N-96-01
II-A-56

EPA 550/9-77-204

Natl. Bibliography or NTIS

NOISE EMISSION STANDARDS
FOR SURFACE TRANSPORTATION EQUIPMENT

INFORMATION IN SUPPORT OF THE PROPOSED REGULATION FOR TRUCK-MOUNTED SOLID WASTE COMPACTORS

PART 1.
DRAFT ENVIRONMENTAL IMPACT STATEMENT
ECONOMIC IMPACT STATEMENT

PART 2.
BACKGROUND DOCUMENT

AUGUST 1977

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF NOISE ABATEMENT AND CONTROL

WASHINGTON, D.C. 20460

FOREWORD

The Draft Environmental Impact Statement, Economic Impact Statement, and Background Document were prepared in support of the Environmental Protection Agency's proposed regulation which sets noise emission standards for newly manufactured truck-mounted solid waste compactors. The proposed regulation has been published pursuant to the mandate of Congress as expressed in the Noise Act of 1972 (86 Stat. 1234).

EPA 550-9-77-204

NOISE EMISSION STANDARDS FOR SURFACE TRANSPORTATION EQUIPMENT

INFORMATION IN SUPPORT OF PROPOSED REGULATION FOR TRUCK-MOUNTED SOLID WASTE COMPACTORS

PART 1
DRAFT ENVIRONMENTAL IMPACT STATEMENT
ECONOMIC IMPACT STATEMENT

AUGUST 1977

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF NOISE ABATEMENT AND CONTROL
WASHINGTON, D.C. 20460

SUMMARY SHEETS

FOR

DRAFT ENVIRONMENTAL IMPACT STATEMENT

PREPARED BY

OFFICE OF NOISE ABATEMENT AND CONTROL

U. S. ENVIRONMENTAL PROTECTION AGENCY

1. Title of Action: Regulation of Noise Emissions for Truck Mounted Solid Waste Compactors. This is an Administrative Action.

2. Description of Action: The Environmental Protection Agency's proposed regulation is intended to reduce the level of noise emitted from truck mounted solid waste compactors used in collecting solid wastes. The regulation is also intended to establish a uniform national standard for this equipment distributed in commerce, thereby eliminating inconsistent State and local noise source emission regulations that may impose an undue burden on the truck mounted solid waste compactor industry. The recommended action proposes to establish noise emission standards for newly manufactured compactors and to establish enforcement procedures to ensure that this equipment complies with the standard.

The proposed regulation is based on anticipated health and welfare benefits to the public by reducing noise emission from truck mounted solid waste compactors. In arriving at the proposed regulation, the Environmental Protection Agency investigated in detail the truck mounted solid waste compactor industry, noise control technology, noise measurement methodologies, and costs of compliance. Three major issues were identified requiring resolution: (1) identification of machines to be regulated, (2) measurement methodology to be employed, and (3) noise levels and effective dates.

Three types of compactors are included as subject to the proposed regulation: front loaders, rear loaders, and side loaders.

The proposed noise emission standards for truck mounted solid waste compactors and effective dates are:

Effective Dates	Maximum Steady A-Weighted Sound Level (dBA) @ 7 Meters Not-to-Exceed Sound Level
January 1, 1979	78 decibels
January 1, 1982	75 decibels

Machinery-related impulse sounds shall not exceed the maximum steady sound level limits by more than 5 decibels.

A two-step reduction in equipment noise levels was concluded to be preferable to a one-step requirement that all equipment meet the most stringent levels achievable and desirable. To minimize market impacts from substitution of unregulated machines identical effective dates were set for all equipment subject to the standards. The second step of the regulation is scheduled to coincide with the second step of the noise regulation for medium and heavy trucks on January 1, 1982. The reduced (80 dBA) sound level limit (at full throttle, maximum engine speed) for new trucks in 1982 should permit attainment of the reduced (75 dBA) limit (during the compaction cycle) for compactors with no additional application of noise control technology.

Other provisions of the regulation relate to sound level degradation of compactors and the proposed LNEP level.

Following the effective date of the regulation, newly manufactured truck-mounted solid waste compactors must be designed and manufactured to meet the appropriate standard for a period (Acoustical Assurance Period) of 3 years of 7500 operating hours, whichever occurs first, after sale to the ultimate purchaser, provided that the product is properly used and maintained.

Low Noise Emission Product sound level for truck-mounted solid waste compactors is 70 dBA, effective January 1, 1978. The reason for selecting a LNEP level 8 dBA rather than the more usual 5 dBA below the initial standard is that certain currently available models come close to meeting a 73 dBA level, and therefore such a LNEP level would provide no incentive for further development of technology.

3. Environmental Impact: Compliance with the proposed standard for truck mounted solid waste compactors, when considered in combination with existing Federal standards for medium and heavy trucks, should result in a reduction of approximately 71 percent in the severity and extensiveness of trash collection noise impact by the year 1991, assuming 100 percent turnover of regulated equipment to quieted units in that period. This represents an improvement of approximately 88 percent over the benefits that are anticipated from current Federal noise regulation of medium and heavy trucks.

List price increases to quiet new truck mounted solid waste compactors are estimated to range from 6.4 to 12.8 percent (based on the complete vehicle), depending on machine type and size. The average list price increase for all machines is estimated to be 10.3 percent. This percentage increase is based on the price of the complete compactor vehicle.

An economic analysis of the truck mounted solid waste compactor manufacturing industry indicates a significant price elasticity of demand. Demand could decrease by as much as 4 percent as a result of the proposed regulation, but total revenues should remain constant as a result of associated price increases.

In terms of societal resources, capital costs for the first year of compliance are estimated at above $27 million, with annual costs (including amortized capital cost, operation and maintenance) at $6.5 million, compared to 1974 net sales estimated at $125 million; and costs are expected to pass through to the end user, and ultimately the consumer of waste collection services. The equivalent annual costs of implementing the regulations are estimated to be $10.7 million for the period of the complete regulatory scenario. Because equipment costs represent a small portion of the total cost of solid waste collection, the consequent cost increase for service is expected to be small, an estimated 0.5 percent.

Air quality, water quality, land use, solid waste disposal requirements, employment, regional economics, foreign trade, national GNP, and energy consumption are not expected to be significantly impacted by the noise levels proposed. The proposed regulation will support the efforts of the Federal Trade Commission and other organizations to inform and protect consumers.

T A B L E O F C O N T E N T S

PART 1

DRAFT ENVIRONMENTAL IMPACT STATEMENT AND ECONOMIC IMPACT STATEMENT

PART 2
BACKGROUND DOCUMENT

TRUCK-MOUNTED SOLID WASTE COMPACTOR

DRAFT ENVIRONMENTAL IMPACT STATEMENT

AND

ECONOMIC IMPACT STATEMENT

ABSTRACT

This Draft Environmental Impact Statement and the Economic Impact Statement address a proposed noise emission regulation for truck mounted solid waste compactors. In arriving at the proposed regulation, the Agency carried out detailed investigations of compactor design; manufacturing and assembly processes; noise measurement methodologies; available noise control technology; costs attendant to noise control methods; costs to test machines for compliance; costs of record keeping; possible economic impacts; and the potential environmental and health and welfare benefits associated with the application of various noise control measures. Data and information generated as a result of these investigations are the basis for the statements made in Part I of this document. Part I has been designed to present, in the simplest form, all relevant information regarding the environmental and economic impacts expected to result from the proposed action. Where greater detail is desired, the Agency encourages perusal of Part II, the "Background Document".

DRAFT ENVIRONMENTAL IMPACT STATEMENT

INTRODUCTION

Congress passed the Noise Control Act (NCA) of 1972, in part, as a result of their findings that inadequately controlled noise presents a growing danger to the health and welfare of the nation's population, particularly in urban areas. For this and other reasons, the Congress established a national policy to "promote an environment for all Americans free from noise that jeopardizes their health or welfare". To further this policy, the NCA provides for the establishment of Federal noise emission standards for products distributed in commerce and specifies four categories of important noise sources for regulation, of which transportation equipment is one.

It has been estimated that over 17 million people located in urban, suburban, and rural areas in the United States are exposed to noise levels form trash collection equipment that jeopardize their health or welfare.

Inasmuch as a number of different types of transportation equipment operates at the same time, the quieting of only one product type is often not in itself sufficient to adequately reduce transportation noise to a level requisite to protect health or welfare. Accordingly, the EPA'S noise regulatory program has effected a coordinated approach to control overall transportation noise in which various types of transportation equipment, alone or in combination, are evaluated to assess their contribution to transportation noise and attendant impact on the nation's population.

Pursuant to the mandate of the Noise Control Act and EPA's approach to the control of transportation noise, noise emission regulations were promulgated on April 13, 1976, for medium and heavy trucks (41 FR 15538).

To further control transportation noise, noise emission standards for truck mounted solid waste compactors are being proposed at this time.

Truck Mounted Solid Waste Compactors

A truck-mounted solid waste compactor (TMSWC, or compactor) is defined, for purposes of this regulation, as a vehicle that is comprised of a mechanically powered truck cab and chassis or trailer, and equipped with a body and machinery for receiving compacting, transporting, and unloading solid waste. The body, which includes a waste-receiving hopper, houses machinery which typically consists of hydraulic actuators (rams) with requisite hydraulic pump, valves, piping, and controls. The hydraulic actuators operate various components that sweep the waste matter into the container portion of the body and compact it. Power generally is drawn from the truck engine by means of a power take-off (PTO) unit, coupled by gears or other mechanical connection to the transmission, engine drive shaft, or fly wheel. Truck-mounted solid waste compactors are used for the collection of solid wastes in residential and commercial areas.

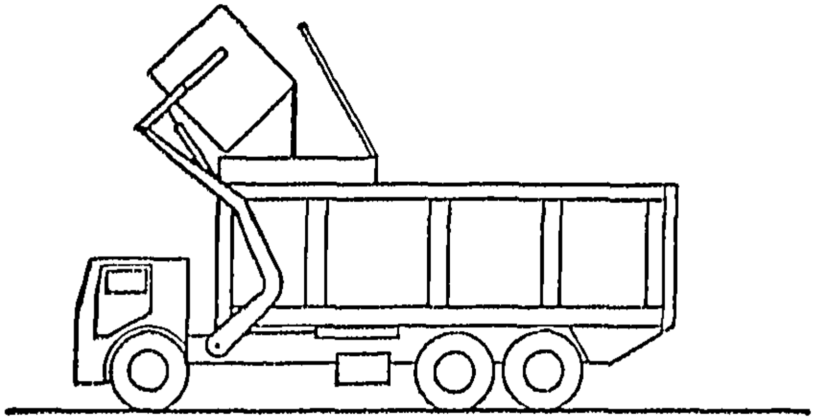
The Agency determined that regulation of truck-mounted solid waste compactors is required to protect the public health and welfare. The following are the major types of compactors:

1. Front Loader. Compactor body that utilizes front mounted hydraulic lift arms to lift and dump waste containers into an access door in the top of the body. Wastes are typically ejected through a tailgate.

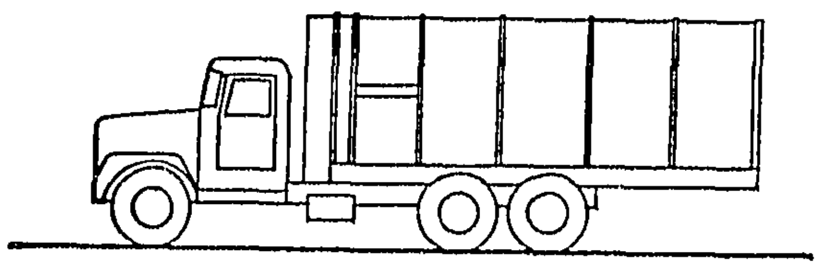
2. Side Loader. Compactor bodies vary; however, wastes are generally deposited manually into a hopper through an access door in the side wall. Packer plates sweep the wastes from the hopper into the body and compress the materials against an interior wall, in the same manner as front loaders. Some are also equipped to hydraulically lift and dump waste containers. Ejection of wastes is usually through a tailgate. Some side loader models are not equipped for packer plate ejection, but typically, hydraulically lift the front end of the body and dump the waste through a tailgate.

3. Rear Loader. Compactor body on which the hopper is located on the rear section. 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 waste against an interior wall surface. In most models, a hydraulically-driven plate is used for tailgate waste ejection.

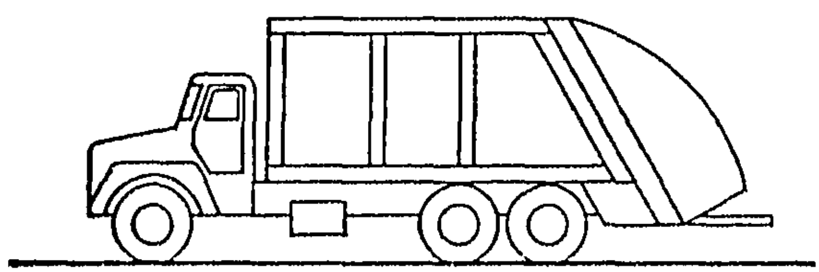
Figure 1 shows line drawings of a front loader, a side loader and a rear loader. Details regarding identification of these machines as candidates for regulation, their design features and functional characteristics are contained in Part 2, the "Background Document".



Front Loader



Side Loader



Rear Loader

Figure 1. Line Drawings of Types of Compactors

PROPOSED NOISE REGULATION

This proposed regulation is intended to reduce the level of noise emitted from truck mounted solid waste compactors. It also establishes a uniform national standard for these machines when they are distributed in commerce, thereby eliminating differing State and local noise control source emission regulations which may impose a burden on the truck mounted solid waste compactor industry.

Statutory Basis

The proposed action establishes noise emission standards for newly manufactured truck mounted solid waste compactors and enforcement procedures to ensure that this equipment complies with the standard. This proposed rulemaking is being issued under the authority of the Noise Control Act of 1972 (P.L.92-574, 86 Stat. 1236).

Alternatives Considered

Two alternatives to noise emission regulation available to EPA are: no action and labeling. These actions may be taken only if (a) the product does not contribute to the detriment of the public health and welfare, or (b) in the Administrator's judgment noise emission regulation is not feasible.

Specialty auxiliary equipment on trucks (of which truck-mounted solid waste compactors are one category) was identified, pursuant to section 5(b)(1) of the Noise Control Act of 1972, as a major noise source on May 28, 1975 (40 FR 23069). Subsequent to this identification comprehensive studies were performed to evaluate truck-mounted solid waste compactor noise emission levels requisite to protect the public health and welfare, taking into account the magnitude and condition of use, the degree of noise reduction achievable through application of the best available technology and the cost of compliance. The results of these studies show that the regulation of truck-mounted solid waste compactor noise is feasible through available technology taking cost of compliance into account. Accordingly, the Act permits no alternative action to be taken.

Proposed Regulation

Regulatory Schedule. The proposed noise emission standards and effective dates are shown in Table 1.

Table 1

PROPOSED NOISE EMISSION STANDARDS

Effective Dates	Maximum Steady A-Weighted Sound Level (dBA) @ 7 Meters Not-to-Exceed Sound Level
January 1, 1979	78 decibels
January 1, 1982	75 decibels

Machinery-related impulse* sounds shall not exceed the maximum steady sound level limits by more than 5 decibels.

The estimated health and welfare benefits from this proposed regulation can be attained only if the compactors conform to the regulated sound levels for a reasonable period of time. Therefore, the Agency proposes to adopt an Acoustical Assurance Period (AAP) of three years of 7500 operating hours, whichever occurs first.

*see discussion of impulse sounds in Part 2, the Background Document.

In conjunction with the proposed regulation, the Low Noise Emission Product (LNEP) program provides incentives for achievement of lower noise emissions from regulated products than those required. The LNEP sound level for compactors is 70 dBA, effective January 1, 1978.

Enforcement. The EPA will use the following two methods to determine whether truck mounted solid waste compactors comply with the acceptable noise emission standard:

> Production verification - Prior to distribution into commerce of any truck mounted solid waste compactor, as defined in this regulation, a manufacturer must submit information to EPA which demonstrates that his product conforms to the standards.
>
> Selective enforcement auditing - Pursuant to an administrative request, a statistical sample of truck mounted solid waste compactor may be tested to determine if the units, as they are produced, meet the standard.

Relationship with Other Federal, State, and Local Government Agencies. The proposed regulation will preempt any non-identical State and local regulations. It will interact with several other government regulatory efforts, and it will require supplementary actions by State and local governments in order to achieve maximum benefit.

Federal Government Agencies. 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 is relying on this regulation to quiet the trucks upon which the compactors are mounted.

State and Local Government. Although the Noise Control Act prohibits any State or political subdivision thereof from adopting or enforcing any law or regulation which sets a limit on noise emissions from such new products, or components of such new products, which are not idential to the standard prescribed by the Federal regulation, primary responsibility for control of noise rests with State and local governments.

Nothing in the Act precludes or denies the right of any State or political subdivision thereof from establishing and enforcing controls on environmental noise through the licensing, regulation or restriction of the use, operation or movement of any product or combination of products.

The noise controls which are reserved to State and local authority include, but are not limited to, the following:

1. Controls on the manner of operation of products
2. Controls on the time in which products may be operated
3. Controls on the places in which products may be operated
4. Controls on the number of products which may be operated together
5. Controls on noise emissions from the property on which products are used
6. Controls on the licensing of products
7. Controls on environmental noise levels.

By use of the noise controls reserved to them, State and local governments are able to supplement Federal noise emission standards and to effect near-term relief from TMSWC noise. The EPA has developed a model ordinance to indicate the form and content of an instrument whereby State and local governments may control TMSWC noise in the absence of Federal regulation or in the time frame before Federal regulations become effective. The model ordinance is contained in section 9 of Part 2 of this document, the "Background Document".

ENVIRONMENTAL IMPACT

The environmental impacts of the proposed regulation include the primary beneficial impact, which is reduced annoyance from trash-collection noise resulting from lower truck mounted solid waste compactor noise and the secondary impacts on other environmental factors.

Impact on the Population of the United States

Compliance with the most stringent proposed standards will, on the average, reduce noise emissions from truck-mounted solid waste compactors by 6 dBA; compared to the noisiest types of units measured, reductions may average as high as 8.9 dBA. In terms of reduced impact on the nation's population, the reduction in sound level, when considered in combination with existing Federal standards for medium and heavy trucks, should result in a reduction of approximately 71 percent in the severity and extensiveness of TMSWC noise impact by the year 1991. This represents an increase of approximately 88 percent in additional benefits over those anticipated to accrue from current Federal noise regulations of meduim and heavy trucks.

Impact on Other Environmental Considerations

Land Use. The proposed regulation will have no adverse impact on land use.

Water Quality. The proposed regulation will have no adverse impact on water quality or supply.

Air Quality. The proposed regulation will have no adverse impact on air quality.

Solid Waste Disposal Requirements. The proposed regulation will have no adverse effects on solid waste disposal requirements.

Wildlife. The proposed regulation will have no adverse effects on wildlife.

ECONOMIC IMPACT STATEMENT

SUMMARY

The establishment of noise standards for newly manufactured truck-mounted solid waste compactors gives rise to expenditures which would otherwise not be directly incurred by the private and public sectors. However, it should be understood that the option of not paying for noise pollution costs is unavailable. The only question is, in what form do we pay; for example, lost worker productivity due to noise induced task interruption, lost sleep due to intrusive noise, or successful litigation for hearing loss.

Recognizing that certain expenditures are necessary to protect the public health and welfare from inadequately controlled noise, the Agency performed analyses to estimate the magnitude and potential impact of these expenditures. Examined in the analyses were the structure of the industry, the estimated cost of abatement by compactor type, the price elasticity of demand, the capital and annual costs of enforcement, the impact of enforcement on annual operating and maintenance costs and the indirect impacts of the proposed regulations.

The following conclusions were reached in these studies:

1. The aggregate list price of truck mounted solid waste compactors may increase by 10.3 percent, based on the cost of the complete vehicle.
2. It is estimated that demand for truck mounted solid waste compactors could decrease by as much as 4 percent, but total manufacturer revenue in such a case should remain unchanged due to increased

due to increased prices. Some pre-buying is expected to occur prior to the effective date of the regulation. However, this will be limited by the available excess production capacity of about 4,000 units, almost entirely rear loaders.

3. The estimated increase in annual costs to users (including increased capital cost, operation and maintenance) through the year 2000 is estimated to be about $6.5 million or an increase of approximately 0.5 percent.

ECONOMIC IMPACT ESTIMATES

Cost of Compliance.

Total capital and annual costs accruing from the proposed regulatory schedule are displayed in Table 2.

Table 2

ESTIMATES OF TOTAL ANNUAL COSTS OF ABATEMENT
($ 000s)

	Year				
Costs	1982	1983	1984	1988	1990
Incremental Capital	27,431	2,802	2,864	3,110	3,233
Total Annual	6,520	6,659	6,807	7,391	7,686

Effects on Manufacturers

Demand Decline. Theoretically, based on economic theory and statistical estimates of demand elasticity, unit demand could be expected to decline in direct dollar-to dollar proportion to price increases resulting from noise control. Further dampening of demand could also ensue from the imposition of higher ownership expenses resulting from the increased costs for operation and maintenance (O&M). Because the O&M cost elasticity is small, dollar sales should remain approximately the same, with price increases offsetting unit sales decline.

Profits. No significant change in profits is expected to occur over a 22 year period.

Competitive Effects. There are indications that a few small firms in the industry, by virtue of their small market share and related financial and operation factors, would incur higher manufacturing costs resulting in slightly higher list price increases. It is possible that one to three manufacturers may cease production of truck mounted solid waste compactors due to industry pressures and competition.

Direct Effect on Prices

Effect on List Prices. The average estimated increase in list price for each type of loader is displayed in Table 3. The potential cost increases on a per model basis may vary from the average since abatement costs are somewhat sensitive to variations between machines.

Table 3

ESTIMATED AVERAGE COST INCREASE AS A PERCENTAGE OF LIST PRICE FOR THE COMPLETE VEHICLE FOR THREE TYPES OF COMPACTORS

Compactor Body Type	Percentage Increase
Front Loaders	6.4%
Side Loaders	12.8%
Rear Loaders	9.8%

Effect on End User. The end user will feel more of the direct impact of increased costs. The truck mounted solid waste compactor body industry operates on the "full cost pass through" principles. Cost increases to the manufacturer are passed down to the end user through the distributor in the form of increased list price.

The consumer of solid waste collection services will ultimately absorb the cost increases through increased collection rates. The rate increases are not expected to be significant due to amortization of the increased costs by the large number of consumers.

(a) The anticipated percent increases for service will be insignificant; approximately 0.51 percent.

