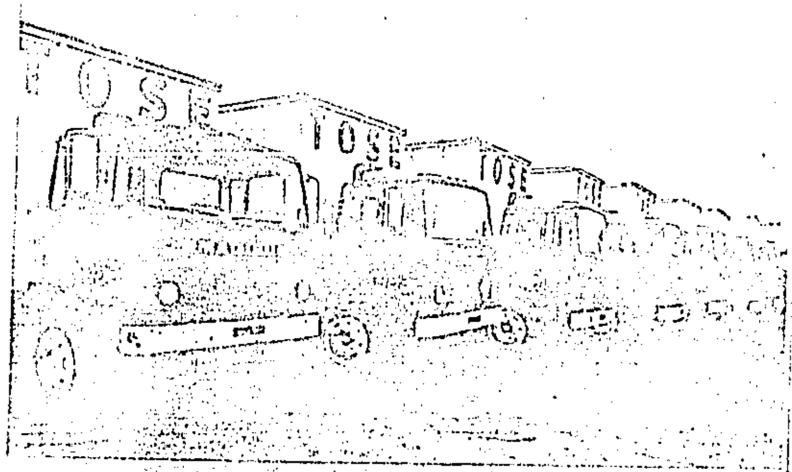
Warner T19D



MAKE AND MODEL	No. of Speeds	GEAR RATIOS 1st	2nd	3rd	4th	5th	Rev.	Nominal Torque Rating (lb-ft)
BORG-WARNER								
T19	4	6.32:1	3.09:1	1.69:1	1.00:1	—	6.96:1	325
T19A	4	4.02:1	2.41:1	1.41:1	1.00:1	—	4.42:1	325
T19D	4	4.02:1	2.41:1	1.41:1	1.00:1	—	4.42:1	375

PART 6

Mid-Range USER REACTION



Magirus trucks with 160-hp Fiat diesels have proven far superior to gasoline-powered equipment in terms of reliability and fuel economy, according to Tose, Inc.

Skyrocketing fuel and labor costs are causing an increasing number of fleetmen to convert from gasoline to mid-range diesel power in their medium-duty trucks.

Typically, diesels provide up to twice the fuel mileage, require less maintenance and offer substantially higher resale value.

On the negative side, diesels cost from $3000 to $6000 more than a gasoline-powered model. And parts replacement for a diesel truck bring premium prices, especially for foreign models.

Still, mid-range diesels have some strong advocates. Here's what some users have to say.

Rowland Jones, vice president of maintenance for Tose, Inc. of Bridgeport, Pa., believes expensive truck parts often are worth the investment.

Tose, a general commodity common carrier operating in six northeastern states, has 35 Magirus 160 A 11 FL straight trucks in pick-up and delivery service. These two-axle units are equipped with 160-hp Fiat diesels and five-speed, manual transmissions. Rated at 27,000-lb GVW, the Magirus vehicles are accumulating a reliability and performance record superior to that of gasoline-powered equipment used previously, Jones said.

Jones admits that parts for the Magirus cost more than equivalent components for American made trucks, but he says improved component reliability balances things out.

Tose's Magirus trucks operating in Philadelphia and New York City average 9.2 mpg and many in New England attain 11 mpg. In contrast, Ford C-700 straight trucks with 361- or 390-cu in. gasoline engines average only 3.5 mpg in city operation.

Fuel savings are substantial, but the most dramatic changes brought about by the use of diesels is reduced downtime.

"After traveling 30,000 miles, the Magirus trucks in this location have yet to suffer a single on-road failure," Jones says.

The reaction of Tose drivers to the new equipment has been uniformly excellent, Jones reports. "They love the improved visibility, comfort and performance. They're even *polishing* their Magirus trucks, on their own time! This translates to maintenance savings, because a man won't mistreat a truck he's proud to drive."

Iowa chooses mid-range diesels

Jones isn't alone in his love affair with mid-range diesels. In 1977, the Iowa Department of Transportation broke with tradition and included operating-cost projections in their "low-bid purchase" procedure. This opened the door to mid-range diesels in medium-duty trucks for the first time.

Iowa DOT has documented significant savings from the use of diesels and today purchasing a gasoline-powered, medium-duty truck is not even considered.