(b) The increased service rates to the consumer will be paid indirectly with taxes (if municipal fleets provide the service) or directly to private haulers.

Effect on Operating & Maintenance Costs. The estimated average O&M cost increases to be faced by users in the collection industry are displayed in Table 4 for each type of compactor, based on a 100 percent population of units conforming to the noise standard.

Table 4

ESTIMATED O&M COST INCREASES (DECREASES)
IN $'s PER VEHICLE PER YEAR

	Dollars
Front Loader	(50)
Side Loader	(55)
Rear Loader	(55)

Actual O&M costs are expected to decrease due to reduced fuel requirements resulting from the progressive noise control technology discussed in Part 2 of this document.

Productivity Effects

Production of goods is estimated to decline in unit volume by no more than 4 percent. Employment is not expected to change significantly due to the noise regulations.

Persons who might be affected by the production reduction amount to less than two percent of the employed population of about 2900 persons within the industry and produce less than three percent of the total units estimated.

An offsetting increase in employment is expected to occur due to testing and compliance resulting from the noise treatment regulation.

Industry growth is not expected to be significantly impacted due to the noise abatement regulation. Adequate lead time is provided to allow for proper planning and avoid adverse conditions in the industry.

Equipment productivity will not be impacted by the noise standards.

Indirect Effects

Impact on Suppliers. Some component suppliers may increase their sales depending on their ability to reduce the noise emissions of their product and thereby contribute to the reduction in overall machine noise. Furthermore, those suppliers specializing in the manufacture of sound damping and sound absorptive materials and other products required for abatement would be expected to experience increased sales.

Impact on Exports and Imports. As the noise control treatments generally represent add-on materials or substitute components, or both, machines for export generally can be produced without noise control treatment, if desired. Consequently, since units produced solely for export need not comply with U.S. noise standards, the impact on exports should be minimal. With respect to imports, the regulation will apply to imported compactors. Therefore, no adverse competitive impact is expected and, in view of the small percentage of machines imported, the proposed regulation should have no applicable impact on the U.S. balance of payments.

Impact on Energy Use. Technological changes due to noise treatment regulations are expected to result in lower fuel consumption. Annual fuel savings of approximately $95 per unit are expected.

Macroeconomic Assessment. No macroeconomic impact is expected as a result of noise abatement regulations on the truck mounted solid waste compactor body industry due to:

(a) The minor size of the industry.

(b) The small size of the changes expected to occur.

Impact on Taxes. There will be an indirect increase in local taxes where collection services are provided by municipal fleets but the amount of the increase to the individual consumer and taxpayer will be insignificant.

EPA 550-9-77-204

NOISE EMISSION STANDARDS FOR SURFACE TRANSPORTATION EQUIPMENT

INFORMATION IN SUPPORT OF THE PROPOSED REGULATION FOR TRUCK-MOUNTED SOLID WASTE COMPACTORS

PART 2
BACKGROUND DOCUMENT

AUGUST 1977

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF NOISE ABATEMENT AND CONTROL
WASHINGTON, D.C. 20460

This document has been approved for general availability.
It does not constitute a standard, specification or regulation.

T A B L E   O F   C O N T E N T S

PART 2

BACKGROUND DOCUMENT

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FIGURES

FIGURES (continues)

TABLES

TABLES (Continued)

TABLES (Continued)

TABLES (Continued)

TABLES (Continued)

SECTION 1

INTRODUCTION

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 "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) 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 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. Such products fall into various categories, of which surface transportation is one. Pursuant to subsection 5(b) (1), the Administrator has published a report identifying truck-mounted solid waste compacters as a major source of noise.

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 (on 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)(1) 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 product." Environmental noise is defined as the "intensity, duration, and character of sounds from all sources" (Section 2 (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 Goverment may assume the duties involved in regulating products distributed nationwide because it is required and equipped to do so. Congress divided the noise emission regulation power 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 powers, 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 would limit the level of environmental noise reaching the boundary of a particular piece of property. Noise emitters would be free, insofar as State regulations are concerned, to use any products whatsoever, as long as they are used or operated in such a fashion so as not to emit noise in excess of the state-specified limits. 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, local areas may balance the issues involved to arrive at a satisfactory environmental noise regulation(s) that protect the public health and welfare as much as deemed possible.

LABELING

The enforcement strategies outlined in Section 8 of this document will be accompanied by the requirement for labeling products distributed in commerce. The label will provide notice to a buyer that a product is sold in conformity with applicable regulations. A label will also make the buyer and user aware that the trash compactor truck possesses noise attenuation devices and that such items should not be removed or rendered inoperative. The label may also indicate the associated liability for such removal or tampering.

IMPORTS

The determination of whether individual new products comply with the Federal regulation will be made by the U.S. Treasury Department (Customs), based on ground rules established through consultation with the Secretary of the Treasury.

It is anticipated that enforcement of the actual noise standard by the use of a standard test procedure would be too cumbersome for Customs to handle, especially in view of the tremendous bulk of merchandise they must pass on each day. A case in point occurs with imported automobiles, in which Customs inspectors presently assess compliance with requirements of the Clean Air Act solely on the basis of the presence of a label in the engine compartment. A similar mechanism (labeling) appears viable for use to assess compliance of imported trash compactor trucks with the proposed regulations.

RATIONALE FOR REGULATION OF THE TRASH COMPACTOR TRUCK

To develop an EPA criterion for identifying products as major sources of noise, first priority was given to those products that contribute most to overall community noise exposure. Community noise exposure is defined as that exposure experienced by the community as a whole as the result of the operation of a product or group of products, as opposed to 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) that was developed especially as a measure of community noise exposure. Since L_{dn} is an equivalent energy measure, it can be used to describe the noise in areas in which noise sources operate continuously or intermittently but are present enough of the time to emit a great deal of sound energy 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 urban traffic noise, aircraft noise, construction site noise, and freeway traffic noise at or above an outdoor L_{dn} of 60, 65, and 70 dB, respectively.

EPA has identified an outdoor L_{dn} of 55 dB (Ref. 1-1) as the day/night average sound level requisite* to protect the public from long-term adverse health and welfare effects in residential areas. Table 1-1 shows that it will be necessary to quiet the major sources contributing to urban traffic noise, construction site noise, freeway traffic noise, and aircraft noise if this level is to be achieved.

Table 1-1

ESTIMATED NUMBER (in Millions) OF PEOPLE IN RESIDENTIAL AREAS SUBJECTED TO DIFFERENT KINDS AND LEVELS OF OUTDOOR NOISE (Ref. 1-1)

Outdoor Ldn Level	Urban Traffic Noise	Aircraft Noise	Construction Site Noise	Freeway Noise
70 dB+	4-12	4-7	1-3	1-4
65 dB+	15-33	8-15	3-6	2-5
60 dB+	40-70	16-32	7-15	3-6

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

NEED FOR CONTINUED COMPLIANCE WITH THE NOISE STANDARD

It is important to the purchaser that the product has been designed and built so that it will continue to meet its noise emission standard for a stipulated period of time or use when it is properly used and maintained.

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

The question of "Useful Life" with respect to product noise regulations was first addressed in the proposed rule making for medium and heavy trucks and for new portable air compressors. The initially proposed useful life provisions required the manufacturer to assume that his product would continue to meet the EPA noise emission standard throughout the product's useful or operational life. This requirement was intended to ensure that the public health and welfare benefits derived from the product standards would not degrade during the product's life as a result of the product's sound level increasing over time. The Agency deferred action on setting a useful life standard in the final regulations for new medium and heavy trucks and portable air compressors based on a need on the part of EPA to further assess to what degree the noise from a properly used and maintained product would increase with time. However, the Agency reserved a section in the regulations for the proposal of useful life standard at a later time.

The Agency has given considerable attention to this question of product noise degradation (increase in noise level with time) and firmly believes 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 would become a nullity and the anticipated health and welfare benefits will be illusory.

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 in compliance with the Federal standard provided it is properly used and maintained according to the manufacturer's recommendations.

In contrast to the previously proposed "Useful Life" requirements, 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 predicated, 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 will require the product manufacturer to assure that the product is designed and built in a manner that will enable it to comply with the 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 his compliance testing and verification program. This procedure, if used, would require a manufacturer to apply a "Sound Level Degradation Factor" (SLDF) to 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 dBA during the prescribed AAP would specify an SLDF of 3 dBA. For production verification the manufacturer would then test to ensure that his product's sound level is 3 dBA below that specified in the applicable Federal standard. For those products not expected to degrade during the AAP the manufacturer would specify an SLDF of zero.

IDENTIFICATION OF MAJOR SOURCES OF NOISE

Section 6(A)(1)(C) of the Noise Control Act specifies four possible categories of products that may be regulated by the Administrator:

1. Construction equipment.
2. Transportation equipment (including recreational vehicles and related equipment).
3. Any motor engine (including any equipment of which an engine is an integral part).
4. Electrical or electronic equipment.

Pursuant to Section 3(3)(A) aircraft are excluded as products under Section 6 of the Act. Aircraft noise regulations have been proposed to the FAA as delineated in Section 7 of the Act. Medium and heavy-duty trucks contribute the most sound energy to the environment of any highway vehicle and, as such, have been identified for regulation as major noise sources. A number of trucks operate with special equipment mounted, some of which may contribute significant noise to the environment aside from that due to the normal operation of the truck in its transportation mode. One such product is the truck-mounted solid waste compactor, which is known to be a source of annoyance and sleep disturbance. In order to preclude a lessening of the beneficial effect of truck noise regulation in reducing noise impact, the EPA has identified the truck-mounted solid waste compactor for noise regulation.

OUTLINE AND SUMMARY OF BACKGROUND DOCUMENT

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 document:

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 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 impact 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 (Reserved).

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 as seen in Table 2-1.

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 step operational sequence for front loading is shown in Figure 2-2. The compaction cycle for a front loader is illustrated in Figure 2-3.

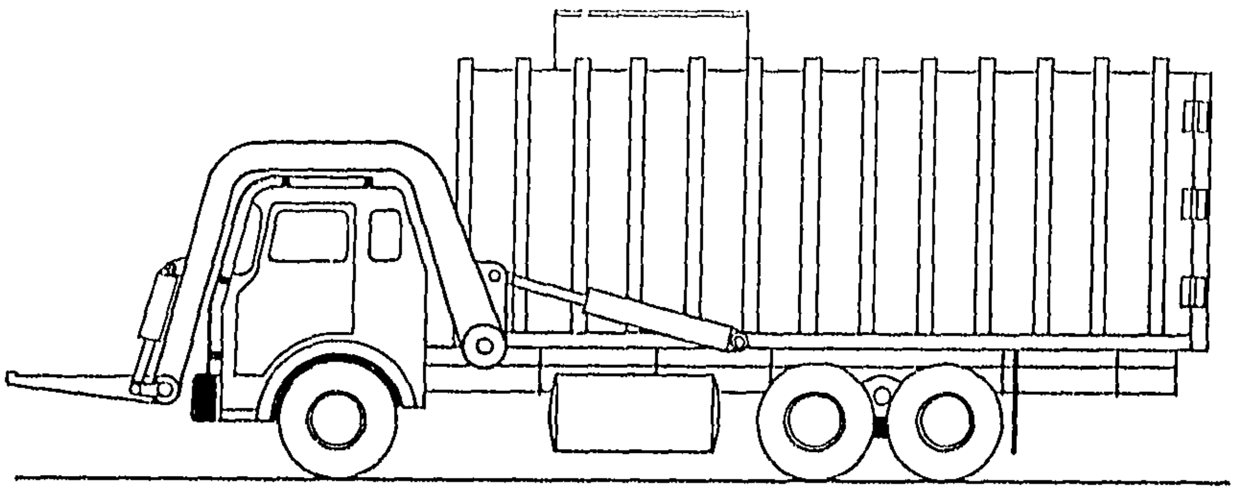


Figure 2-1. A Front Loader

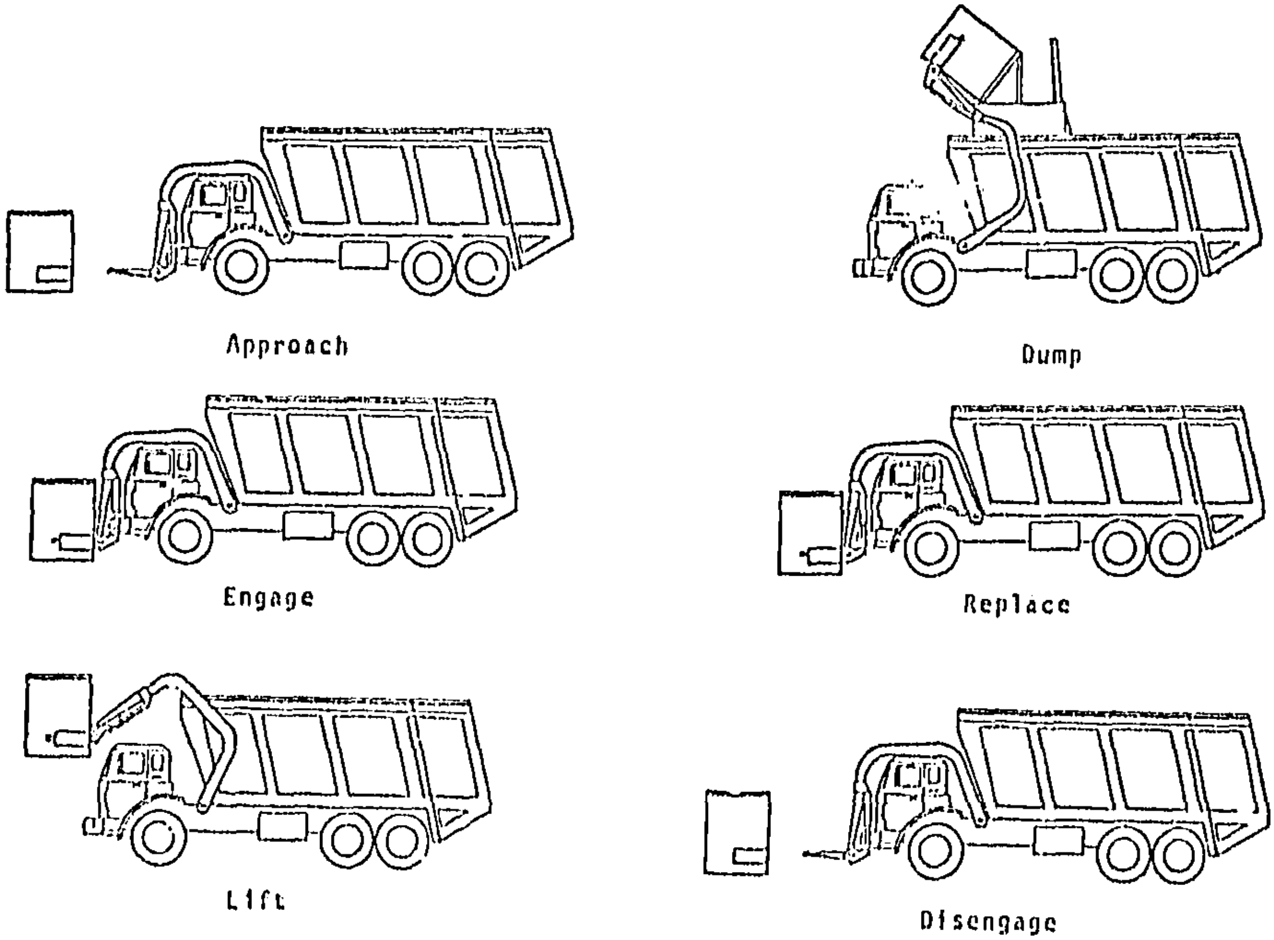


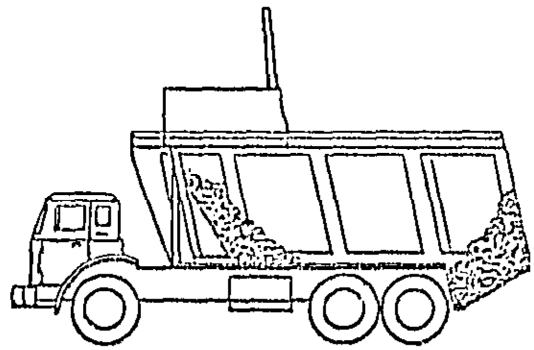
Figure 2-2. Six Step Operational Sequence for Front Loading

TABLE 2-1

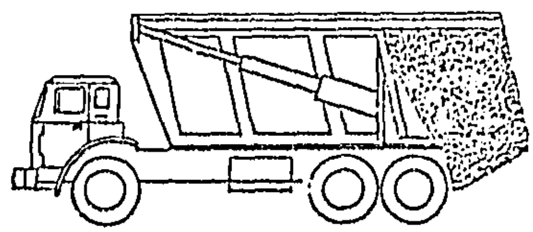
CLASSIFICATION OF TRUCK MOUNTED SOLID WASTE COMPACTOR BODIES

Classification	Range of Body Cubic Yard Capacity	Estimated Compaction Density (Pounds/Cubic Yard)		Estimated Compactor Body Power Source		
				Truck Engine		Gasoline Auxiliary
		Range	Average	Gasoline	Diesel	
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

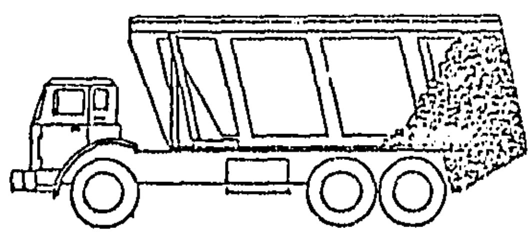
SOURCE: Field interviews with product manufacturers, distributors and product literature. The Virginia Town & City "Fuel Conservation in Solid Waste Management", Kenneth A. Shuster, December, 1974, and associated working papers.



Dump



Compaction



Return

Figure 2-3. Operation of a Front Loader (Compaction Cycle)

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 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, would 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.

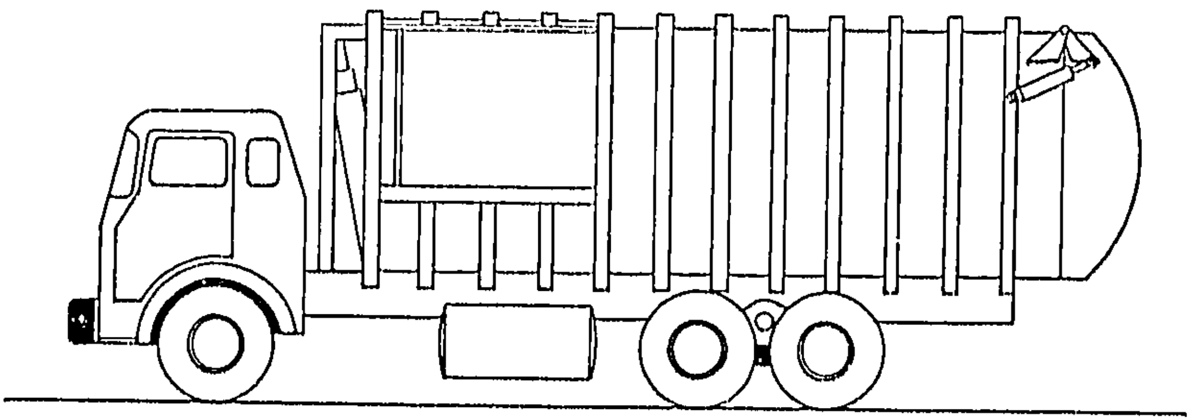


Figure 2-4. A Side Loader

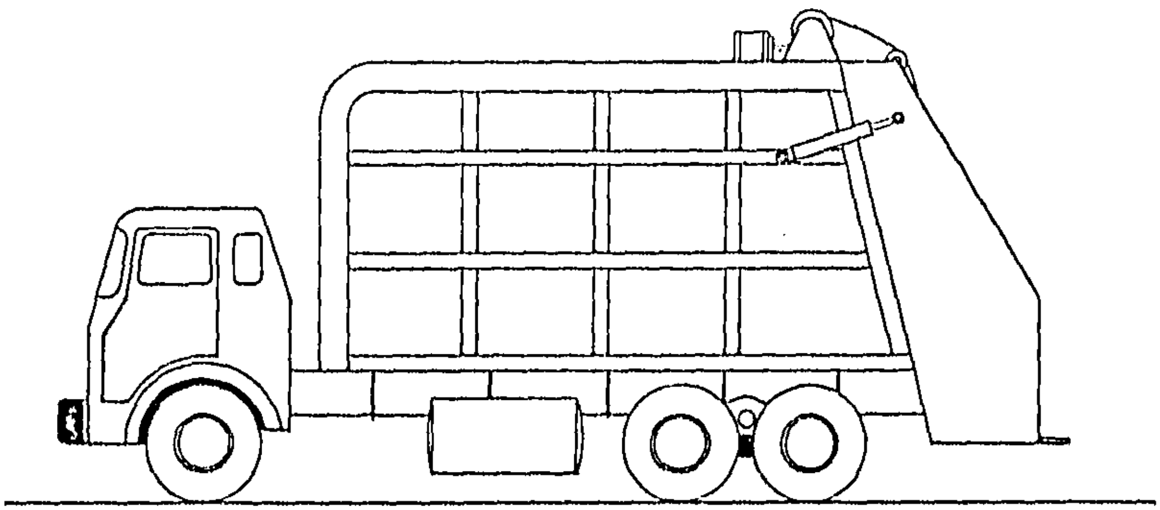


Figure 2-5. A Rear Loader

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. This type of compactor has been excluded from consideration because the potential economic impact associated with these units is insignificant. Fewer than 50 units were shipped in 1974 and the estimated number of units in operation is less than 100.

As indicated in Table 2-1, packer bodies can also be classified by body cubic year capacity 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.

TABLE 2-2

TRUCK MOUNTED SOLID WASTE
COMPACTOR BODY APPLICATIONS
BY PRODUCT CLASSIFICATION

	Percent of Total Units Employed by Major Application	
Equipment Classification	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.

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*Residential includes single-family dwellings and duplexes.

2. All other categories of bodies are used principally for residential waste collection. Commercial and industrial application of this equipment is typically 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 versus multi-man crews. This provides a competitive advantage for side loaders as compared to the more broadly used rear loader.

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. A truck would periodically remove either a detachable container or the entire unit and dispose of the collected wastes.

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

Potential disadvantages would include a 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. This product concept entails 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.

Disadvantages relating to models currently available, may include higher levels of crew personal injury attributable to lifting wastes to a higher level for deposit in the body. Crew productivity may also be reduced by the higher lift height.

No. U. S. manufacturer currently produces this type of body. They are imported from Europe and currently have insignificant penetration in the U.S. market.

No noise measurements were made of this type 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 represents a return to prepacker body collection practices. Noise levels would probably be reduced but crew productivity would be substantially lower.

THE INDUSTRY

Solid Waste Generation

The demand for the product of the compactor body industry is derived from the generation of solid wastes, particularly by residences and commercial establishments, that are subject to collection and disposal.

The availability of solid waste generation data is relatively limited and of recent origin. While estimates are universally accepted as accurate, 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 at 144 million tons. Resource reclamation provided for the disposal of 9 million tons, resulting in a net solid waste disposed quantity of 135 million tons.

Projections of total residential and commercial solid wastes 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 of four percent between 1973 and 1980. New 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, relative to the traditional open body collection truck, is that compaction allows larger quantities of wastes to be

TABLE 2-3

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

	Estimated				Projected				Total Quantity, Average Annual Growth Rate, 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.

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 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.

collected between trips to the disposal site. Consequently, more waste collection points can be served between trips and a substantially higher proportion of total collection crew time is productive.

Even with the advent of this equipment, waste collection remains an extremely labor intensive operation. Recent product enhancements 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 is shown in Table 2-5. It can be seen that approximately 76,000 units are in operation. Rear loaders account for 73 percent of the total. The estimated functional life of front loaders is eight years and rear and side loaders is seven years.

Unit and Dollar Manufacturer Shipments

The units and value of manufacturer shipments in 1964, 1967, and 1972 and estimates for 1974 by loader type are shown in Table 2-6. 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. The unit growth rate remained the same and dollar growth increased to 22 percent between 1967 and 1974.

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		1967		1972		Estimated 1974*			1964 - 1974		Average Annual Growth** Rate, 1967 - 1974	
	(000s) Units	Millions Dollars	(000s) Units	Millions Dollars	(000s) Units	Millions Dollars	(000s) Units	% of Total	Millions Dollars	(000s) Units	Millions Dollars	Units	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%	$66.0	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, MC72(2)37A, Page 17; interviews with product manufacturers.

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* 1974 shipments and mix by loader type estimated from field interviews with product manufacturers.

** Rounded to nearest percentage point.

It is estimated that 73 percent of 1974 shipments were rear loaders.

Export Sales

The estimated value of manufacturers' exports in 1974 are shown in Table 2-7. Approximately 20 percent of manufacturers' shipments, or $25 million, are estimated to be exports. More than 90 percent of the value of exports are completed bodies.

CHARACTERISTICS OF INDUSTRY SEGMENTS

The general structure of the compactor body industry is depicted in the schematic shown in Figure 2-6. Generally, the packer body manufacturer purchases raw materials and components from suppliers and builds the body. Bodies are then sold to either truck chassis dealers or truck body distributors, dominantly 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. Currently, 25 companies have been identified as manufacturers of packer bodies in the United States (Table 2-8).

TABLE 2-7

ESTIMATED VALUE OF TRUCK MOUNTED SOLID WASTE COMPACTOR BODY MANUFACTURER'S 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.

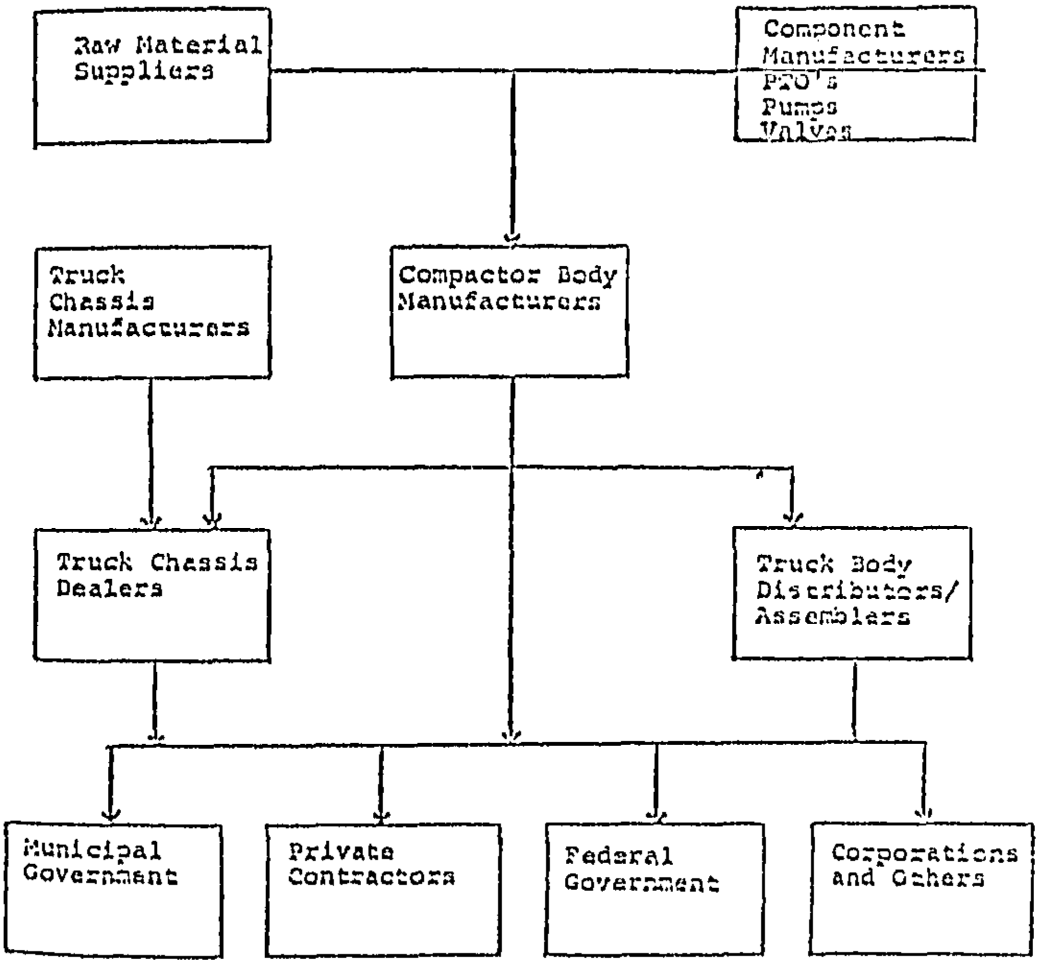

Figure 2-6. Truck Mounted Solid Waste Compactor Body Industry Structure

2. These companies, including total corporate revenues, range in size 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 bodies, but favorable investment incentives and labor climates have attracted many plants in 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 is summarized below:

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

b. Ten companies produce side loaders. Body cubic capacity ranges from 10 to 38 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 dominant sizes are 16, 20, and 25 cubic yards.

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	DIVISION/ SUBSIDIARY	REFUSE COMPACTOR BODY
Company S	1946	50	$ 1.9	$	$ .3	$	$	n/a	$
Company T (a)	n/a	27,079	904.6	8.6	754.2	337.1	330.0	n/a	
Company U (b)	1912	40,765	1,478.0	37.5	982.0	331.0	158.8	n/a	
Company V	n/a	n/a	25.0	n/a	n/a	n/a	n/a	n/a	
Company W (b)	1918	24,400	1,315.0	22.7	1,020.8	342.2	139.9	n/a	
Company X (c)	1939	27	2.4	.1	.1	.1	.2	.7	
Company Y	1956	n/a	30.0	n/a	n/a	n/a	5.0	5.0	
Company R	1899	14,900	490.1	25.4	318.6	182.0	101.8	n/a	4.0
Company C (a)	1901	1,633	70.3	2.8	41.7	22.1	23.6	n/a	
Company AA (d)	1953	140	7.1	.2	3.4	.9	.9	7.1	
Company D (e)	1937	200	11.4	.4	8.5	1.8	1.8	1.8	
Company BB	1945	175	7.9	(.3)	n/a	n/a	n/a	7.9	
Company CC	1960	14	.2	n/a	.1	n/a	n/a	6.8	
Company B (f)	1952	230	6.8	n/a	4.8	1.9	1.5	54.2	
Company DD (g)	n/a	n/a	257.9	9.6	203.4	70.0	71.4	n/a	
Company EE (b)	1906	2,151	109.1	5.2	57.0	37.6	25.6	13.3	
Company FF (i)	1966	200	13.3	(.7)	8.3	2.0	.5	8.7	
Company I (g)	n/a	1,622	61.8	1.7	38.8	16.7	16.1	n/a	
Company GG	1953	150	n/a	n/a	n/a	n/a	n/a	20	
Company HH (fg)	n/a	n/a	123.0	2.8	86.6	22.4	24.8	1.2	
Company II (h)	n/a	80	2.4	.1	1.4	.4	.3	n/a	.2
Company JJ	1978	7	n/a	n/a	n/a	n/a	n/a	n/a	
Company KK	n/a	28	1.3	n/a	n/a	n/a	n/a	n/a	
Company LL	1973	3	.2	n/a	n/a	n/a	n/a	n/a	
Company MM	n/a	35	4.0	n/a	n/a	n/a	n/a	n/a	

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

(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

	Production Facilities			
Company Name	Facility Size (Thousands of Square Feet)	Owned or Leased	Number of Employees	Products Manufactured
Company S			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	
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	27	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	202	n/a		-Containers, refuse compactor bodies, stationary compactors, roll-off hoists, transfer trailers.
	n/a	n/a	1,100	
	n/a	n/a		-Refuse compactors.

TABLE 2-9 (continued)

Company Name	Production Facilities: Facility Size (Thousands of Square Feet)	Owned or Leased	Number of Employees	Products Manufactured
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	400	O	n/a	-Front loaders, side loaders, stationary compactors.
Company D		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.
Company BB	33	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.

TABLE 2-9 (continued)

	Production Facilities			
Company Name	Facility Size (Thousands of Square Feet)	Owned or Leased	Number of Employees	Products Manufactured
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.

SOURCE: Dun & Bradstreet, Inc., Analytical Reports, unless otherwise indicated.

(a) Annual Report, 1974 and interviews with company management.
(b) Moody's Investors Service, Inc. "Industrial Manual, 1975".
(c) Annual Report, 1974 and Form 10-K filed with the Securities and Exchange Commission, 1974, Pages 2, 3 and 9.
(4) Annual Report, 1974.
(e) Total manufacturing facilities in Huntington Park & Los Angeles, California: 194,000 square feet.

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

a. Two firms dominate the market with approximately 60 percent of all front loaders shipped. The remainder of shipments is rather evenly distributed among the other nine producers.

b. Three firms shipped about 20 percent of total side loaders each.

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.

The geographic markets served by a plant are limited, typically 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 other manufacturers, two of the largest shippers of rear loaders serve a national market.

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 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

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.

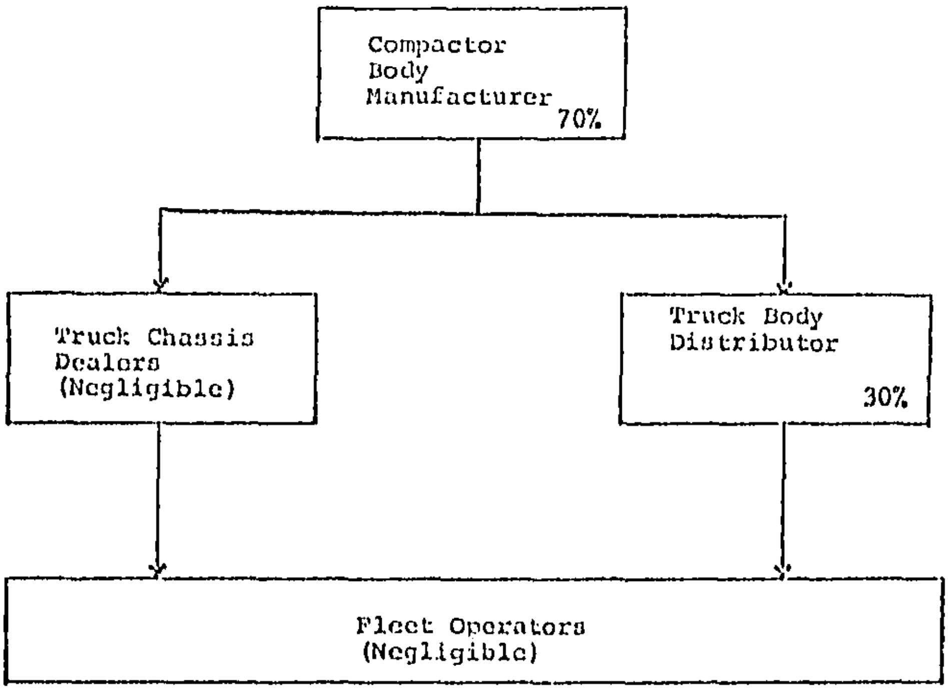

Figure 2-7. Estimated Body Mounting Practices for Truck Mounted Solid Waste Compactor Bodies (Percent of Total New Bodies Mounted)

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*

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.

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*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.

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, respectively.

10. Manufacturer warranty provisions vary considerably. Typically, only parts are covered, but service adjustment policies may cover labor in some instances. Warranty periods range from 90 days for selected components or the complete body to 12 months or the complete unit excluding selected components.

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 dominant pattern is for manufacturers to utilize distributors to sell and deliver bodies to packer truck fleet operators. Leasing companies finance the purchase of about ten percent of all units sold, dominantly, new bodies. Rental of packer body truck 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 but does provide perspective. Note that the total number of firms is 2,420 and that the average sales revenue per firm is $1.8 million.

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.

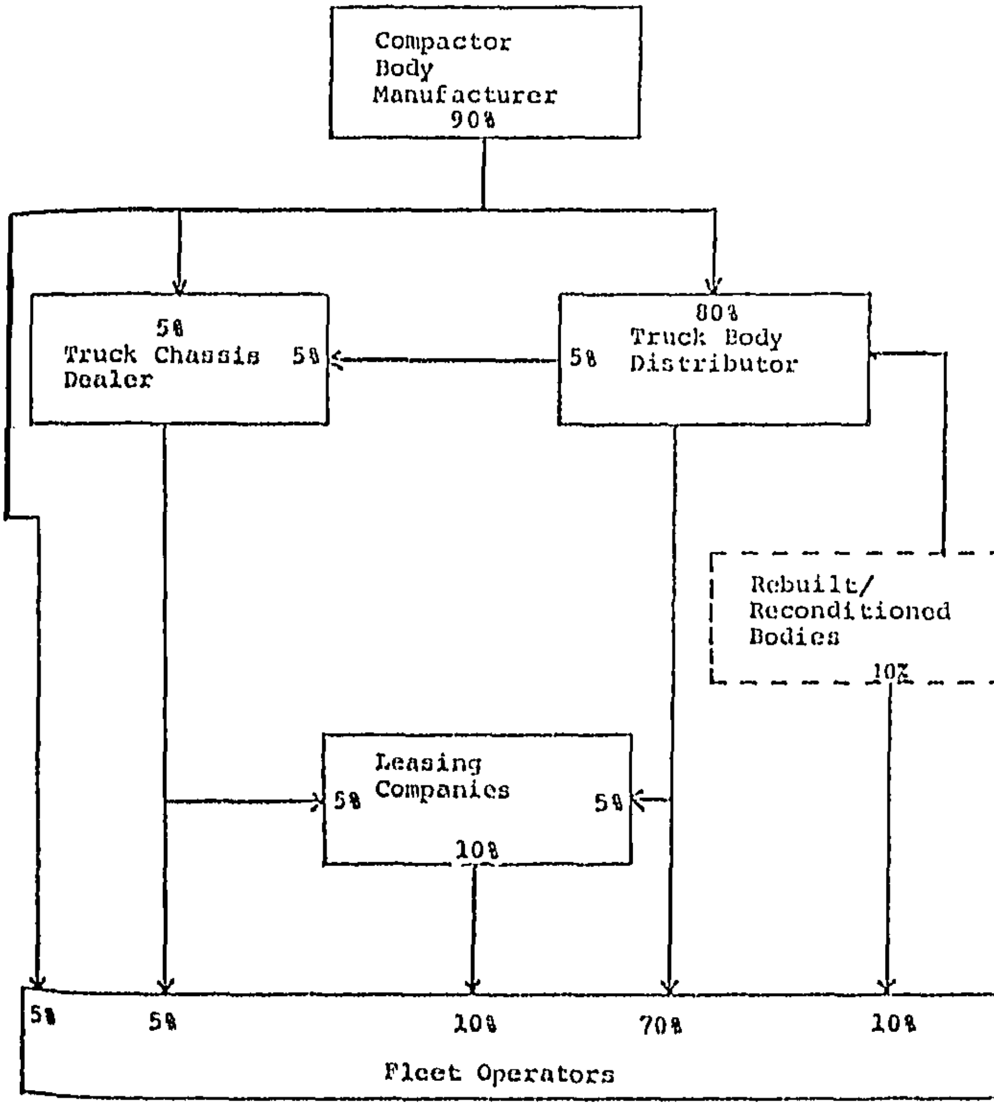


Figure 2-8. Truck Mounted Solid Waste Compactor Body Channels of Distribution, Based on Total New and Used Units Sold Annually

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

TABLE 2-15

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

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

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

4. These firms have average total assets of $700,00.

<u>End Use Market Fleet Operators</u>

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

1. <u>Private Contractors</u>. 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 agglomerated 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.

TABLE 2-16

PROFILE OF TRUCK MOUNTED SOLID WASTE COMPACTOR BODY DISTRIBUTORS, 1972

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

Financial

		Percent of Median Net Revenue
Average 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

SOURCES: 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

SOURCES: 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.

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 Tonnag Number (Thousands)	Total Daily Tonnag Perce
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
Per Contractor			10.2		6.2		2,728			

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.

b. These firms serve 27.3 million customers, operate 61,500 total trucks (41,602 of which are packer 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, all 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, as measured in terms of number of employees and packer trucks employed.

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. This includes between 800 and 900 governmental units which account for approximately two-thirds of the population within municipalities and townships, about 85 percent of governmental general expenditures, and slightly more than 80 percent of the expenditures for sanitation other than sewage.

TABLE 2-19

PRIVATE CONTRACTOR TRUCK EQUIPMENT COMPOSITION, 1970

Equipment Type	Thousands 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.

* Adjustedto reflect rounding.

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. 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.

It is shown in Table 2-20 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 firms 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 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 their total shipments.

SECTION 3

TRUCK-MOUNTED SOLID WASTE COMPACTOR SOUND LEVELS

SOUND LEVEL MEASUREMENTS

A total of 32 noise measurement tests were run on 28 different trucks (4 trucks were measured in two modes). For most of the tests, a microphone was placed at 7 meters (approximately 23 ft.) from each of the four sides of the truck and both the maximum steady "A" -weighted level and maximum impulse "A"-weighted level were recorded. In addition, the cycle time of the truck was measured. All the data which have been obtained is recorded in Table 3-1. In this table, the energy average of the individual microphone measurements around the truck and the Sound Exposure Level (SEL) have been recorded for each test. The number of measurement tests made for each category of truck were:

Rear Loaders	-	23
Front Loaders	-	6
Side Loaders	-	3
TOTAL	-	32

A number of these trucks already had some degree of noise control incorporated (7 rear loaders, 1 front loader, and 1 side loader) and their noise levels are accordingly lower than the other trucks. The sample taken is not intended to be representative of the solid waste compactor truck population in general, but rather what was available for measurement. Particular interest was shown in the quieted trucks which are in service and the measured sample therefore incorporated a disproportionately large number of these quieted vehicles.

Table 3-1. MEASURED SOUND LEVELS: SOLID WASTE COMPACTORS

Measurement Number	Body Manufacturer (Company)	Loader Type	Fuel	MAX STEADY LEVELS AT 7m			MAX IMPULSE LEVELS AT 7m		Remarks
				Energy Average	Cycle Time (Sec)	SEL	Energy Average	SEL	
1	A	Rear	Gasoline	74	30	87.5	78	75	Quieted truck
2	A	Rear	Gasoline	87	12	94.5	89.5	85	2000 rpm
3	B	Side	Diesel	74	10	84	-NO IMPACTS-		300 rpm FPTO 3 measurement points
4	C	Front	Diesel	79	35	88	86	85	Lifting
5	D	Rear	Gasoline	74	20	87	89	78	
6a	E	Side	Gasoline	77.5	8	84	84.5	80	Sweep — Uses auxiliary engine
6b	E	Side	Gasoline	76	75	95	84	79	Pack — Uses auxiliary engine
7	E	Rear	Gasoline	76	17	88	94	82	1 measurement point (side)
8a	F	Front	Diesel	83	40	92	89	80	(50 ft + 6 dB) Dump 1 measurement point (side)
8b	F	Front	Diesel	85	40	100	98	93	(50 ft + 6 dB) Compact
9	F	Rear	Gasoline	79	16	96	88	87	50 ft + 6 dB
10	G	Rear	Diesel	80	25	94	87.5	86	50 ft + 6 dB
11	G	Front	Diesel	83	—	—	-NO IMPACTS-		50 ft + 6 dB
12	H	Rear	Diesel	87	—	—	93.4	—	50 ft + 6 dB
13	H	Front	Diesel	87	20	100	97.4	97	50 ft + 6 dB
14	I	Rear	Diesel	79	40	95	84	—	
15	I	Rear	Diesel	82	—	—	82	—	1 measurement point (side)
16	F	Front	Diesel	85	20	—	94	—	1 measurement point (side)
17	I	Rear	Diesel	84	40	—	85	—	1 measurement point (side)
18a	J	Rear	Gasoline	82*	—	—	—	—	"Conventional" * (see note)
18b	J	Rear	Gasoline	67*	—	—	70*	—	"Silencer" * (see note)
19	J	Rear	Gasoline	74	8	83	84	79	Includes: Flywheel PTO, Overhead measurement (5 points total)
20	F	Front	Gasoline	80	20	90	82	84	Includes: Transmission PTO (Includes overhead measurement -5 points total)
21	J	Rear	Gasoline	73	27	85	83	78	Includes: Flywheel PTO (Includes overhead measurement 5 points total)
22	F	Front	Gasoline	74	25	87	75	68	Flywheel PTO (cushions)
23	J	Rear	Gasoline	74	10	82	79	73	Front PTO (includes overhead measurement 5 points total)
24	I	Rear	Gasoline	75	28	87	79	75	Front PTO (includes overhead measurement 5 points total)
25	K	Rear	Gasoline	76	Cont.	—	-NO IMPACTS-		(10m + 3 dB)
26a	H	Rear	Diesel	79	—	—	—	—	Packing
26b	H	Rear	Diesel	78	—	—	—	—	Ejecting
27	I	Rear	Gasoline	79	—	—	—	—	3 measurement points
28	I	Rear	Gasoline	78	—	—	—	—	3 measurement points

*NOTE: These measurements were made at a single measurement point with a Type 2 meter under inadequately controlled conditions, primarily to show the difference between "conventional" and "silenced" configurations in a staged demonstration. Consequently, the levels measured are not believed to be reliable, and the data are not included in the statistical analysis.