Ernie Shillak says Iowa's fleet of 47,500-lb GVW Ford LN-7000 dump trucks with Cat 3208 diesels and five-speed transmissions cut fuel consumption 38% compared with Fords powered by 360- or 375-cu in. gasoline engines.

William McCall, director of the Iowa DOT Office of Supplies and Equipment, says diesels have proven "substantially more reliable" than gasoline engines, especially when used in snow removal operations.

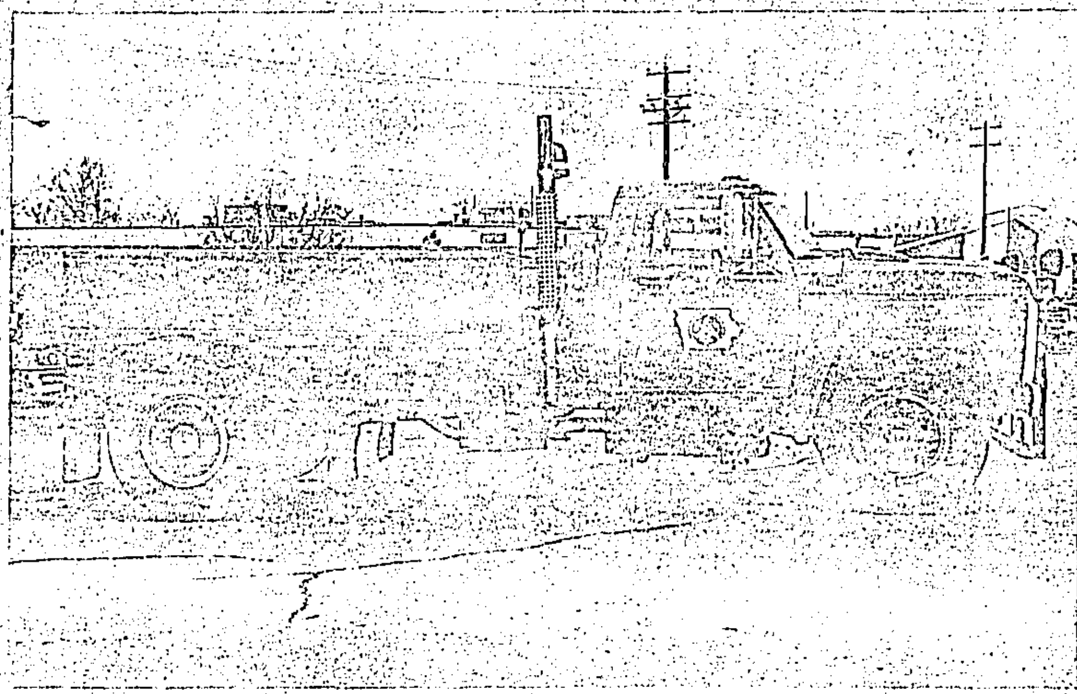
Shillak said: "One of our biggest problems was that gasoline engines in snow plowing operations would load up with fine, wet snow and stop dead. The diesels seem immune to accumulated snow in the engine compartment. And the increased horsepower and torque characteristics of the Cat 3208 make snow removal faster and easier."

Of more than 2000 trucks operated by Iowa DOT, approximately 800 are medium-duty straight trucks. Of these, 800, 300 are diesels.

Iowa DOT purchasing agent Dave Slater says it won't be long until the entire medium-duty fleet is diesel.

Continued

Mid-Range/USER REACTION



The Iowa Department of Transportation says units like this Ford dump truck with Cat 3208s cut fuel consumption by 38% compared with gasoline-powered Fords. Used for snow removal during the winter months, Iowa DOT's diesel trucks are relatively immune to being shut down by accumulations of wet snow in the engine compartment and get the work done notably faster than "gas jobs."

Reportedly, Michigan, Minnesota and Nebraska are also well on their way toward dieselization of mid-range equipment.

Less downtime for diesels

Positive experience with mid-range diesels at Marty's Express, a Philadelphia-based, short-haul carrier of general freight serving New Jersey and New York, closely parallels operating experiences of other fleets contacted by CCJ.

In addition to 140 heavy-duty Mack tractors, the fleet includes 12 medium-duty Mercedes Benz LP-1138 straight trucks with OM 352 diesels rated at 120 net hp. Purchased in 1972, these 25,000-lb GVW Mercedes with 20-ft freight bodies are used in both local and short run service. So far, they have accumulated 250,000 miles.