Figures 3-1 through 3-4 show histograms of the measured noise levels in each category. Both the maximum steady level and the maximum impulse levels are shown. The energy average around the truck is employed whenever it is available. Figure 3-1 is a histogram for all of the trucks measured and Figures 3-2 and 3-3 are histograms for the rear and front loaders, respectively.

Table 3-2 summarizes these various noise measurements in terms of the mean level and its standard deviation for each type of truck. Front loaders appear to be noisier than rear loaders on both steady levels and impacts. This is probably due to the lack of speed control of the engine and the banging of the container on the arms of the loader. Side loaders appear to be quieter than rear loaders, but the sample of side loaders measured is too small to make this conclusion firm.

Since certain of the compactor trucks measured had some degree of noise control treatment, it is informative to separate the sound level data out in terms of "conventional" and "quieted" units. As there appears to be a difference in the sound emissions between gasoline-powered and diesel-powered vehicles, it also is instructive to categorize the sound level data to show this difference. This is done in Table 3-3, which lists the mean values of the compactor truck sound levels of the various types of compactor, subcategorized into "conventional" and "quieted" units, and also classed in terms of diesel or gasoline-powered units.

TIME HISTORIES

Typical time histories of the three types of compactors are shown in Figures 3-4 through 3-6.

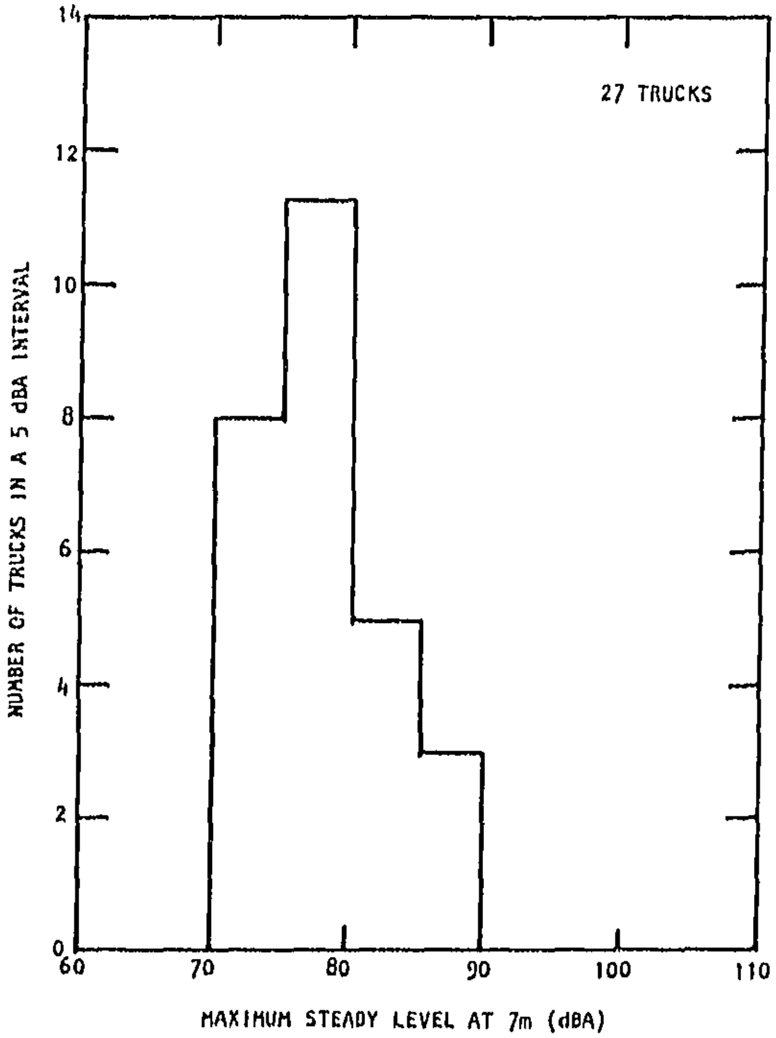


Figure 3-1a. HISTOGRAM OF ALL TRUCKS

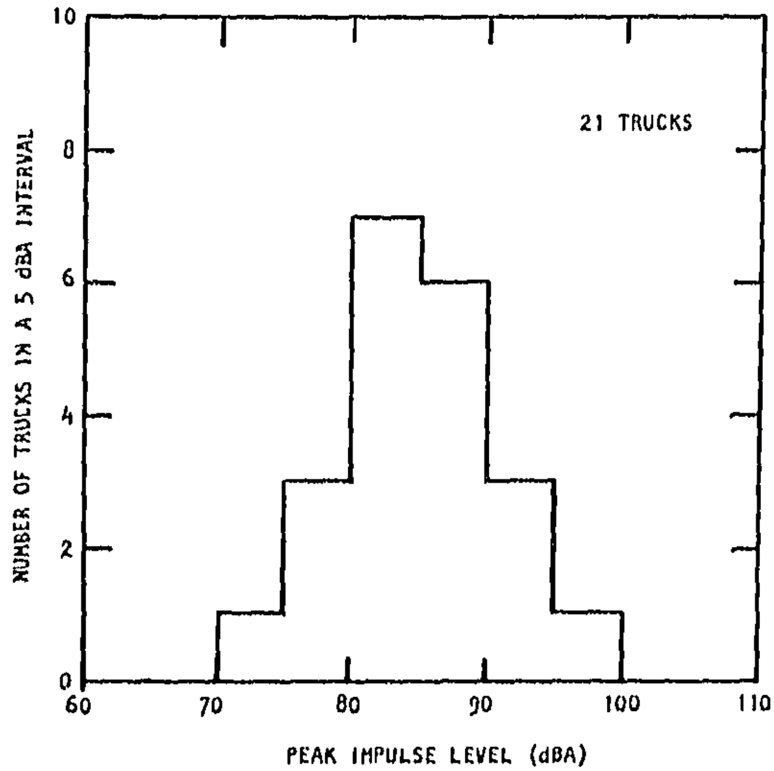


Figure 3-1b. HISTOGRAM OF ALL TRUCKS

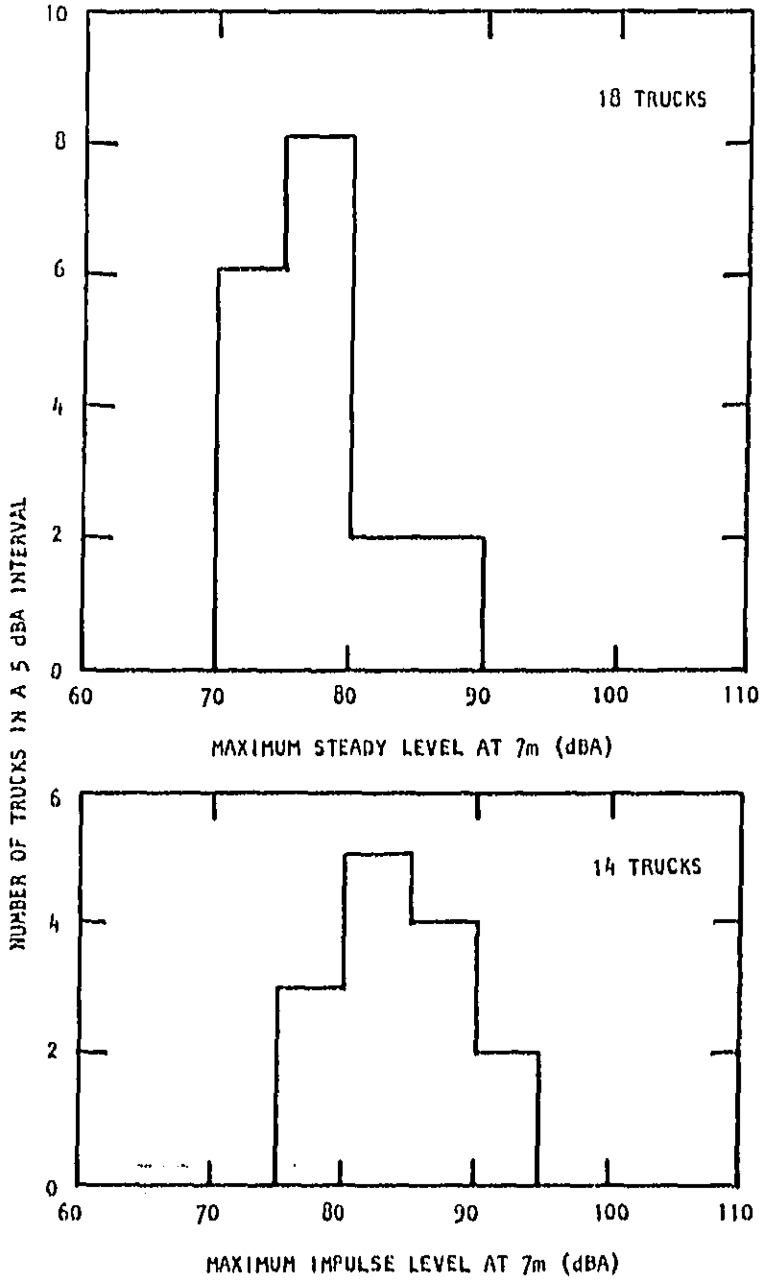


Figure 3-2. HISTOGRAM OF REAR LOADERS

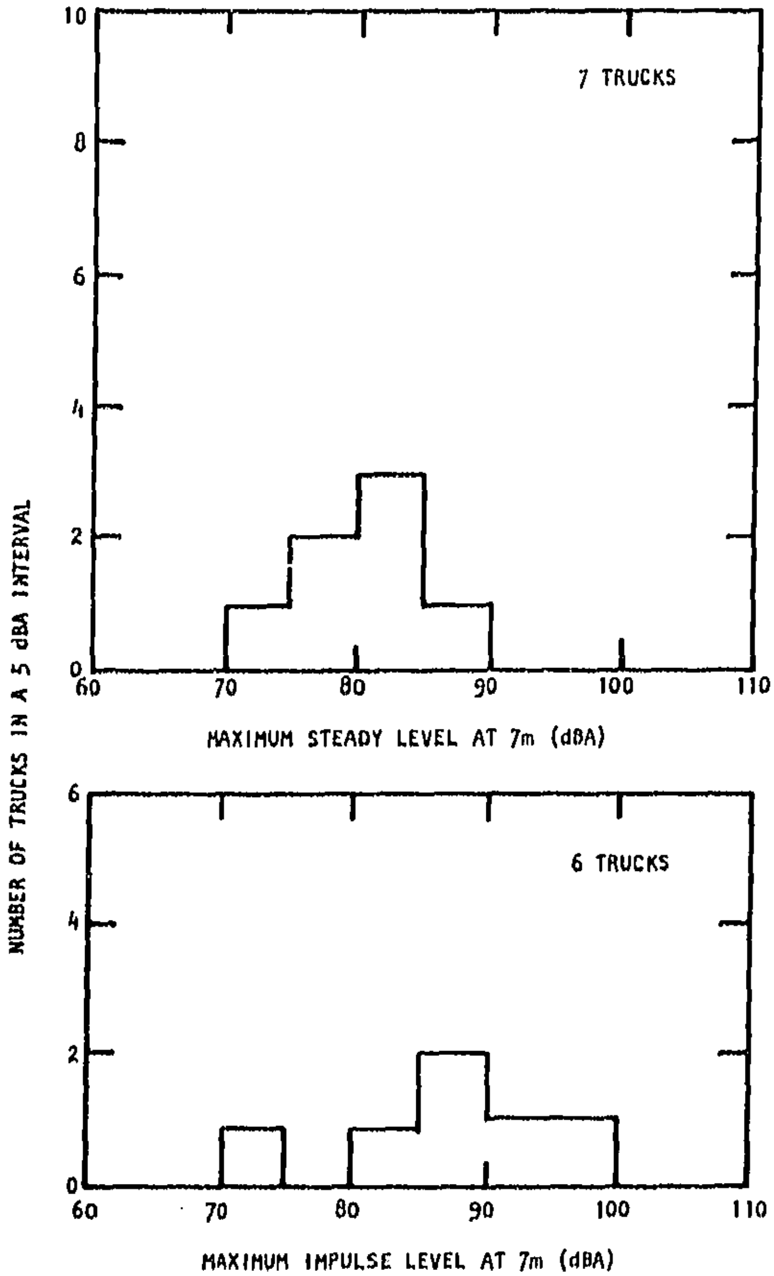


Figure 3-3. HISTOGRAM OF FRONT LOADERS

Table 3-2. SUMMARY OF SOUND LEVEL DATA

Compactor Type	Mean	Standard Deviation	Number of Vehicles
	Maximum Steady Level (dBA at 7 m)		
All Vehicles	79.0	4.56	27
Rear Loaders	78.3	4.38	18
Front Loaders	81.9	4.49	7
Side Loaders	75.8	-	2
	Maximum Impulse Level (dBA at 7 m)		
All Vehicles	85.9	5.86	21
Rear Loaders	85.4	5.1	14
Front Loaders	87.2	8.1	6
Side Loaders	84	-	1

Table 3-3. SUMMARY OF SOUND LEVEL DATA BY VEHICLE CATEGORY

Category	Conventional or Quieted	Mean Sound Level dBA	Standard Deviation dBA	Number of Samples
Rear Loader	Conventional	80.0	4.0	13
Rear Loader	Quieted	74.0	0.7	5
Front Loader	Conventional	83.2	3.1	6
Front Loader	Quieted	74.0	-	1
Side Loader	Conventional	77.5	-	1
Side Loader	Quieted	74.0	-	1
Gasoline-Powered	Unquieted	78.5	3.7	9
Gasoline-Powered	Quieted	74.0	0.6	6
Diesel-Powered	Unquieted	82.7	3.1	11
Diesel-Powered	Quieted	74.0	-	1

Figure 3-4 shows the time history of a rear-loader. The time history of a rear loader has typically three phases corresponding to different functions during the cycle. There is typically an impact at the end of each phase due to the bottoming of the hydraulic cylinders.

The time history of a front loader in loading and compaction is displayed in Figure 3-5. The noise level of a front loader is quite erratic during its loading cycle, due to the variations in engine speed. There are numerous impulses due to the banging of the container and closing of the cover during the dump portion of the cycle. Fewer peaks occur during the compaction phase.

In Figure 3-6, which depicts an operational passby of a side loader, various noise events can be distinguished. There is the noise of the truck as it arrives, the squeal of its brakes as they are applied, the shouts of the crew between each other, the banging of the garbage cans or containers, the actual compaction of the garbage by the trucks, the bursting of bottles or the breaking of items as they are compacted, release of the air pressure of the truck's brake air reservoir and, again noise from the truck as it moves off. All these many different noises are part of the refuse collection process. The noise of major concern in this study is that due to the compaction by the garbage truck itself. This noise is believed to be controllable by Federal regulations of the source, whereas the other sources are not susceptible to Federal regulatory control.

The truck whose time history is shown in Fig. 3-6 was a quieted one with the engine governed at 900 rpm. The truck was also equipped with a front power takeoff and was powered by a 6-cylinder diesel engine.

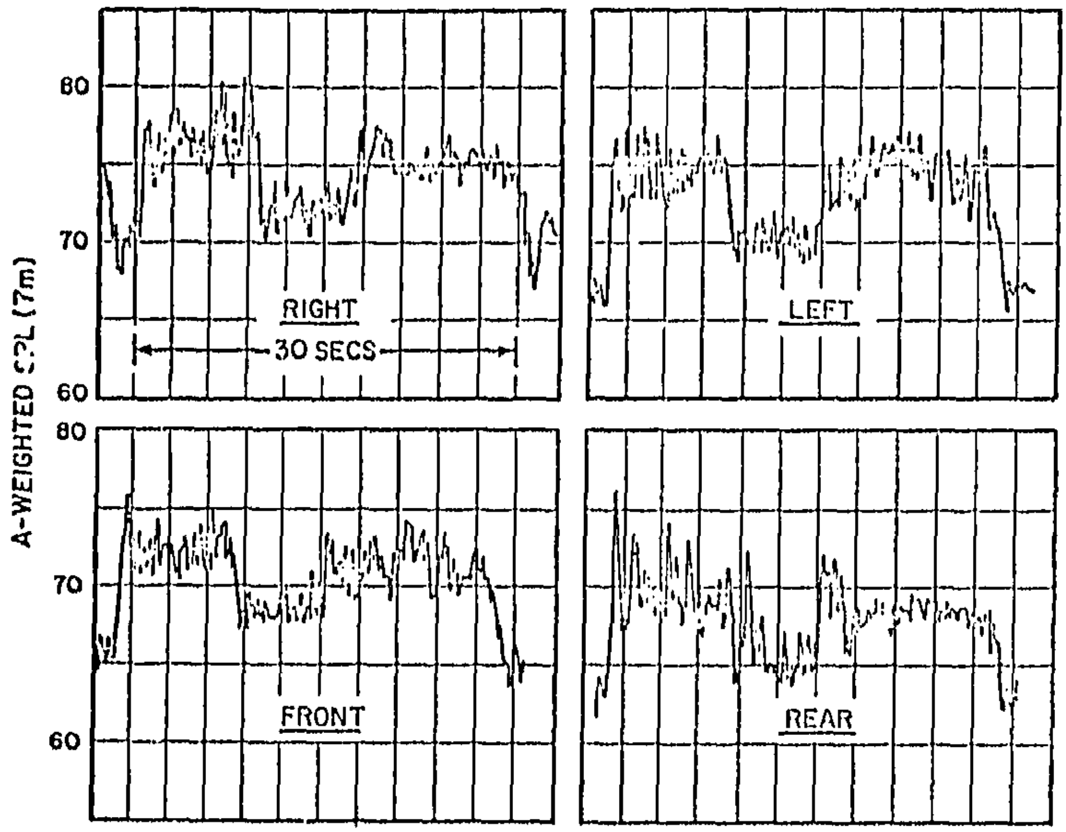


Figure 3-4. TIME HISTORIES OF QUIETED REAR LOADER

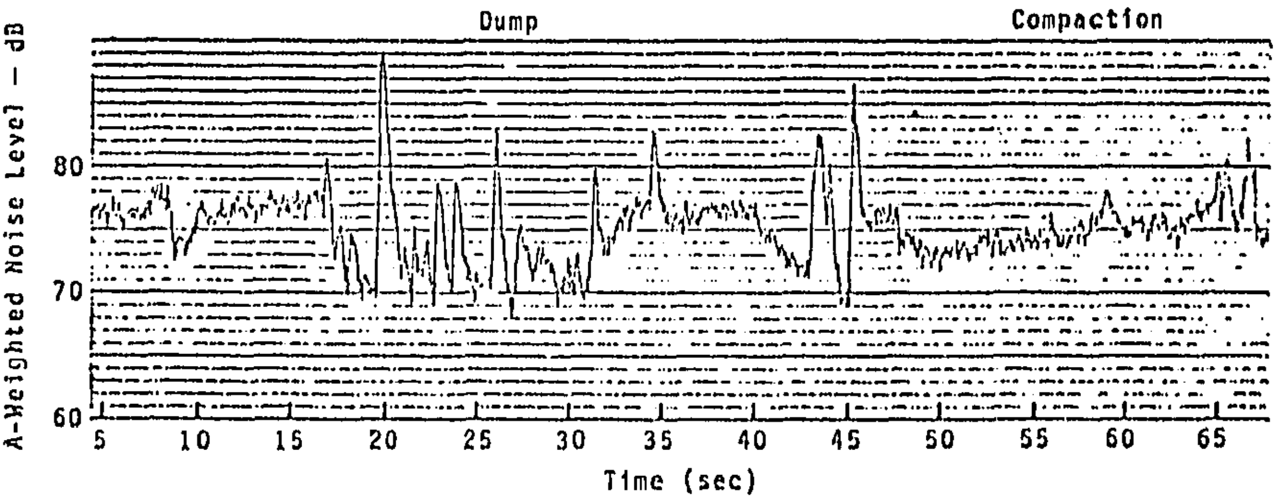


Figure 3-5. Time History of the A-Weighted Noise Level Generated by a Front Loader During a Dump and a Partial Compaction Cycle. Noise Levels were Measured 50 ft to the Left of the Vehicle Center.

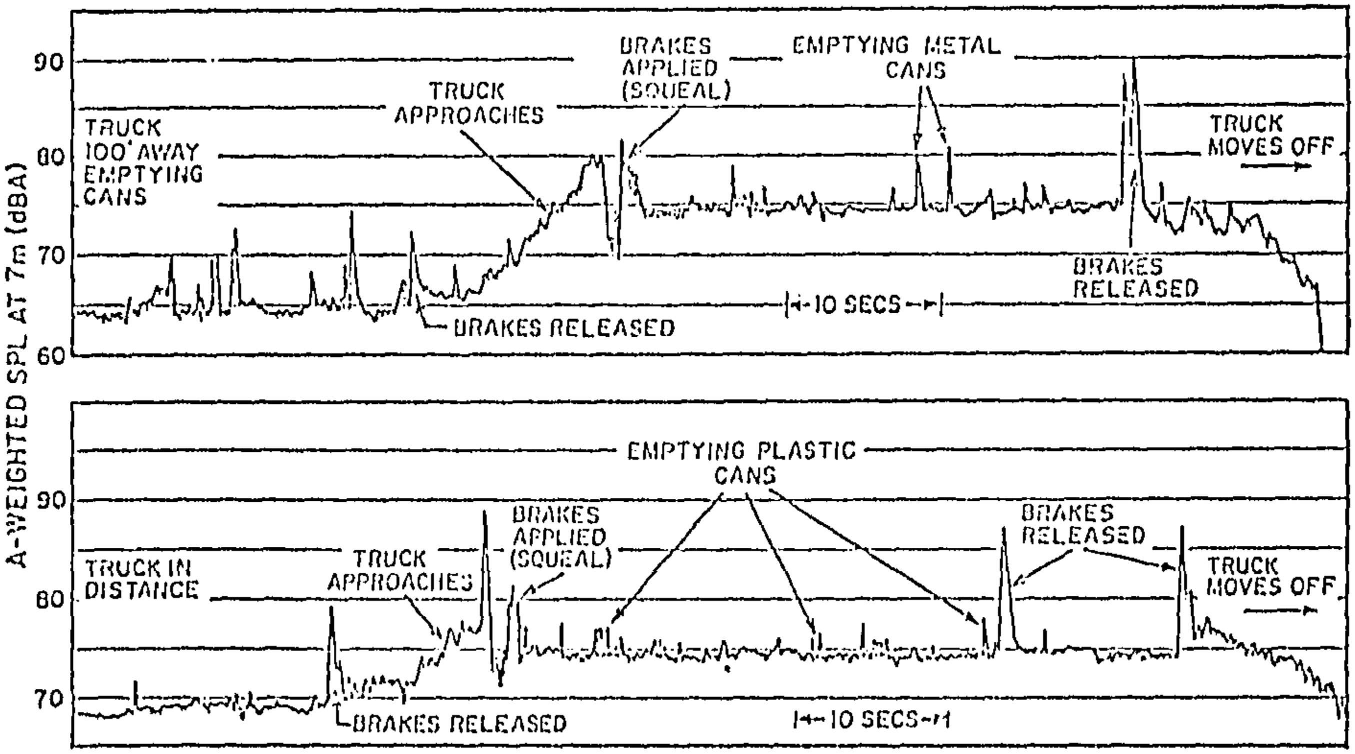


Figure 3-6. Operational Passby of a Sideloader

The scenario consists of the truck driving up (80 dBA) and applying its brakes, producing a squeal (82-85 dBA). The truck is left idling (75 dBA) while it is being loaded. There are impacts from the loading of the garbage cans (80 dBA metal and 77 dBA plastic). The side loading compactor is cycled (75 dBA) and the air brakes are released (87-90 dBA). Finally, the truck moves off (80 dBA peak).

NOISE SOURCES

Component Sound Levels

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

(1) Truck Chassis,

(2) Transmission power take-off,

(3) Hydraulic pump, and

(4) Compactor body when isolated from the chassis.

Table 3-4 details the measured noise levels of each of these components. This particular truck was not a standard one but had had some noise control treatment incorporated. The chassis had a better than standard muffler installed, the truck cycled at an engine speed of 1050 rpm and electric switches were used to reverse the hydraulic cylinders, rather than allowing them to bottom. The interesting point was that 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 power takeoff and some from the hydraulic pump.

The chassis and power takeoff noise were found to be very much speed dependent. Figure 3-7 shows the variation of noise with speed of the chassis

Table 3-4. NOISE CONTRIBUTIONS

SPL (dBA at 7m)

	Right	Left	Front	Rear	Energy Average
Chassis	64	64.5	63	63	64
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.

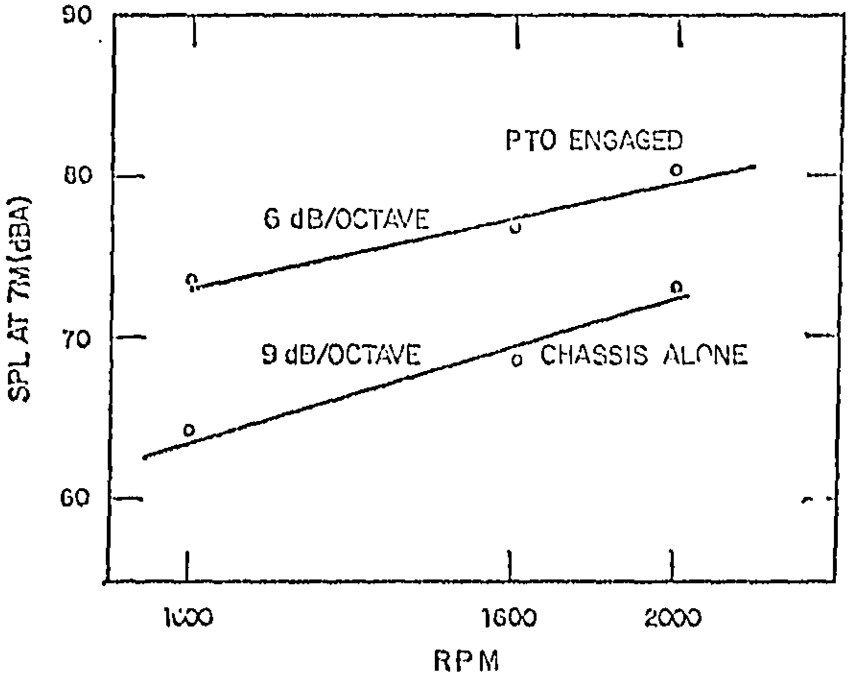


Figure 3-7. Truck Chassis and PTO Noise

and power takeoff individually. Many trucks cycle at engine speeds up to 1800 rpm and it can be seen from this figure that a substantial noise reduction can be achieved by reducing the truck engine speed while it is cycling.

Figure 3-8 shows the various spectral contributions from these noise sources. The low frequency noise comes from the engine. The hydraulic pump generates two pure tones at 125 and 250 Hz. The high frequency noise is due entirely to the transmission power takeoff which both radiates sound directly and through vibrations in the chassis frame.

Truck Chassis Noise

It is clear from the previous section that the overall noise from a solid waste compactor truck is very much a function of the noise from the chassis itself. The noise level generated by the chassis is a function of both the engine rpm and the degree of quieting of the chassis. EPA has issued a regulation setting a not-to-exceed noise level of chassis; clearly the overall noise level of the solid waste compactor truck will be a function of this regulation noise level. The EPA truck noise regulation provides a measurement procedure in which the chassis noise is measured at a distance of 50 feet, at full power and maximum rpm in accordance with the SAE test J 366b. Clearly, under these conditions the chassis will generate much more noise than when it is cycling and generating only a small fraction of its rated horsepower. EPA analysts have reviewed this difference in noise level and predicted the chassis noise as a function of both engine rpm and the EPA regulation. Figure 3-9 predicts the noise levels of seven chassis as a function of engine rpm based on a regulation level of 80 dBA as measured by SAE test J 366b. Similar plots can be made for other levels of regulation. Clearly, substantial reductions in noise can be achieved by lowering the engine rpm during cycling.

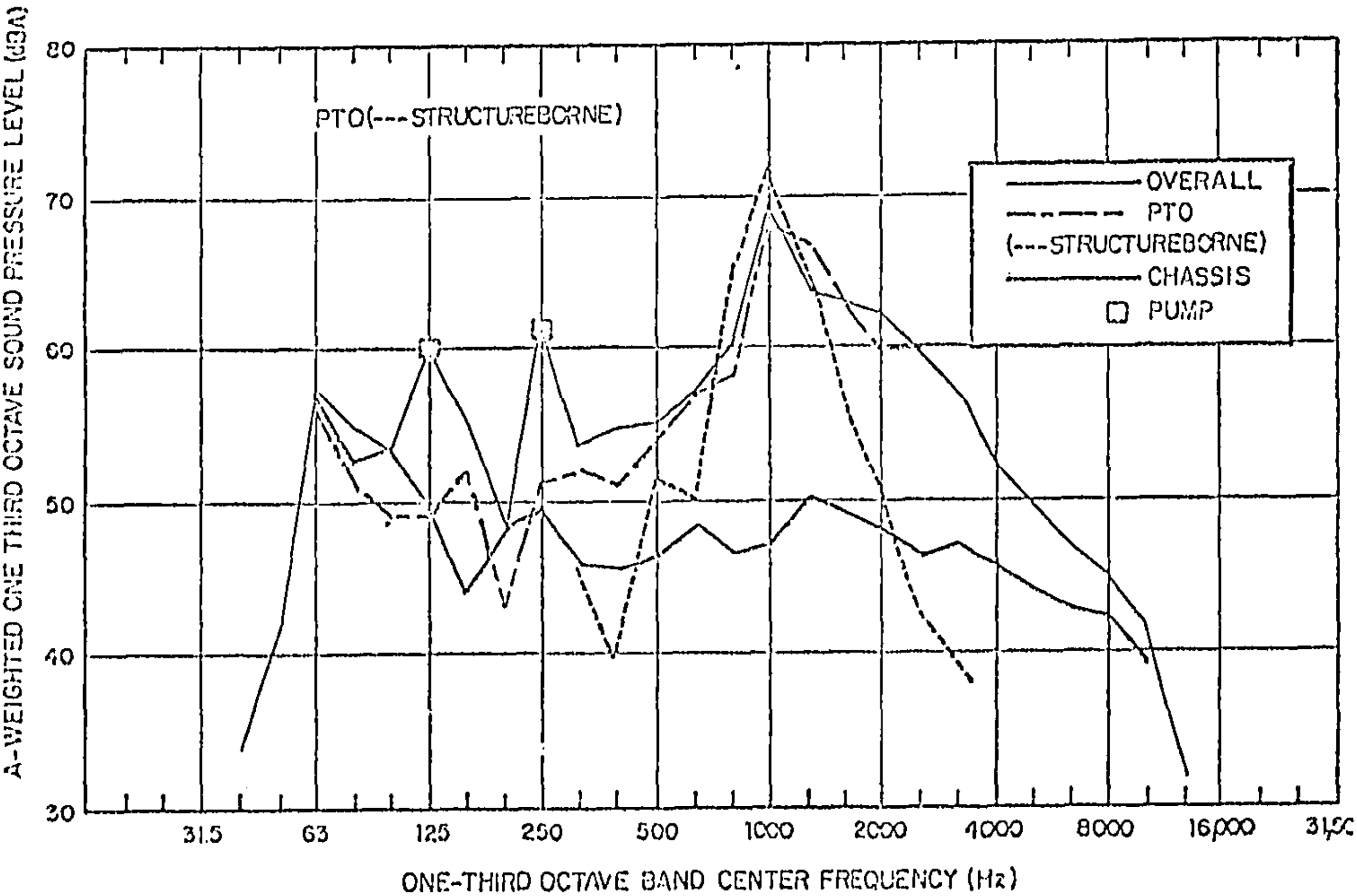


Figure 3-8. Noise Diagnosis (Right Side at 7 m).

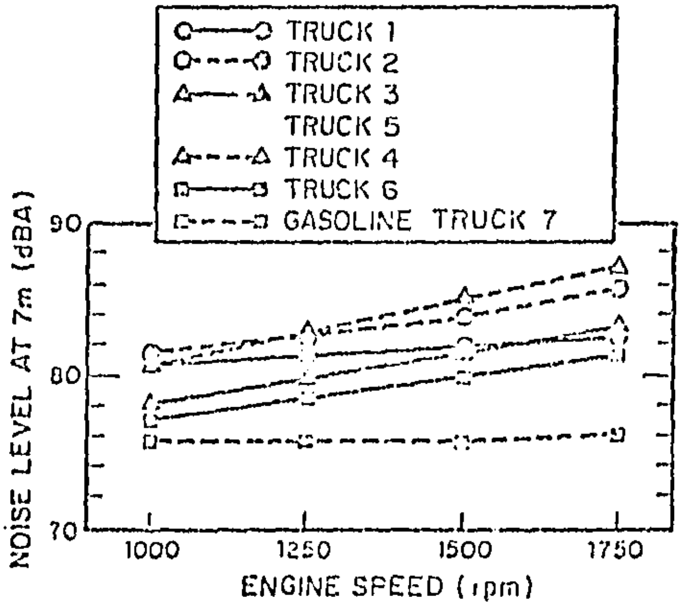


Figure 3-9a. Noise Levels of Unregulated Chassis

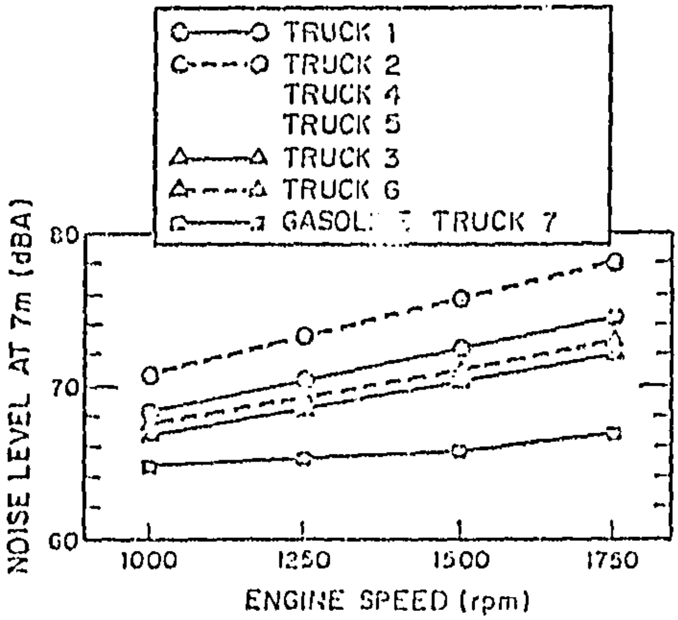


Figure 3-9b. Noise Levels of Chassis Regulated to 80 dBA Under Test SAE J 366b

SAN FRANCISCO NOISE DATA

Noise measurements have been reported on solid waste compactor trucks operating in the city of San Francisco (Ref 3-1). One hundred and fifty-two noise measurements, listed in Exhibit 3-1, were made on compaction vehicles operating in the streets of the city rather than under the controlled conditions of the methodology used in the EPA measurements. Table 3-5 summarizes the statistical data for two scavenger fleets.

Since San Francisco contains a considerable amount of row housing, a reverberant build-up of noise can take place on the narrow streets. The noise measurements were made at a distance of 50 ft from the rear of the truck. Elsewhere in this report, the noise data presented are based on measurements made at 7 meters (about 23 ft.). Finally, the trucks measured by the city of San Francisco were measured while compacting garbage and this may contribute some noise to the measurements. For the foregoing reasons, the San Francisco measurements show significantly higher sound levels (when corrected by 6dB to account for the greater distance of the measurement point from the vehicle) than those tested and reported in Table 3-1.

Table 3-6 compares the noise levels of six trucks measured both by EPA investigators and by San Francisco. Again, it is seen that the noise levels measured by the city of San Francisco for the maximum steady level are generally as high as or higher than the EPA levels, even though the San Francisco levels were measured twice as far from the truck. The agreement is much better for the maximum impulse levels which, because of their short duration, would not experience significant reverberant build-up.

Table 3-5. SUMMARY OF SAN FRANCISCO NOISE MEASUREMENTS
(Measured 50 ft. to Rear of Compactor Vehicle)

Fleet	Max Steady Compacting		"Crushing Spikes" Average of 3 highest peaks		No. of Vehicles
	Sound Level dBA	Std Deviation	Sound Level dBA	Std Deviation	
A	75.35	0.51	78.32	0.32	57
B	78.57	0.36	81.08	0.32	95

Table 3-6. NOISE LEVELS OF SAN FRANCISCO COMPACTOR TRUCKS

Operator	Truck No.	EPA 23 ft to rear		City of San Francisco In Street 50 ft	
		Max Steady	Max Impulse	Max Steady	Max Impulse
Sunset	X43A	73	88	77	81
Sunset	29A	76.5	85	78	81
Sunset	21A	74	86	74	79
Sunset	51A	75.5	78.5	(80 82	83 86)
Golden Gate	29	76	82	73	78
Golden Gate	1	72	80	--	--

SOUND LEVEL DEGRADATION

There are two general causes of degradation: (1) changes in the noise emitted by individual components; and (2) changes in noise abatement performance of noise treatments.

The sources of noise from waste compactors are listed in Table 3-7. They comprise the truck chassis (engine casing, exhaust and fan), power takeoff (PTO) and hydraulic pump, all of which may be subject to degradation. In discussing waste compactor noise degradation, we include the noise treatments applied to the truck chassis in order to comply with the EPA noise emission regulations on new medium and heavy trucks as noise sources rather than as noise treatments.

The noise emissions from the two International Harvester DOT Quiet Trucks that had initial noise levels of approximately 80 dBA (low enough to comply with the 83-dBA regulatory level) increased by about 1 dBA from the initial levels during the approximately 150,000 miles of use (Ref. 3-2). Truck diesel engines are warranteed for 50,000 miles or 24 months on parts and labor, and for 10,000 miles or 24 months on parts (Ref. 3-3). Truck gasoline engine warrantee periods are half of the periods for diesel engines (Ref. 3-3). Waste compactor truck diesel engines are overhauled approximately every 150,000 miles (Ref. 3-4). Gasoline engines probably have a shorter average period between overhauls of between 80,000 and 100,000 miles. However, because the noise level from chassis equipped with gasoline engines is lower, the shorter life and thus greater degradation of gasoline engines is probably less of a factor than chassis with diesel engines. Department of Commerce data indicate an overall average annual mileage of 12,200 miles for all Compactor Vehicles.

Table 3-7. Available Data On Noise Degradation For Waste Compactors Regulated at 78 dBA at 7m in 1979.

Noise Sources	Typical Noise Levels Without Regulation	Noise Levels With Regulation	Noise Reduction	Noise Sources Expected to Degrade	Type of Data Available on Source Degradation	Sources of Available Data on Noise Source Degradation	Treatment to Comply With Regulations	Noise Treatment Expected to Degrade	Type of Data Available on Noise Treatment Performance Degradation	Sources of Available Data on Noise Treatment Degradat
Truck Chassis • Exhaust • Engine • Fan	80 dBA (diesel at @1750 rpm)	75 dBA (diesel at @1250 rpm)	5 dBA	Yes, for 83 dBA truck regulation • Engine-source & treatment • Exhaust muffler	• DOT Quiet Truck field tests • Engine useful life • Engine warrantee • Muffler useful life	• DOT Quiet Truck reports • Engine mfrs • Muffler mfrs • Waste compactor users	Reduce engine speed	No	-	-
Power Take-Off	79 dBA	-(1)	-	Yes, but does not impact overall level unless PTO fails	• PTO useful life • PTO warrantee	• Waste compactor users	Replace trans. PTO with front or flywheel PTO	No	-	-
Pump	~68 dBA(2)	64 dBA	4 dBA	Yes	• Pump useful life • Pump warrantee	• Waste compactor users	None	-	-	-

(1) Noise from front or flywheel PTO not significant.

(2) Estimated from level of 64 dBA at 1250 rpm using 30 log of pump speed.

Discussions with trash collection service operators indicate that vehicles used in residential operations (rear loaders and side loaders) may be driven less than 10,000 miles per year. Front loaders used in commercial trash pickup service, are driven greater distances, perhaps 15,000-25,000 miles per year. These vehicles therefore may be driven 5 to 6 years or more before first overhaul.

Exhaust mufflers are another source of chassis noise degradation. In general, exhaust mufflers on trucks have an average life longer than engines, many lasting longer than five years (Ref.3-5). Therefore, it appears that over the first 50,000 to 75,000 miles of use, the chassis noise from waste compactors equipped with gasoline or diesel engines will not degrade significantly. Replacing the transmission PTO with a flywheel or front PTO reduces the noise from the PTO to insignificant levels, so that the degradation of the PTO can be ignored. When the engine speed is reduced to comply with the proposed regulations on waste compactors, the noise from the pump is also reduced to an insignificant level; more than 10 dBA below the chassis noise level (see Table 3-7). Thus, the pump degradation can also be ignored.

The noise treatments of reducing the engine speed and replacing the transmission PTO with a front or flywheel PTO are not expected to significantly alter degradation of compactor noise. In fact, the reduction in engine speed will probably reduce engine wear and, therefore, decrease engine noise degradation. 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. Therefore, the chassis noise degradation will probably dominate waste compactor noise degradation.

Waste Compactors on 80 dBA-Regulated Chassis

During normal use, the two International Harvester DOT Quiet Trucks that had noise levels of approximately 78 dBA (low enough to comply with the 80-dBA regulatory level) demonstrated reductions in their initial noise levels over an average mileage of 90,000 miles.

With an 80-dBA chassis, the chassis noise is reduced to a level where the noise from the hydraulic pump will be a factor in the overall computer noise degradation. Otherwise, as discussed for compactors mounted on 830-dBA chassis, the PTO noise degradation and the degradation of noise treatments can be ignored. Pumps are warranteed for six months by the Heil Company, and, in general, last from one to two years during normal use (Ref. 3-6).

REFERENCES

3-1. Noise Control/Technology for Speciality 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

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
411	77.0	78.0	78.0	80.0
X4	74.0	75.0	76.0	77.0
F4	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

EXHIBIT 3-1 (Cont.)

Vehicle No.	Compacting (dBA)	Crushing Spikes (dBA)		
69B	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
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

EXHIBIT 3-1 (Cont.)

Vehicle No.	Compacting (dBA)	Crushing Spikes (dBA)		
51A	80.0	80.0	83.0	83.0
34A	81.0	84.0	85.0	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
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

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, we discuss each of these factors 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 are identical to those observed under ordinary operating conditions. What is important is that standardized data enable one to predict environmental levels. The consequences of inadequate correlation are less than expected environmental protection in certain cases and inefficient allocation of noise-abatement resources in others. As illustrated in Figure 4-1, the lines corresponding to the desired level of environmental control and the not-to-exceed regulated level divide the 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. Category IV sources will appropriately not be quieted.

In practice, the shortcomings of standard test procedures are inevitable, but may be minimized. Figures 4-1a and 4-1b contrast test procedures that correlate poorly and well with environmental levels. The problems associated with procedures that correlate poorly are inevitably worse that those that correlate well. Our objective will be to develop a standard measurement procedure that correlates well with environmental levels, consistent with other test requirements.

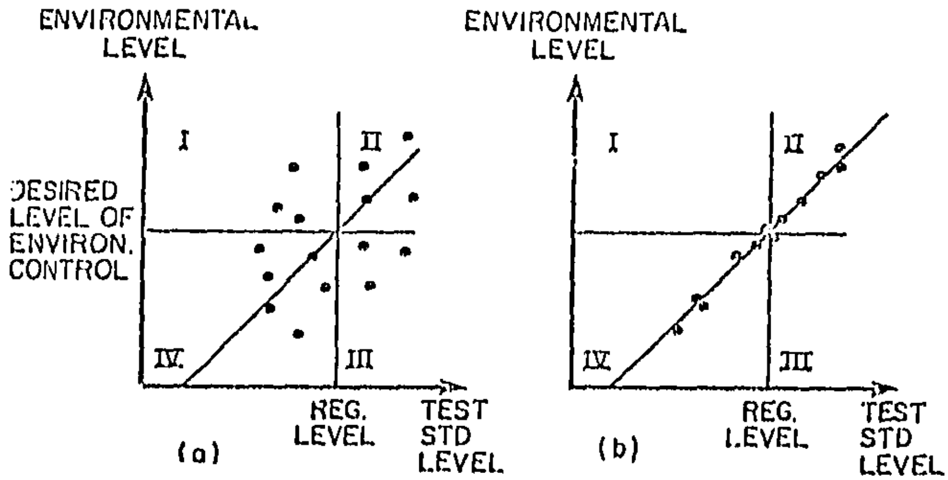


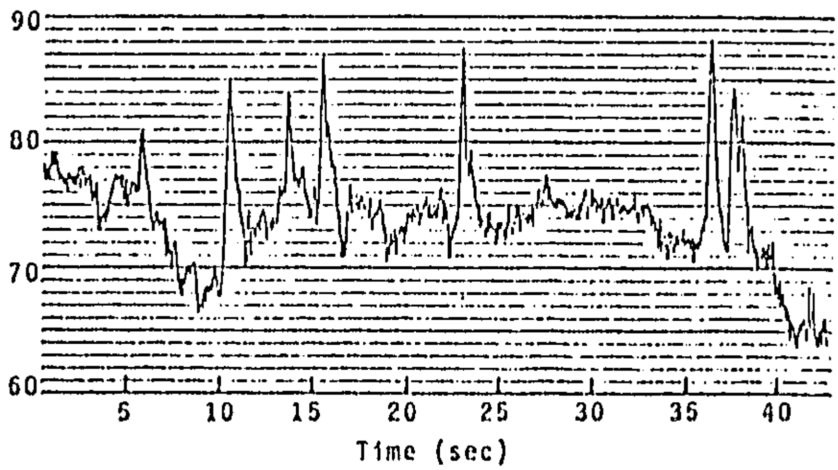
Figure 4-1. Illustration of Test Standards That Correlate (a) Poorly and (b) Well With Environmental Levels.