Shop foreman Gus Peraino says after seven years of trouble-free operation, the Mercedes are being overhauled for the first time. "We've hardly had any on-road failures with the Mercedes during this time and very little downtime. Parts availability has been more than adequate," he said.

Like other imported truck users, Peraino says parts costs are high. For example, a clutch assembly for a Ford straight truck costs $85 versus $350 for a Mercedes assembly. Parts required to complete an in-frame overhaul of an OM 352 diesel cost Marty's Express $3500. But Peraino says the investment will keep the Mercedes fleet running for at least five years.

"We could buy a rebuilt Ford 330 or 361 gasoline engine for $850, but we consider the diesel's initial and overhaul cost a wise investment," company president Domonic Marano said. "The Mercedes diesels average 10.1 mpg and many are hitting 11 to 12 mpg in our operation. The diesel's reliability is great, so I don't worry that parts cost three times more."

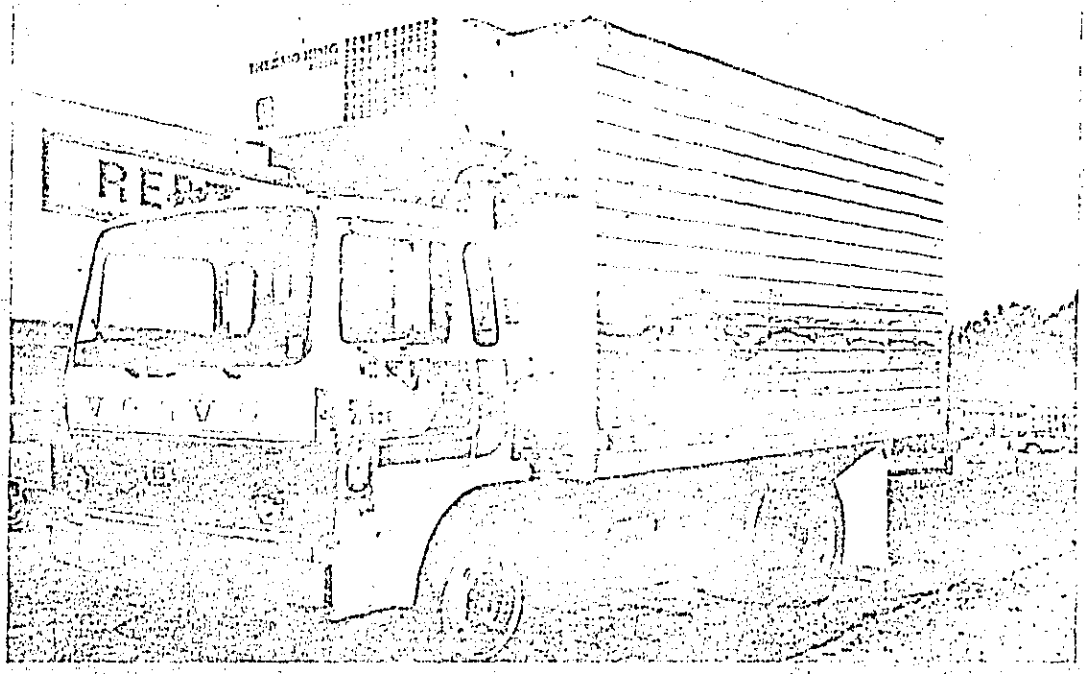
Traditionally, diesels are more difficult to start after a winter weekend "cold soak." Peraino says using block heaters eliminated this problem, and fuel heaters will be installed to deal with poor-quality fuel that caused waxing of filters last year.

"By the end of this month, you won't find a single gasoline vehicle in this fleet, and that includes the salesmen's cars," Peraino said. "At Marty's Express, gasoline engines are a thing of the past."

Dairies adopting mid-range diesels

Experience with mid-range diesels at two dairy companies further confirms the advantages over gasoline engines and shows the merit of using automatic transmissions in route delivery trucks.

At Southland Corporation's Dairy Group headquartered in Dallas,



This F613 Volvo with TD60 six-cylinder turbocharged diesel, five-speed transmission and 16-ft Nabors refrigerated body is used by the State of Mississippi to transport perishables to correctional facilities. State officials say the Volvo was selected for its excellent fuel economy and ability to withstand the rigors of sustained highway speeds during an average round trip of 300 miles.

Texas, 170-hp Detroit Diesel Allison 453-Ts are used to power two-axle, 31,000-lb GVW Chevrolet 70 Series straight trucks fitted with 18-ft refrigerated bodies. Used in milk and ice cream route delivery service, 40 of these trucks have been added to locations around the country in the past 18 months.

Distribution Systems manager Don Wilson says the 453-Ts far "outclass" the 366-cu in. gasoline engines previously specified for delivery trucks. Gasoline engines averaged 3.5 mpg, while the diesels average 7 mpg and go as high as 11 mpg, he said.

"Besides *doubling* our fuel mileage, the Detroits will cost less to maintain over the eight to 10 years we keep route trucks, which average 15,000 to 18,000 miles a year. I expect the diesels to operate a minimum of 150,000 miles before requiring any major work. And using MT-643 automatic transmissions should prevent engine abuse caused by improper shifting. No way would I put a manual box in one of these diesel trucks," Wilson said.

Still another dairy fleet manager, who requested anonymity, uses MT-653 automatic transmissions in conjunction with International Harvester DT-466 diesels rated at 210 hp in two-axle, IH CO-1950B straight trucks. Fitted with 22-ft refrigerated bodies, these trucks have a GVW of 35,000 lb and average 28,000 miles yearly.

Trucks with 537 gasoline engines and manual transmissions gave 5.4 mpg. The DT-466 diesels purchased in 1977 with manual Spicer transmissions average 7.2 mpg. DT-466s average 8.1 mpg when fitted with the Allison MT-653 offering full lock-up in every gear!

The benefit of mating mid-range diesels with automatics doesn't stop with fuel mileage improvement, according to reports. "The MT-653s extend our rear brake lining life between 12,000 and 15,000 miles. And by eliminating clutch replacement work, we save more than enough money to cover the cost of eventually rebuilding the Allison," he says.

This company's first DT-466s have run approximately 80,000 miles without major problems. While parts availability for this engine has proven somewhat less than ideal, and minor problems such as an occasional broken injector line have been experienced, the dairy is completely "sold" on this mid-range diesel. □□□

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49

PRICE INDICIES FROM THE DEPARTMENT OF COMMERCE, BUREAU OF LABOR STATISTICS.

PRICE INDICES

	1973	1974	1975	1976	1977	1978	1979	1980		FACTOR
CPI, BLS All Items, Wage Earners, Price 1967 = 100			154.1	170.6	186.1	203.1	223.1	261.8 = (Nov 1980)		1.70
Industrial Products Index, BLS Nationwide annual averages Sales to commercial consumers Gasoline, Reg	100.0	191.2	226.8	218.5	264.4	248.8	387.2	579.1 - 1980: 11 mo. avg		2.64
Diesel Fuel	100.0	220.8	247.0	272.2	306.8	316.9	465.1	681.1	" "	2.74
WPI: Index of hourly average earnings, seasonally adjusted, private nonfarm economy, transportation and public utilities			181.8	198.6	213.2	231.0	249.4	265.9		1.46

Survey of Current Business; Economic Report of President,

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
AIR, NOISE, AND RADIATION

JAN 30 1981

On January 19, 1981, the Administrator of the U.S. Environmental Protection Agency signed a one year deferral of the effective dates for more stringent noise emission regulations for medium and heavy trucks and truck-mounted solid waste compactors which were scheduled to go into effect in 1982.

Based on the current economic state of the trucking industry, the Agency believes that it is appropriate to defer the January 1, 1982 effective date of the 80 dB regulation for medium and heavy trucks for one year until January 1, 1983.

Since the 76 dB noise regulations for truck-mounted solid waste compactors is related to the 80 dB level for truck chassis, the effective date of the compactor regulation is deferred one year from July 1, 1982 to July 1, 1983.

The deferral in effective dates is expected to provide immediate relief to the industry's cash flow problems which appear to be particularly acute at this time.

Enclosed for your information is a copy of the Federal Register Notice announcing the one year deferral (46 FR 8497, Tuesday, January 27, 1981). For further information, contact Timothy M. Barry, Senior Project Officer, Standards and Regulations Division, (ANR-490), U.S. Environmental Protection Agency, Washington, D.C., 20460, or phone (703) 557-2710.

Sincerely,

Henry E. Thomas
Director
Standards and Regulations Division