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. Undoubtedly, manufacturers will 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 of obvious desirability. A test which is nonrepeatable is invariably corrupted by random, or at least 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.

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 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 4-1. 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.



(a) Left side – Location No. 1.

Figure 4-2. Time History of the A-Weighted Level Measured 50 Feet to the Left Side of a Front Loader

Alternative Measurement Methodologies

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

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.

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.

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 published in manufacturer's advertisements

specifying the operation of the engine at maximum allowable engine or dump 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 it 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, we conclude that compactors without mechanical speed controls should be tested at the maximum engine or pump rpm allowed by the manufacturer.

Measurement Criteria

As indicated under Noise Characteristics, the key measurement problems relate to characterization of steady and impulsive noise levels, the number of microphone locations required, and means to combine levels acquired at various locations.

Steady Levels

The major question concerning steady levels is which scale should be used. Although many scales (A,B,C, etc.) have been proposed and are often available on sound level meters, the A-weighting scale has achieved overwhelming acceptance. The A-scale has been used exclusively by EPA for evaluation of impact and for regulation of all non-aircraft sources of noise. Consequently the use of A-weighting for compactor measurements appears most suitable.

Measurement of Impulse Noise

An impulse noise is one which lasts for a very short time and is generally associated with the impact of two components. The measurement of impulse noise can present a severe problem since, if the response of the instrument being used to measure the impulse is not fast enough, the true peak reading will not be obtained. ANSI, in the standard, ANS1.4-1971, Specification for Sound Level Meters, describes two speeds of response for sound level meters: on the "fast" response the meter must read 0-2 dB below the steady reading when a pulse of 0.2 seconds is applied; on the "slow" response the meter must read 3-5 dB below the steady reading when a pulse of 0.5 seconds is applied. These speeds correspond to averaging times of 0.125 seconds and 1.0 seconds, respectively. The human hearing mechanism itself also has a finite response time to an impulsive sound.

Authors differ as to the duration of this response time, and many authors argue that it is the energy in the impulse which determines the human response. Meter response of 0.125 second yields impulse results that correspond well to the "true" impulse of compaction sounds (Ref. 4-1). When the sound is tape recorded, however, and played back into a graphic level recorder (GLR), the response of the recorder is specified in terms of the maximum writing speed of the pen. The response time of the pen then depends on the magnitude of the impulse, being slower for larger impulses. Bruel and Kjaer (Technical Review No. 1, 1974) do suggest a correlation between averaging time and writing speed, providing the impulses are not too large (6-8 dB). A 0.125 sec (SLM fast) averaging time corresponds to a writing speed of 8 mm/sec (3.15 ins/sec) on paper 50 mm (2 ins) wide. Similarly, an averaging time of 1.0 sec corresponds to a writing speed of 10 mm/sec (0.4 ins/sec) on paper 50 mm (2 ins) wide and 20 mm/sec (0.8 ins/sec) on paper 100 mm (4 ins) wide.

If one is interested in measuring the levels of impulse noise, then the fast meter response or writing speeds of 80 or 160 mm/sec (3.15 or 6.3 ins/sec) should be used. If a slow meter response is used, the true peak level of the impulse will not be observed. However, the meter response will be related to the energy in the impulse, averaged over the 1.0 sec time constant of the meter.

Microphone Locations

Compacting-vehicle machinery is often distributed around the vehicle requiring noise measurements at various locatons. Drive train equipment such as the engine and fan are located at the front. PTO's 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 at 90 degree intervals around the vehicle.

Combining Noise Levels

The truck noise levels are measured on four sides; one then needs a single number to describe the noise level of the truck. The quantity of concern is 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.

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.

A precision sound level meter which meets the Type 1 requirement of American National Standards Specification for Sound Level Meters, S1.4-1971.

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 SAE Recommended Practice J184, Qualifying a Sound Data Acquisition System.

A sound level calibrator with an accuracy of ± 0.5 dB.

A microphone windscreen may be used provided that its effect on "A" weighted sound level is negligible under zero wind velocity conditions for the type of noise source being measured.

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, located within 50 ft (15 meters) of either the vehicle or the microphone.

The microphone shall be located 4 ft $\pm$1/2 ft (1.2 meters) above the ground plane and 23 ft $\pm$1 ft (7 meters) 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 and 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

The waste compaction equipment shall be operated with the vehicle stationary.

The vehicle engine will be started and allowed to reach its recommended operating temperature. In addition, if the ambient temperature is below

$60^{\circ}F$, the compaction equipment will be operated for enough cycles to allow the hydraulic oil and components to reach a stable operating temperature.

The compaction equipment shall be operated empty. Trucks which normally load containers will be measured loading an empty container.

The compaction equipment shall be operated in accordance with its normal operating procedures. The truck engine will be operated at its speed which is governed for the cycle or if there is no such speed, the maximum allowable engine or pump speed, whichever is lower.

The waste compaction equipment shall be run through two complete compaction cycles for each noise measurement taken. If the readings differ by more than 2 dBA, further readings will be taken until two agree within 2 dBA and the average taken.

The meter shall be set for "fast" response and on the "A"-weighted network.

Truck Chassis Noise

For waste compaction equipment mounted on a chassis, the truck engine will be operated at "solenoid speed" with the power takeoff not engaged. The noise level will be recorded at this condition with the meter set for "fast" response and "A"-weighting.

Waste Compaction Equipment Cycling Noise

The waste compaction equipment will be operated through its normal cycle. The maximum noise level, ignoring any peaks due to impacts, will be recorded with the meter set for "fast" response and "A"-weighting.

Waste Compaction Equipment Impact Noise

The waste compaction equipment will be operated through its normal cycle. The peak noise level due to impacts will be recorded with the meter set for "fast" response and "A"-weighting.

Cycle Time of Waste Compaction Equipment

The waste compaction equipment will be operated through its normal cycle. The time from the beginning to the end of the cycle will be recorded.

Noise level measurements shall be taken at each of the four microphone positions around the vehicle and the following data will be reported.

1. Truck chassis noise,
2. Maximum noise level at each location, ignoring impacts,
3. Maximum impact level,
4. The four-location energy average for each of the above three data categories, computed according to the equation

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

where L_i is the A-weighted sound level corresponding to the ith truck orientation,

5. Cycle time.

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 operaton of the instruments and precautions to be observed. Specific items to be considered are:

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

Proper signal levels, terminating impedances, and cable lengths on multi-instrument measurement systems.

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.

Proper orientation of the microphone relative to the source of sound as specified by the manufacturer.

Measurement shall be made only when wind speed is below 12 mph (19 Km/hr).

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.

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 50 ft

(15 meters) 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 S1.2-1971 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. A number of 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 and the European ISO adopts a 7 m (23 ft) distance. In this methodology, we have selected the latter distance (7 m) for two reasons. First, a smaller measurement site is required for the closer distance. 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 we are concerned with measuring 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).

Operaton of the Compactor Truck Empty

A decision had to 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 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 approximately 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 antilogs of the levels on the four sides of the truck and then taking the log of the result. That is, if the four measurements are L_1, L_2, L_3 and L_4, the energy averaged level, $\bar{L}$, is

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

a result that is influenced more strongly by the highest levels measured at individual microphone positions.

REFERENCES

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.

Section 5

EVALUATION OF EFFECTS OF TRUCK MOUNTED SOLID WASTE COMPACTORS ON PUBLIC HEALTH AND WELFARE

INTRODUCTION

Pursuant to the Noise Control Act of 1972, the Environmental Protection Agency (EPA) has proposed noise emission regulations on newly manufactured truck mounted trash compactor units. The proposed regulations specify levels not to be exceeded as measured according to a specified test procedure, and are intended to control compaction noise, including truck engine contributions.

Predictions of both costs and benefits involved are required as 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 trash compactors. Costs of compliance and economic impact for different regulatory programs are presented in Section 7 of this document.

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 to approximate typical, or average, situations. The approach taken to determine the benefits associated with the noise regulation is therefore statistical, in that an effort is made 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 will remain.

Measures of Benefits to Public Health and Welfare

The phrase "public health and welfare," as used here, includes personal comfort and well-being as well as the absence of clinical symptoms such as hearing damage. People are exposed to noise generated from trash compacting operations most notably when inside their homes. 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 individual noise events.

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) are presented for comparison with reductions expected for the 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 of 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 frequently depends on the activity and location of the individual. In addition, measures of average urban noise level tend to cancel out the disruptive and annoying peak noise levels produced by individual trash compaction cycles. Additional benefits are obtained by the reduction of current noise levels generated from a single compaction activity. These benefits are evaluated in terms of sleep disturbance and speech interference at current noise emission levels and at the reduced levels associated with the reduction of noise attributable to an individual trash compaction cycle.

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 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) 1979	1982	1985
Base	U**	U**	U**
Option 1	80	75	75
Option 3	U**	79	79
Option 5	U**	75	75
Option 7	78	75	75
Silent	0	0	0

* In all cases, truck regulations are 83 dB(A) in 1978 and 80 dB(A) in 1982.

** U = unregulated.

Outline of the Health and Welfare Section

A description of the existing trash compactor noise environment is presented in the following section. The next section presents the predicted reduction of the population impacted within various land uses due to the reduction of average community noise levels by regulating truck-mounted trash compactors. Following that, predictions of changes in sleep disturbance and speech interference due to a single trash collection cycle are estimated for each land use for the regulations under consideration.

TRASH COLLECTION NOISE ENVIRONMENT

A single collection cycle is defined as a collector truck arriving at a location, loading trash into the truck, compacting the trash, and finally, the truck pulling away. This collection event may be considered a stationary noise source which produces a noise field that attenuates in intensity with distance.

Four elements must be evaluated to define the population exposure produced by the noise environment from a single 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 occuring 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 the truck is being loaded, while the engine is accelerating during the compaction cycle, and while it is idling and then driven off.

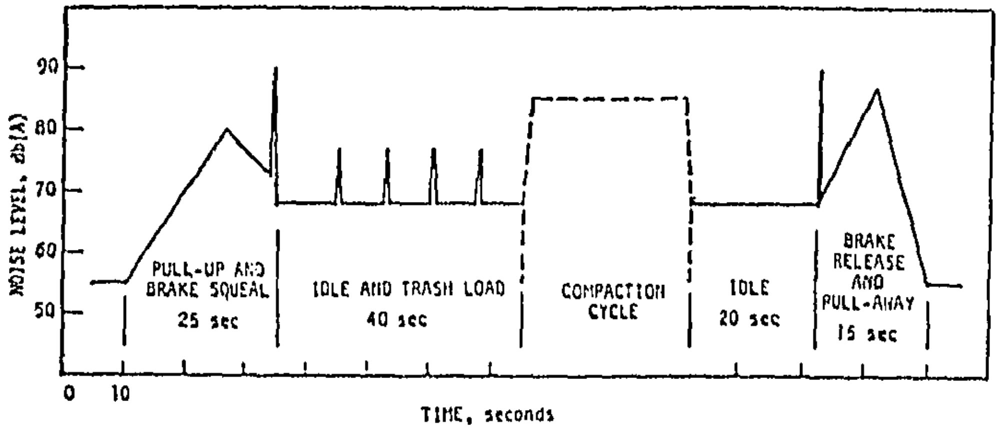


Figure 5-1. Typical collection cycle noise levels at 7 m.

Medium and heavy gasoline and diesel trucks, the type which carry trash compactors, have been recognized as major contributors to environmental noise. The noise produced by these vehicles will be regulated to a not-to-exceed level of 83 dBA (based on the J336b test) in 1978 and to a level of 80 dBA 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. Also included in Table 5-2 are estimates for three possible levels of future truck noise reduction. The average values of truck noise during pullup, idle and pull-away phases (independent of the increased noise level during the compaction cycle), are calculated by summing the equivalent energy of each component in the cycle, and used for the analysis in this report.

Compactor Noise per Collection Cycle

A summary of measurements of the noise emissions associated with the compaction cycles on 28 different trucks* (Reference 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. A relatively large number of quieted compactors were in the measured sample so that average sound levels may be much lower than those which would be observed in actual operation. However, for purposes of this analysis it is assumed that the measurement results presented in Table 5-3 are representative of average national values, 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 (Reference 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 maximum steady sound level (Lmax), the maximum impulse level,

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*Four trucks were measured in two different modes so therefore the sample consisted of 32 measurements

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 @50 Ft. dB(A)		
		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				
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

TABLE 5-3
AVERAGE A-WEIGHTED SOUND LEVELS AT 7m OF EXISTING REFUSE COMPACTORS

(from Table 3-1, Section 3)

Compactor Type	Maximum Steady Level at 7m, L_{max}					Maximum Impulse at 7m	
	Sound Level dB(A)		Compaction Cycle Time (seconds)		SEL[a]	Sound Level dB(A)	SEL
	Average	Range	Average	Range	Range	Average	Range
Front-loader	~~81.9~~ 82.7	74-87	~~31~~ 34	20-40	87-100	87.2	68-97
Side-loader	75.8	72-80	~~31~~ 32	8-75	84-95	84	79-80
Rear-loader	~~78.3~~ 78.8	74-76	~~24~~ 23	8-40	82-96	85.4	73-87

NOTES: a Calculated from SEL = L_A + 10 log (duration)

where SEL = Sound Exposure Level

and L_A is 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 impulsive sounds. EPA data indicates that the number of impulses 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 was calculated using:

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

where

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

t_I = impulse time = number of impulses x 0.5 seconds

L_c = sound pressure level of steady-state compaction from Table 5-3, dB(A)

L_I = sound pressure level of impulse noise, from Table 5-3, dB(A).

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.
ESTIMATES OF THE AVERAGE A-WEIGHTED SOUND LEVEL AT 7m PRODUCED BY DIFFERENT COMPACTOR TYPES.

Compactor Type	Sound Level dB(A)	
Front-loader	85.8	+ 85.4
Side-loader	76.7	76.4
Rear-loader	79.4	80.2

Sound Propagation and Amplification

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 which occurs when 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), if the amplification factor is estimated to be 2.2 dB, and if a 7.6 meter (25 feet) separation of building fronts amplifies sound at the source by 8 dB, a sound source of 80 dB, referenced at 7 m free field, would on the 15 meter wide street be amplified to 82.2 dB and on a 7.6 meter wide street (alley) to 88 dB.

Since the apparent build-up in sound level is a function of the width between facing buildings, the technique suggested in Reference 5-4 was used to calculate the amplification and propagation factors for representative street widths. It was determined that 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 compactors activity in urban areas. These reverberant buildup factors were added to the percentage of collections occurring on various street widths in urban areas (see Table 5-6).

Sound levels attenuate 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 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 (Reference 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.

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 10 to 18 dB; this is representative of the typical summer situation. In winter, with windows closed, the attenuation varies from 15 to 27 dB, and with double-glazed windows, noise may be reduced as much as 45 dB.

The maximum, closed value in winter 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, and a value of 20 dB for the other dwelling areas to represent the attenuation of outdoor noise by the exterior shell of the house. These attenuation factors represent an average between summer, winter, new construction, and old construction.

Average Noise Levels Per Unit Area

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

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:

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

where

L_{iL} = the noise level for each truck-compactor combination, dB(A)

L_T = truck noise level, from Table 5-2, dB(A)

t_c = time truck noise in the collection cycle (omitting compaction time) = 100 sec

$\bar{L}_c$ = average noise level for each compactor type, from Table 5-4, dB(A)

t_c = compaction time from Table 5-3, sec.

(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.

$$L = \left(f_{FL}\right)\left(L_{FL}\right) + \left(f_{SL}\right)\left(L_{SL}\right) + \left(f_{RL}\right)\left(L_{RL}\right) \qquad (5\text{-}3)$$

where

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.

TABLE 5-5
AVERAGE PERCENT OF DIFFERENT TYPE COLLECTOR VEHICLES
OPERATING PER DAY IN EACH LAND-USE CATEGORY.

Land Use	Collector Type 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

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

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 on streets wider than 24 meters and one-half on streets where amplification may be a problem. In urban row apartment areas, 25 percent of the impact situations will be on streets 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 meter (15 foot) wide alleys, 20 percent on 7.6 meter (25 foot) streets, and 20 percent of the time on 15.2 meter (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.

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* 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.

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

TABLE 5-6.
AMPLIFICATION FACTORS DUE TO REVERBERANT BUILDUP IN NARROW STREETS (GROUND REFLECTION IGNORED).

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

[a] Assumes continuous building fronts

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 relates to general aversiveness due to trash collection cycle noise as a component of the overall noise levels of urban areas. The second method relates to sleep disturbances and speech 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 average sound level (L_{dn}). Sleep disturbances are calculated using the Sound Exposure Level (SEL) 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})

The Noise Control Act of 1972 required EPA to present information on noise levels that are "requisite to protect the public health and welfare with an adequate margin of safety." The equivalent A-weighted sound level in decibels, L_{eq}, was selected as the primary measure of noise levels since it is the descriptor which correlates best with the overall long-term effects of pervasive environmental noise on the public health and welfare (Reference 5-5).

The basic definition of L_{eq} is:

$$L_{eq} = 10 \log_{10} \left(\frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} \frac{p^2(t)}{p_0^2} \cdot dt \right) \quad (5\text{-}4)$$

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:

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

The L_{eq} is associated with a specific time period $t_2 - t_1$, or T. When associated with a specific short time interval, 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 Average Sound Level (L_{dn})

In describing the impact of noise on people, the measure called the day-night average 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. This is expressed by the following equation:

$$L_{dn} = 10 \log_{10} \frac{1}{24} \left\{ 15 \left(10^{L_d/10} \right) + 9 \left[10^{(L_n+10)/10} \right] \right\} \quad (5-6)$$

where L_d is the "daytime" equivalent level obtained between 7 a.m. and 10 p.m., and L_n is the "nighttime" equivalent level obtained between 10 p.m. and 7 a.m.

Sound Exposure Level (SEL)

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 severe 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 (SEL). The SEL 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 SEL is defined as:

$$SEL = 10 \log \int_0^T \left(\frac{p^2(t)}{p_0^2} \right) dt \quad dB(A) \quad (5-7)$$

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:

$$SEL = L_{max} + 10 \log (T) \qquad (5\text{-}8)$$

where T is the time in seconds over which the sound is present, in this case the time of the compaction cycle, or the truck collection cycle, and L_{max} is the maximum A-weighted sound level.

Values of SEL 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 5-8 was used. For triangular pulses, SEL was approximated by:

$$SEL = L_{max} + 10 \log(t/2) \qquad (5\text{-}9)$$

where L_{max} is the maximum sound level.

The calculated SELs were combined in the same manner as the sound levels. Table 5-7 presents the results of these calculations and defines the existing noise environment for a single compaction.

TABLE 5-7.

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

Land Use Type	L_A (dB(A))	SEL	Propagation
Suburban Single-Family Detached	78.0	98.9	-6 dB/dd
Suburban Duplexes	78.0	98.9	-6 dB/dd
Urban Row Apartments	81.9	102.8	-6.5 dB/dd
Dense Urban Apartments	83.6	104.6	-8 dB/dd
Very Dense Urban Apartments	83.9	105.6	-8.5 dB/dd

Compactor Noise Levels Under Regulatory Options

The average life of a compactor is about 7 years (Reference 5-6). Therefore, 1/7 of the compactor fleet is replaced each year.* Two assumptions were made of the compactor noise levels under the regulation options. First, that manufacturers would design to a level 2 dB below the not-to-exceed level, and secondly, the maximum impulse levels would be regulated to a maximum of 5 dB over the steady-state levels. Using these assumptions, the regulatory schemes presented in Table 5-1, the regulated truck noise levels of Table 5-2, and the method outlined in the preceding section, the tables in Exhibit 5-A at the end of this section were calculated, presenting the average sound level L_A for each land use area to the year 2000.

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

1. An average time of collection (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 collector type is listed in Table 5-3, the average time of non-compacting truck noise is given in Table 5-2, the fraction of collection in each land-use class in Table 5-5. The average time in each dwelling cagetory was calculated as:

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

$$t_{avg} = \sum \left[(t_c \times f_c) + t_T \right]$$

where

t_c = compaction time, Table 5-3

f_c = fraction of compaction in land-use class, Table 5-5

t_T = truck noise time, Table 5-2

Average times for the complete collection cycle and components of the collection cycle are shown in Table 5-8.

TABLE 5-8.
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	20.8	100	120.8
Suburban Duplexes	21.1	100	121.1
Urban Row Apartments	21.5	100	121.5
Dense Urban Apartments	23.5	100	123.5
Very Dense Urban Apartments	24.7	100	124.7

2. The number of seconds per day the noise source operated in each 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.

3. L_{eq} for each year and dwelling category was calculated as:

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

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.

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

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

TABLE 5-10

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

YEAR	Suburban 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	0.8146	1.7614	3.3873	8.3615
1977N	0.0042	0.0520	0.5471	3.0525	7.5349
1977T	0.3068	0.8666	2.3085	6.4398	15.8953
1978D	0.3081	0.8292	1.7933	3.4486	8.5129
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	3.1649	7.8101
1979T	0.3180	0.8982	2.3929	6.6760	16.4770
1980D	0.3175	0.8546	1.8482	3.5542	8.7735
1980N	0.0044	0.0545	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	0.8866	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	1.9409	3.7324	9.2132
1984N	0.0046	0.0573	0.6029	3.3634	8.3024
1984T	0.3380	0.9547	2.5437	7.0958	17.5156
1985D	0.3370	0.9071	1.9618	3.7727	9.3127
1985N	0.0046	0.0579	0.6094	3.3997	8.3920
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
1988D	0.3480	0.9358	2.0260	3.8962	9.6177
1988N	0.0048	0.0598	0.6293	3.5111	8.6669
1988T	0.3528	0.9957	2.6554	7.4073	18.2845

TABLE 5-10 (CONTINUED)

YEAR	Suburban Single-Family Detached (SSF)	Suburban Duplexes (SD)	Urban Row Apartments (UR)	Dense Urban Apartments (DU)	Very Dense Urban Apartments (VDU)
1989D	0.3518	0.9470	2.0479	3.9363	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	9.6003
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

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 except that the source time, t_s, was calculated using the Table 5-9 values for day and night, respectively, and the reference time t_r, was 54,000 sec for day and 32,400 sec for night.

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.

Consideration of Ambient Noise Levels

The previous analysis of compactor noise and calculation of L_{dn} assumes no background ambient noise levels, i.e., levels of noise due to all other conditions. These ambient levels must be considered since it is total noise exposure upon which the EPA's assessment of health and welfare impacts rests.

It has been previously determined that day and night ambient levels can be represented as a function of population density (Reference 5-7) as follows:

$$ADL = 7.90 \times \log PD + 29.1 \qquad (5\text{-}11)$$
$$ANL = 9.73 \times \log PD + 17.4 \qquad (5\text{-}12)$$

where

ADL = ambient daytime equivalent sound level
ANL = ambient nighttime equivalent sound level
PD = population density (people per square mile)

Population densities used in the compactor study are in units of people per hectare and can be converted to people per square mile by dividing by 3.861×10^{-3}. The total ambient day-night equivalent sound level, L_{dn} is computed as follows:

Suburban Single Family Detached	-	56.18
Suburban Duplexes	-	59.74
Urban Row Apartments	-	62.67
Dense Urban Apartments	-	65.94
Very Dense Urban Apartments	-	67.84

However, for purposes of this analysis, where ambient levels exceed minimum impact criteria levels (L_{dn} = 55 dB), the ambient levels were arbitrarily set instead to a level of 1 dB under the criteria level under the assumption that ambient levels will be lowered by coordinated Federal, State and local efforts to reduce noise.

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

$$L_{dn} = 10 \log \left[10^{L_{dn}^{C}/10} + 10^{L_{dn}^{A}/10} \right] \qquad (5\text{-}13)$$

where

L_{dn}^{C} = the compactor sound levels calculated by Equation 5-6 and applied to the options in the previous section

L_{dn}^{A} = ambient noise levels as discussed above.

The results of these calculations for each year, area, and option are presented in Exhibit 5-D at the end of this section.

NOISE IMPACT FROM TRASH COMPACTORS

To assess the impact of compactor noise, a relationship between the noise levels in terms of L_{eq} and L_{dn} (Exhibits 5-B and 5-C) and the responses of the people exposed to the noise is needed. 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_{eq} or L_{dn}. The different forms of response to noise, such as hearing damage, speech or other activity interference, and annoyance, and their relationship to L_{eq} or L_{dn} are discussed in the EPA Levels Document (Reference 5-5). For the purposes of this study, criteria based on L_{dn} presented in the EPA Levels Document are used. 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 the public health and welfare) no adverse impact in terms of general annoyance and community response exists.

The community reaction and annoyance data contained in Appendix D of the Levels Document (Reference 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 19.5 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 maximum impact on the people exposed. Such a change in level would increase the percentage of the population that is highly annoyed by 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) constitutes a 25 percent impact and a 10 dB excess (L_{dn}=65) constitutes a 50 percent impact.

For convenience of calculation, percentages of impact may be expressed as Fractional Impact (FI). A FI of 1.0 represents an impact of 100 percent, in accordance with the following formula:

$$FI = \begin{cases} .05 \quad (L-55) & \text{for } L > 55 \\ 0 & \text{for } L \leq 55 \end{cases} \qquad (5\text{-}14)$$

where L is the observed or measured L_{dn} for the environmental noise. Note that FI can exceed unity for exposures greater than L_{dn} = 75 dB.

The impact of noise may be described in terms of both extensiveness (i.e., the number of people impacted) and intensiveness (the severity of impact). The fractional impact method explicitly accounts for both the extent and severity of impact.

The Equivalent Noise Impact (ENI) associated with a given level of noise (L_{dn}^{i}) may be assessed by multiplying the number of people exposed to that level of noise by the fractional impact associated with the level as follows:

$$ENI_i = (FI_i)P_i \qquad (5\text{-}15)$$

where ENI_i, is the magnitude of the impact on the population exposed to noise (L_{dn}^{i}) and is numerically equal to the number of people who would all have a fractional impact equal to unity (100 percent impacted). FI_i is the fractional impact associated with a day-night average sound level of (L_{dn}^{i}); over 55 dB, and P_i is the population exposed to this level of noise. To illustrate this concept, if there are 1000 people living in an area where the noise level exceeds the criterion level by 5 dB (and are thus considered to be 25 percent impacted, FI = 0.25), the environmental noise impact for this group is the same as for 250 people who are 100 percent impacted, (1000 x 25% = 250 x 100%).

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

$$ENI = \sum_i P_i \cdot FI_i, \qquad (5\text{-}16)$$

where FI_i is the fractional impact associated with (L^i_{dn}) and P_i is the population exposed to this level of noise. In this analysis, the mid-level of each 1 dB sector of levels above L_{dn}=55 dB was used in computing ENI.

Without ambient levels included, the distance associated with each 1 dB decrease in L_{dn} from the source until it reaches the threshold of 55 dB is determined from the attenuation rates for the various land use types. However, with ambient levels included, the determination of distance associated with each 1 dB decrease in L_{dn} is as follows:

$$R = R_o \cdot \left[\frac{10^{L_o/10}}{10^{L_R/10} - 10^{LA_{dn}/10}}\right]^{(\log 2)/d} \qquad (5\text{-}17)$$

where

- R = distance from source
- R_o = reference noise source distance (7m)
- L_o = L_{dn} at source
- L_R = L_{dn} at distance R from source
- LA_{dn} = ambient noise level
- d = attenuation rate (-6, -6.5, -8 or 8.5 depending on land use category)

The change in impact associated with regulations on the noise emissions from trash compactor vehicles may be assessed by comparing the magnitude of the impacts, both with and without regulations, in terms of the relative change in impact (RCI), which is calculated from the following expression:

$$RCI = 100 \frac{[ENI\ (before) - ENI\ (after)]}{ENI\ (before)} \qquad (5\text{-}18)$$

While the exact value of present or future ENI's may not be known precisely, the relative reductions of the ENI due to noise regulations - of primary interest here--are known with much greater accuracy than the absolute value of the ENI since the changes in the theoretical components of ENI can be well defined. For instance, it may not be possible to determine whether the present estimated ENI due to urban street traffic noise, 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 ENI by more than 0.1 million. Extensive investigation of such small changes may seem innocuous 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 ENI. Thus, the changes found to occur in ENI 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 ENI, 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 ENI, for each land use area is calculated 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 is displayed in Table 5-11. Also included in Table 5-11 is the year by year percentage benefit in extensiveness and severity of impact relative to the impact in 1976. Tabulated complete results of ENI and RCI are presented in Exhibit 5-E at the end of this section.

To further illustrate the significant benefits and relief afforded the population by reducing new trash compactor noise levels, Tables 5-12 and 5-13 are presented. In Table 5-12, 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 5-13 is presented as an example to show that the impact is not uniform over the entire population.

TABLE 5-11

EQUIVALENT NUMBER OF PEOPLE IMPACTED (ENI) (in millions)
PERCENTAGE BENEFIT (RCI)

Year		Options: Base	One	Three	Five	Seven	Silent
Base 1976	Total	1.62	1.62	1.62	1.62	1.62	1.62
	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	1.20	1.00	1.14	1.03	0.93	0.63
	RCI	26.2	38.1	29.6	36.3	42.6	61.1
	RCI*	0.0	52.55	5.0	14.2	22.5	47.5
1991	Total	0.99	0.47	0.68	0.47	0.47	0.36
	RCI	39.0	71.1	57.8	71.1	71.1	77.8
	RCI*	0.0	52.5	31.3	52.5	52.5	63.6
2000	Total	1.03	0.52	0.77	0.52	0.52	0.38
	RCI	36.4	67.7	52.5	67.7	67.7	76.5
	RCI*	0.00	49.5	25.2	49.5	49.5	63.1

RCI - percentage benefit from base year (1976)

RCI* - percentage benefit from base option. Base option includes benefits from medium and heavy truck regulations.

TABLE 5-12

PEOPLE EXPOSED TO L_{dn} OVER 55
(in millions)

L_{dn}	Baseline 1976	Options (1991)					
		Base	One	Three	Five	Seven	Silent
55-59	14.5	9.4	5.4	7.2	5.4	5.4	4.1
60-64	1.7	0.7	0.42	0.49	0.42	0.42	0.30
65-69	.4	0.2	0.03	0.08	0.03	0.03	0.01
>70	.1	0.01	0.0	0.0	0.0	0.0	0.0
Total	16.7	10.31	5.9	7.8	5.9	5.9	4.4

TABLE 5-13

PEOPLE EXPOSED TO L_{dn} >55 FOR EACH LAND USE TYPE
(in millions)

		Base Option (1976)				
L_{dn}	SSF	SD	UR	DU	VDU	TOTAL
55-59	0.0	0.0	5.6	7.0	1.9	14.5
60-64	0.0	0.0	.43	1.0	.3	1.7
65-69	0.0	0.0	0.0	.33	.1	.4
>70	0.0	0.0	0.0	.04	.04	.1
Total	0.0	0.0	6.0	8.4	2.3	16.7
ENI	0.0	0.0	.86	1.49	.45	2.8

SSF - Suburban Single Family Detached
SD - Suburban Duplexes
UR - Urban Row Apartments
DU - Dense Urban Apartments
VDU - Very Dense Urban Apartments

REDUCTION OF INDIVIDUAL TRASH COLLECTION NOISE IMPACT

Until now, the analysis of truck mounted trash compactor noise impact has been concerned with the contribution that compactors make to average day-night urban noise (Ldn). The impact contributions which are calculated in this way are somewhat generalized and do not necessarily represent specific impact situations. For example, they do 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.

Annoyance is difficult to describe. It may pass rapidly and the cause remain unnoticed. Or it may add to other agents causing stress and lead to physiological problems (Reference 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 (Reference 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 a change in sleep stage (from "deeper" to "lighter" stage) or, if the intrusive noise is intense or long enough, an actual awakening may result. In either case, repeated disturbance of people's activities may be expected to adversely affect their well-being. Covariance of verbalized annoyance with the interference of activities has been amply demonstrated in many social surveys (Reference 5-5, 5-16, 5-17, 5-18).

For these reasons it seems appropriate for the analysis of the noise impact associated with trash collection to examine the activities of speech communication and sleep in some detail, both in order to determine the direct effect trash compactor noise may have on them, 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, if not the most, intrusive noise source.

Sleep Disturbance

The sleep periods of humans are typically classified into five stages. In Stages I and II sleep is light and the sleeper is 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 cause impact (irritability, etc.) even though the sleeper may not awaken (Reference 5-14).

Two recent studies (Reference 5-10, 5-11) have summarized and analyzed sleep disturbance data. These studies show a relationship between frequency of response (disturbance or awakening) and noise level, and furthermore demonstrated that the duration of the noise stimulus is a critical parameter in predicting response. The studies also showed that the frequency of sleep disruption is predicted by noise exposure better than is arousal or behavioral awakening. An important fact is 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 afflicted; however, the disturbance may disrupt the total sleep quality and thus lead to, in certain situations, behavioral or physiological consequences (Reference 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 5-14 shows the percentage of day, evening and night time collections occurring in the trash collection model 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 and only the fraction of total refuse collection activity that occurs during nighttime hours is applicable.

TABLE 5-14

PERCENTAGES OF TOTAL REFUSE COLLECTIONS.

	1976 Population (millions)	Daytime Collection 6:00 am - 6:00 pm		Evening Collection 6:00 pm - 10:00 pm		Nighttime Collection 10:00 pm - 6:00 am	
		% 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
Total	216.9	89.9	195.1	3.3	7.1	6.7	14.5

To determine impact on sleep and the reduction in sleep disturbance achievable with noise emission regulations for compactor trucks, the following method was utilized:

Step 1. Average SEL 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 these levels are decreased in steps of 1 dB 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 from the 7-meter level is calculated by multiplying the population density within each land use area in which trash collection activity takes place by the width of the 1 dB bands (calculated in Step 2) and then by the number of trash compactions within the given land uses. The number of trash compactions 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 a curve relating sleep impact to sound exposure level (Figure 5-2 for disruption and Figure 5-3 for awakening). This procedure is analogous to the fractional impact method used for calculating ENI for generalized impact.

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 SEL level inside the home, the following transmission losses were applied to the propagated noise levels, depending on land use.

1. A noise level reduction of 20 dB was used for Urban Row, Dense and Very Dense Urban areas to represent an average of the case in which the windows of half of the homes are open and half are closed because of the type of building construction (Ref. 5-19).
2. A noise level reduction of 15 dB is used for suburban and rural areas to represent an average of the case in which the windows of all homes are open (Ref. 5-19).

The fractional impact of the disruption of sleep by noise is given in Figure 5-2 where the frequency of no sleep disturbance (as measured by changes in sleep state, including behavioral awakening) is plotted as a function of the SEL of the intruding noise. Note in Figure 5-3 that levels exceeding SEL = 95dB are an extrapolation of the data. It also should be noted that, in the calculations of the impact of trash collection noise, the analysis ignored impact contribution below SEL = 50 dB. This cut-off was selected to account for the continuous presence of ambient noise. However indoor sound exposure levels from trash collection activity rarely exceed SEL = 82 dB. Likewise, frequency of behavioral awakening as a function of SEL is shown in Figure 5-3. These relationships, adapted from Figures 1 and 2 of Reference 5-10, consist of data derived from a review of most of the recent experimental sleep data and noise relationships. The curves of Figures 5-2 and 5-3 have been modified slightly from those contained in

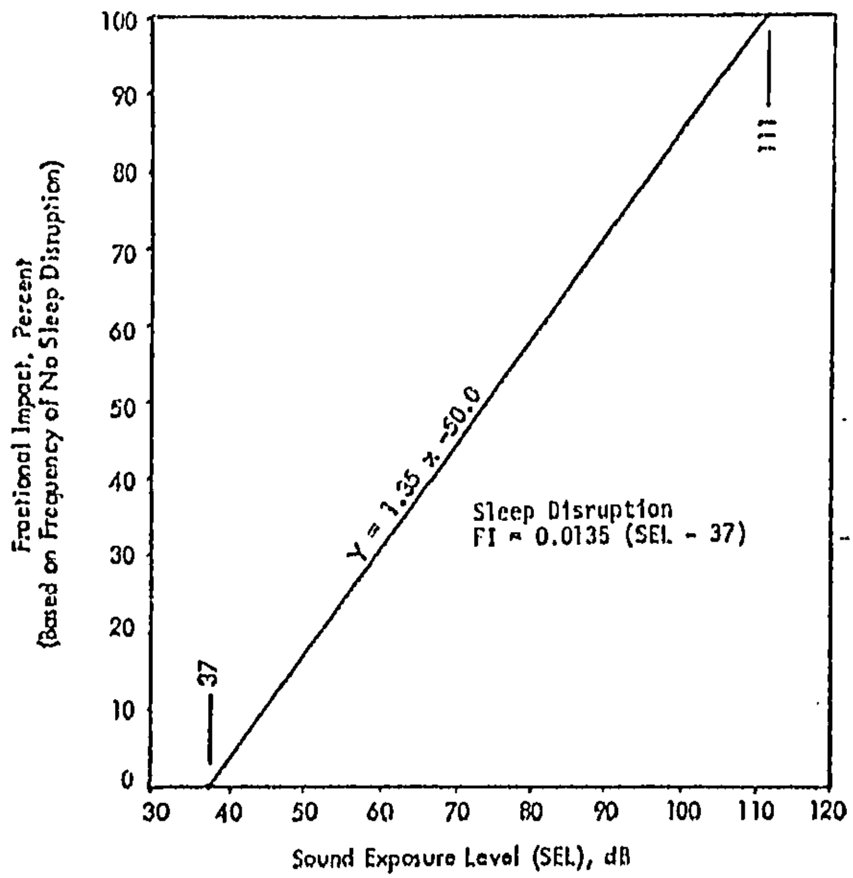

Figure 5-2. Fractional Impact of Sleep Disruption as a Function of Sound Exposure Level (Regression of Sleep Disruption on SEL)

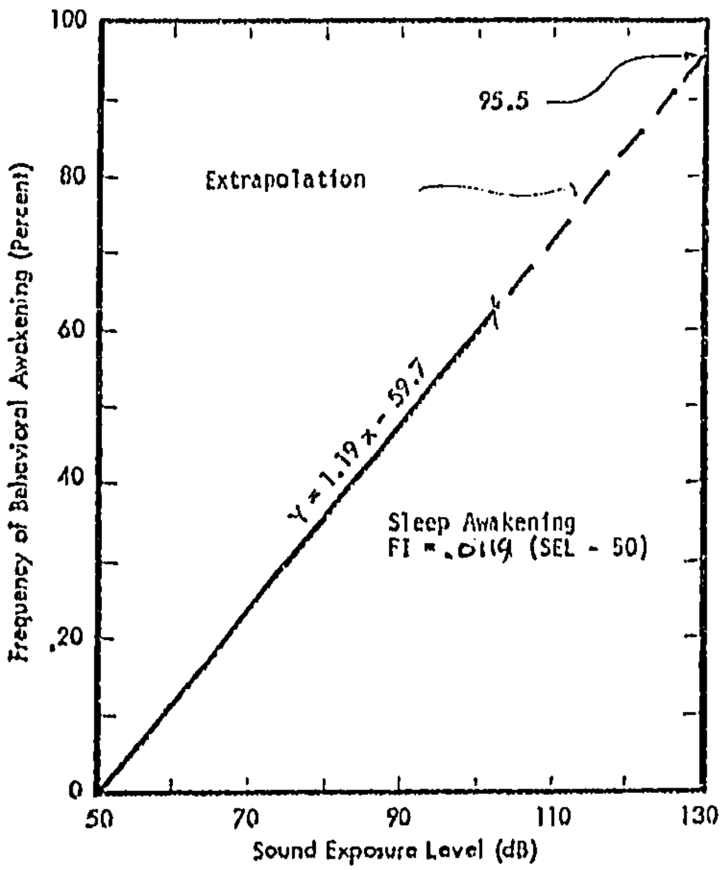

Figure 5-3. Frequency of Arousal or Awakening from Sleep in College and Middle Aged Men and Woman as a Function of Sound Exposure Level (regression of percent awakened on SEL)

References 5-10 and 5-11*. The curves indicate the approximate degree of impact (percent disruption or awakening) as a function of noise level. Furthermore, the noise data contained within these references were measured in terms of "effective perceived noise level" with a reference duration of .5 second ($EPNL_{.5\ sec.}$) was converted to SEL by the following approximate relationship:

$$SEL = EPNL_{.5\ sec} - 16\ dB \qquad (5\text{-}19)$$

The ENI for sleep disturbance and awakening was derived for each of the regulatory schedules and study years under investigation using the formula, $ENI = \sum P_i \cdot F_i$. The FI equations for sleep disturbance and sleep awakening are based on Figures 5-2 and 5-3. Table 5-15 shows the sleep disturbances (ENI) 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 5-16 shows the sleep awakening ENI 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.

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

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:

$$P_a^i = 1 - [(P_{na}^i)^C]$$

where

P_a^i = probabilty of sleep disruption at L^i

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

C = compactions per night per hour from Table 5-14

L^i = noise level in the i^{th} increment.

The probability factor was multiplied by the population contained in the 1-dB annulus and the sum of the annuli 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:

$$P_{na}^i = 1 - [L^i - 50) (.0019)].$$

It should be noted that the calculation of people-impacts is a measure of people times events. One person impacted (e.g. awakened) 10 times is assumed to be equivalent to 10 people being impacted one time each.

*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.

TABLE 5-15

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

Year		Base	One	Three	Five	Seven	Silent
		Options					
Base 1976	Total	34.1	34.1	34.1	34.1	34.1	34.1
	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	23.4	19.1	22.2	17.7	17.7	11.0
	RCI	31.5	44.0	34.8	47.9	47.9	67.7
	RCI*	0.0	18.4	5.1	24.4	24.4	53.0
1991	Total	18.0	7.6	7.6	7.6	7.6	4.4
	RCI	47.2	77.6	77.6	77.6	77.6	87.1
	RCI*	0.0	57.8	57.8	57.8	57.8	75.6
2000	Total	19.0	8.1	8.1	8.1	8.1	4.7
	RCI	44.3	76.3	76.3	76.3	76.3	86.2
	RCI*	0.0	57.4	57.4	57.4	57.4	75.3

RCI - percentage benefit from base year (1976)
RCI* - percentage benefit from base option in given year. Base option includes benefits from medium and heavy truck regulations.

TABLE 5-16

SLEEP AWAKENINGS ENI
(ENI in millions; RCI percentage benefits)

Year		Base	One	Options Three	Five	Seven	Silent
Base 1976	Total	30.3	30.3	30.3	30.3	30.3	30.3
	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	20.8	17.0	19.8	18.7	15.8	9.8
	RCI	31.3	43.9	34.7	38.2	47.8	67.7
	RCI*	0.0	18.3	4.8	10.1	24.0	52.9
1991	Total	16.1	6.8	10.7	6.8	6.8	3.9
	RCI	47.0	77.5	64.7	77.5	77.5	87.1
	RCI*	0.0	57.8	33.5	57.8	57.8	75.8
2000	Total	17.0	7.2	11.3	7.2	7.2	4.2
	RCI	44.0	76.2	62.8	76.2	76.2	86.1
	RCI*	0.0	57.6	33.5	57.6	57.6	75.3

RCI - percentage benefit from base year (1976)
RCI* - percentage benefit from base option in given year. Base option includes benefits from medium and heavy truck regulations.

Speech Interference

As is the case with sleep disruption, speech interference occurs as a result of individual noise events. Interference of speech (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, although it does, of course, affect the duration of the interference, whereas in sleep disturbances the cumulative effect of noise can change the impact from one of sleep disturbance to actual sleep awakening. Therefore, the appropriate noise metric for measuring speech interference is an L_{eq} occurring for the duration of the event, rather than a SEL which considers the effects of the duration of the event.

Also, unlike sleep disruption, interference of speech may occur both indoors and outdoors. The degree of speech interference from noise is dependent on the particular circumstances involved. Noise level and duration, separation distance of the conversers, and loudness of voice are all factors. The relationship of these factors is described in Reference 5-5. Sentence intelligibility of 95% with a normal voice is assumed as the minimum value for satisfactory outdoor communication. However, 100% speech intelligibility in a normal voice is considered necessary for acceptable conversation in the indoor environment. The methodology for determining outdoor and indoor speech interference will be discussed separately in the following sections.

Outdoor Speech Interference

The population exposed to potential outdoor speech interference are those people who are outside of any building but not along a street. The population exposed does not include 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 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}) tends to be about 5 dB 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 equivalent number of "impacted people" living within each band is derived using the fractional impact relationship of the criteria shown in Figure 5-4 (Reference 5-5). This number is multiplied by the number of compaction cycles occurring during the time in which people are estimated to be outdoors each day (.4 hours, i.e., 2.7 percent of the day) (Reference 5-13) to give the total ENI due to outdoor speech interference.

The potential ENI for outdoor speech communication for selected years is given in Table 5-17 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.

TABLE 5-17

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

Year		Base	One	Three	Five	Seven	Silent
			Options				
Base 1976	Total	30.5	30.5	30.5	30.5	30.5	30.5
	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	19.3	17.0	18.7	17.7	15.9	10.7
	RCI	36.8	44.3	38.7	41.9	48.0	64.9
	RCI*	0.0	11.9	3.1	8.3	17.6	44.6
1991	Total	15.0	8.1	11.4	8.1	8.1	6.1
	RCI	50.7	73.5	62.5	73.5	73.5	80.0
	RCI*	0.0	46.0	24.0	46.0	46.0	59.3
2000	Total	15.7	8.4	11.9	8.4	8.4	6.4
	RCI	48.7	72.3	60.9	72.3	72.3	79.0
	RCI*	0.0	46.5	24.2	46.5	46.5	59.2

RCI - percentage benefit from base year (1976)
RCI* - percentage benefit from base option in given year. Base option includes benefits from medium and heavy truck regulations.

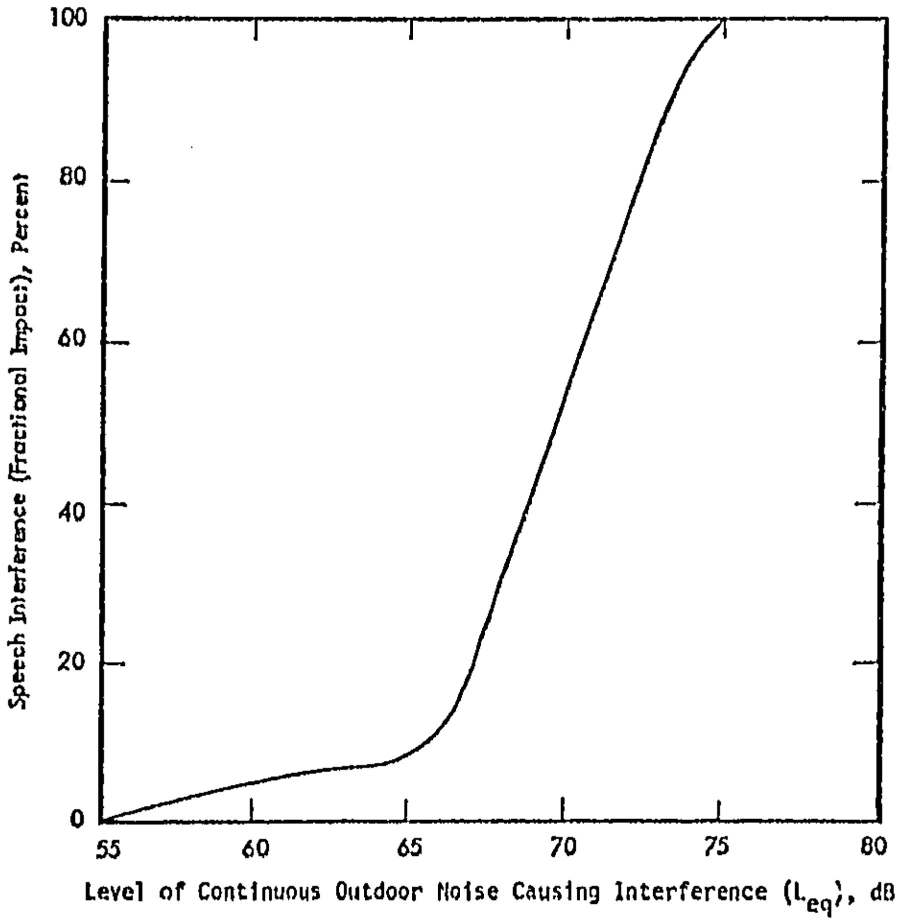

Figure 5-4. Fractional Impact Criteria of Outdoor Speech Interference (Normal Voice at 2 Meters)

Indoor Speech Interference

Indoor speech interference is assumed to occur when trash collection activity noise propagates through walls of residences or buildings and remains above a typical indoor background level of 45 dB. The criterion of impact for indoor speech interference is given in Figure 5-5 (Reference 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 compacting operation is occurring, the probability of a disruption in communication is given by Figure 5-5. Before the fractional impact is computed, the same reductions in levels due to transmission through walls which were 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 (Reference 5-13). Taking the fraction of the daytime spent inside and the number of compaction 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 ENI for indoor speech interference and the percent reduction are given in Table 5-18 for each of the regulatory options. A complete listing of results is presented in Exhibt 5-J at the end of this section.

Adding these impacts to the outdoor impact described above gives the total estimated equivalent noise impact due to the 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 5-19. The associated percent reduction is also shown in Table 5-19.

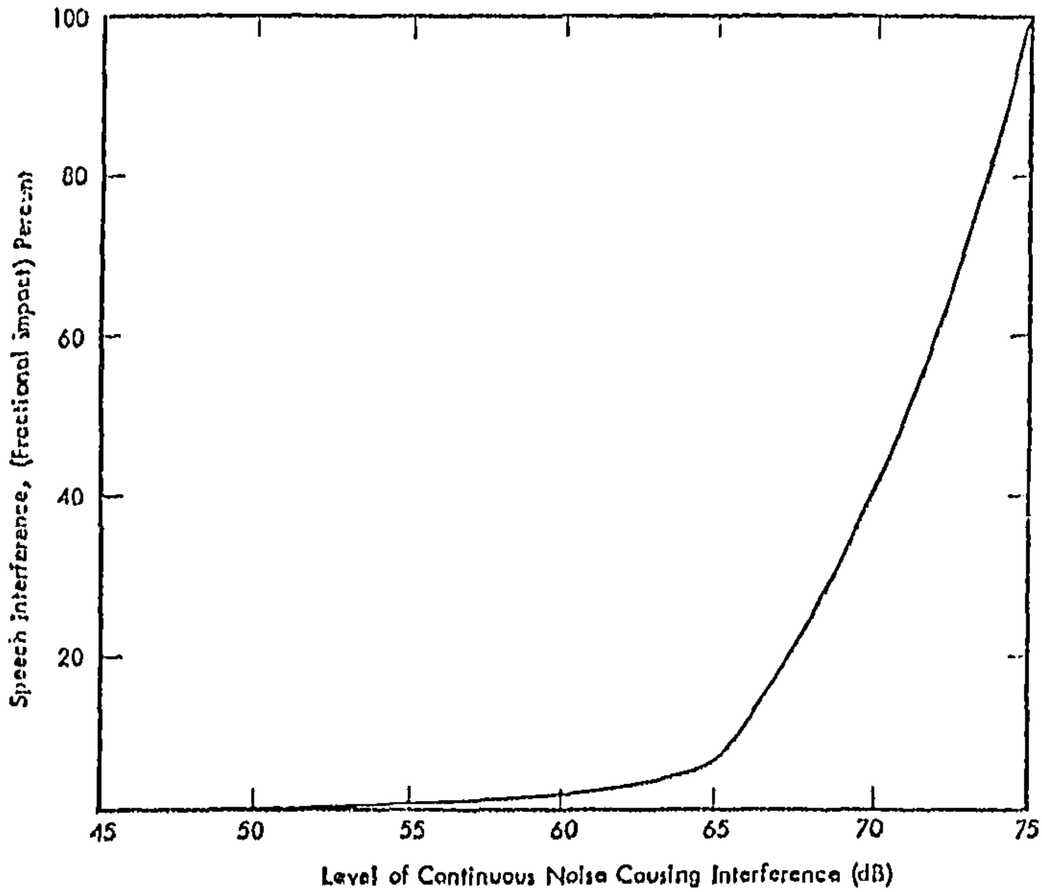

Figure 5-5. Fractional Impact of Indoor Speech Interference (Relaxed Conversation at Greater Than 1 Meter Separation, 45 dB Background in the Absence of Interferring Noise.)

TABLE 5-18

INDOOR SPEECH INTERFERENCE
(ENI in millions; RCI percentage benefit)

Year		Base	One	Options Three	Five	Seven	Silent
Base 1976	Total	0.92	0.92	0.92	0.92	0.92	0.92
	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	0.59	0.52	0.57	0.54	0.48	0.32
	RCI	36.0	43.7	37.9	41.2	47.4	65.2
	RCI*	0.0	11.9	3.4	8.5	18.6	45.8
1991	Total	0.47	0.25	0.35	0.25	0.25	0.17
	RCI	49.4	73.3	61.5	73.3	73.3	81.5
	RCI*	0.0	46.8	25.5	46.8	46.8	63.8
2000	Total	0.49	0.26	0.37	0.26	0.26	0.18
	RCI	46.5	71.8	59.3	71.8	71.8	80.4
	RCI*	0.0	46.9	24.5	46.9	46.9	63.3

RCI - percentage benefit from base year (1976)
RCI* - percentage benefit from base option in given year. Base option includes benefits from medium and heavy truck regulations.

TABLE 5-19

TOTAL OUTDOOR AND INDOOR SPEECH INTERFERENCE
(ENI in millions; RCI percentage benefit)

Year		Base	One	Options Three	Five	Seven	Silent
Base 1976	Total	31.4	31.4	31.4	31.4	31.4	31.4
	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	19.9	17.5	19.3	18.2	16.4	11.0
	RCI	36.0	44.3	38.5	42.0	47.8	65.0
	RCI*	0.0	12.1	3.0	8.5	17.6	44.7
1991	Total	15.5	8.4	11.8	8.4	8.4	6.3
	RCI	50.6	73.2	62.4	73.2	73.2	79.9
	RCI*	0.0	45.8	23.9	45.8	45.8	59.4
2000	Total	16.2	8.7	12.3	8.7	8.7	6.6
	RCI	48.4	72.3	60.8	72.3	72.3	79.0
	RCI*	0.0	46.3	24.1	46.3	46.3	59.3

RCI - percentage benefit from base year (1976)
RCI* - percentage benefit from base option in given year. Base option includes benefits from medium and heavy truck regulations.

SUMMARY AND CONCLUSIONS

The impacts from trash compactor noise are based primarily on a single equation:

$$ENI = FI \times P$$

where

ENI is the equivalent noise impact

FI is the fractional impact produced by the noise

and P is the population impacted.

This basic equation finds many forms as the investigated area of impact changes from urban noise to individual collection events. Table 5-20 summarizes the forms used in the preceding sections. Three areas of impact are distinguished:

a. Annoyance from urban noise.

b. Sleep disturbance from individual events.

c. Speech interference from individual events.

The following conclusions may be drawn from the data shown in Tables 5-11, 5-15, 5-16, and 5-19:

(1) Substantial benefits in terms of reduction in extensiveness and severity of impact are realized as a result of a compactor regulation in concert with reduced new truck emissions as promulgated (Reference 5-1).

(2) 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.

TABLE 5-20

SUMMARY EQUATION DESCRIBING CALCULATION OF TRASH COMPACTOR NOISE IMPACTS

Basic Equation: Equivalent Noise Impact = Fractional Impact x Population

a. Impact of total urban noise.

$$ENI_{traffic} = \sum_{i=55\,dB}^{L_{dn}\,max} \left(FI^{i}_{annoyance} \times Pop_i \right)$$

where

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

b. Sleep disturbance and sleep awakening from individual events.

$$ENI_{\substack{sleep\\disturbance\\(awakening)}} = \sum_{\substack{i=37\,dB\\(50)}}^{SEL\,max} \left(FI^{i}_{\substack{sleep\\disturbance\\(awakening)}} \times \text{Pop Density} \times \text{Size of Area} \right)$$

where

$$FI_{sleep\ disturbance} = 1.35\ SEL - 50.0 \times .01$$

$$FI_{sleep\ awakening} = 1.19\ SEL - 59.7 \times .01$$

TABLE 5-20 (Continued)

c. Speech interference from individual events.

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

where L_{eq} * is defined over the duration of the event
L_{max} is the maximum level of a triangular time history passby
L_b is the background level
FI_{speech} is defined in reference 5-6.

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

(4) Regulating a truck-mounted compactor more stringently than engine-related truck noise (as measured during the compaction mode) results in only minimal benefits, as the engine noise is the predominant source of noise.

(5) Benefit is afforded mainly to those people in dense urban areas. The population living in suburban or low density urban areas receive lesser benefit.

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Section 5

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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 sound level in dB(A))
Exhibit 5-B: L_{eq} (Equivalent sound level for a 24-hour period)
Exhibit 5-C: L_{dn} (Day-night equivalent sound level)
Exhibit 5-D: $L_{dn}A$ (Day-night equivalent sound level with ambient)
Exhibit 5-E: ENI and RCI for General Annoyance
Exhibit 5-F: SEL (Sound Exposure Level)
Exhibit 5-G: ENI and RCI for Sleep Disturbance
Exhibit 5-H: ENI and RCI for Sleep Awakening
Exhibit 5-I: ENI and RCI for Outdoor Speech Interference
Exhibit 5-J: ENI and RCI for Indoor Speech Interference

Symbols defining columns are as follows:

SSF - Suburban Single Family Detached
SD - Suburban Duplexes
UR - Urban Low Apartments
DU - Dense Urban Apartments
VDU - Very Dense Apartments

Exhibit 5-A

L_A For Each Case

Base

Year	SSF	SD	UR	DU	VDU
1976	78.043	78.036	81.875	83.591	83.935
1977	78.043	78.036	81.875	83.591	83.935
1978	77.570	77.564	81.421	83.157	83.540
1979	77.115	77.110	80.986	82.743	83.166
1980	76.679	76.674	80.572	82.350	82.814
1981	76.263	76.259	80.178	81.978	82.485
1982	75.729	75.726	79.676	81.508	82.073
1983	75.235	75.233	79.215	81.079	81.703
1984	74.784	74.782	78.797	80.692	81.373
1985	74.670	74.669	78.692	80.596	81.292
1986	74.560	74.559	78.591	80.503	81.214
1987	74.453	74.452	78.492	80.413	81.138
1988	74.349	74.348	78.397	80.325	81.065
1989	74.348	74.348	78.397	80.325	81.065
1990	74.349	74.348	78.397	80.325	81.065
1991	74.349	74.348	78.397	80.325	81.065
1992	74.349	74.348	78.397	80.325	81.065
1993	74.349	74.348	78.397	80.325	81.065
1994	74.349	74.348	78.397	80.325	81.065
1995	74.349	74.348	78.397	80.325	81.065
1996	74.349	74.348	78.397	80.325	81.065
1997	74.349	74.348	78.397	80.325	81.065
1998	74.349	74.340	78.397	80.325	81.065
1999	74.349	74.348	78.397	80.325	81.065
2000	74.349	74.348	78.397	80.325	81.065

Option 1

Year	SSF	SD	UR	DU	VDU
1976	78.043	78.036	81.875	83.591	83.935
1977	78.043	78.036	81.875	83.591	83.935
1978	77.570	77.564	81.421	83.157	83.540
1979	77.085	77.082	80.926	82.664	83.021
1980	76.513	76.512	80.440	82.179	82.506
1981	76.155	76.150	79.964	81.702	81.995
1982	75.310	75.314	79.090	80.812	81.048
1983	74.466	74.472	78.217	79.923	80.102
1984	73.622	73.630	77.343	79.035	79.161
1985	73.195	73.209	76.899	78.552	78.617
1986	72.924	72.931	76.511	78.166	78.222
1987	72.460	72.466	76.148	77.791	77.840
1988	72.105	72.111	75.730	77.427	77.459
1989	72.106	72.111	75.730	77.427	77.465
1990	72.106	72.111	75.730	77.428	77.469
1991	72.105	72.111	75.730	77.428	77.459
1992	72.106	72.111	75.730	77.429	77.469
1993	72.106	72.111	75.730	77.428	77.465
1994	72.106	72.111	75.730	77.428	77.465
1995	72.106	72.111	75.730	77.429	77.469
1996	72.105	72.111	75.730	77.428	77.459
1997	72.106	72.111	75.730	77.428	77.465
1998	72.106	72.111	75.730	77.428	77.469
1999	72.105	72.111	75.730	77.429	77.459
2000	72.106	72.111	75.730	77.428	77.469

Exhibit 5-A

L_A For Each Case

Option 3

YEAR	SSF	SD	UR	DU	VDU
1976	78.043	78.036	81.875	83.591	83.535
1977	78.043	78.036	81.875	83.591	83.535
1978	77.570	77.564	81.421	83.157	83.540
1979	77.115	77.110	80.996	82.743	83.166
1980	76.675	76.674	80.572	82.350	82.814
1981	76.263	76.259	80.178	81.978	82.485
1982	75.632	75.630	79.533	81.236	81.811
1983	75.021	75.023	78.904	80.707	81.144
1984	74.430	74.437	78.290	80.052	80.484
1985	74.193	74.202	78.012	79.792	80.109
1986	73.956	73.959	77.734	79.454	79.739
1987	73.719	73.734	77.451	79.156	79.371
1988	73.482	73.499	77.181	78.900	79.009
1989	73.482	73.499	77.181	78.900	79.009
1990	73.482	73.499	77.181	78.900	79.009
1991	73.482	73.499	77.181	78.900	79.009
1992	73.482	73.499	77.181	78.900	79.009
1993	73.482	73.499	77.181	78.900	79.009
1994	73.482	73.499	77.181	78.900	79.009
1995	73.482	73.499	77.181	78.900	79.009
1996	73.482	73.499	77.181	78.900	79.009
1997	73.482	73.499	77.181	78.900	79.009
1998	73.482	73.499	77.181	78.900	79.009
1999	73.482	73.499	77.181	78.900	79.009
2000	73.482	73.499	77.181	78.900	79.009

Option 5

YEAR	SSF	SD	UR	DU	VDU
1976	78.043	78.036	81.875	83.591	83.535
1977	78.043	78.036	81.875	83.591	83.535
1978	77.570	77.564	81.421	83.157	83.540
1979	77.115	77.110	80.996	82.743	83.166
1980	76.675	76.674	80.572	82.350	82.814
1981	76.263	76.255	80.178	81.978	82.485
1982	75.419	75.417	79.302	81.086	81.526
1983	74.576	74.576	78.427	80.194	80.568
1984	73.732	73.735	77.552	79.302	79.613
1985	73.300	73.303	77.077	78.754	79.021
1986	72.896	72.950	76.626	78.313	78.467
1987	72.488	72.492	76.198	77.858	77.950
1988	72.106	72.111	75.790	77.427	77.469
1989	72.106	72.111	75.790	77.427	77.469
1990	72.106	72.111	75.790	77.428	77.469
1991	72.106	72.111	75.790	77.428	77.469
1992	72.106	72.111	75.790	77.428	77.469
1993	72.106	72.111	75.790	77.428	77.469
1994	72.106	72.111	75.790	77.428	77.469
1995	72.106	72.111	75.790	77.428	77.469
1996	72.106	72.111	75.790	77.428	77.469
1997	72.106	72.111	75.790	77.428	77.469
1998	72.106	72.111	75.790	77.428	77.469
1999	72.106	72.111	75.790	77.428	77.469
2000	72.106	72.111	75.790	77.428	77.469

Exhibit 5-A

L_A For Each Case

Option 7

YEAR	SSF	SD	UR	DU	VDU
1976	78.042	78.036	81.875	83.591	83.935
1977	78.043	78.035	81.875	83.591	83.935
1978	77.570	77.564	81.421	83.157	83.540
1979	77.005	77.001	80.838	82.567	82.905
1980	76.443	76.441	80.256	81.977	82.275
1981	75.883	75.884	79.675	81.388	81.643
1982	75.038	75.040	78.903	80.503	80.705
1983	74.192	74.196	77.932	79.617	79.771
1984	73.346	73.352	77.060	78.733	78.839
1985	72.948	72.954	76.634	78.282	78.333
1986	72.666	72.671	76.351	77.995	78.043
1987	72.385	72.390	76.070	77.710	77.755
1988	72.105	72.111	75.790	77.427	77.469
1989	72.106	72.111	75.790	77.427	77.469
1990	72.106	72.111	75.790	77.428	77.469
1991	72.105	72.111	75.790	77.429	77.465
1992	72.106	72.111	75.790	77.428	77.469
1993	72.106	72.111	75.790	77.428	77.469
1994	72.106	72.111	75.790	77.429	77.465
1995	72.106	72.111	75.790	77.428	77.465
1996	72.105	72.111	75.790	77.429	77.469
1997	72.106	72.111	75.790	77.429	77.469
1998	72.106	72.111	75.790	77.428	77.469
1999	72.105	72.111	75.790	77.428	77.465
2000	72.106	72.111	75.790	77.429	77.469

Silent

YEAR	SSF	SD	UR	DU	VDU
1976	76.879	76.868	80.543	82.079	82.037
1977	76.875	76.868	80.543	82.075	82.037
1978	76.251	76.240	79.914	81.450	81.408
1979	75.622	75.611	79.286	80.822	80.780
1980	74.994	74.983	78.657	80.193	80.151
1981	74.365	74.354	78.029	79.565	79.523
1982	73.508	73.497	77.171	78.708	78.666
1983	72.651	72.640	76.314	77.850	77.808
1984	71.794	71.783	75.457	76.993	76.951
1985	71.565	71.554	75.229	76.765	76.723
1986	71.336	71.326	75.000	76.536	76.494
1987	71.108	71.097	74.771	76.308	76.266
1988	70.879	70.868	74.543	76.075	76.037
1989	70.879	70.868	74.543	76.075	76.037
1990	70.879	70.868	74.543	76.079	76.037
1991	70.875	70.869	74.543	76.075	76.037
1992	70.879	70.869	74.543	76.075	76.037
1993	70.879	70.868	74.543	76.079	76.037
1994	70.875	70.869	74.543	76.079	76.037
1995	70.875	70.869	74.543	76.079	76.037
1996	70.875	70.869	74.543	76.075	76.037
1997	70.879	70.868	74.543	76.075	76.037
1998	70.879	70.868	74.543	76.079	76.037
1999	70.875	70.868	74.543	76.075	76.037
2000	70.875	70.869	74.543	76.079	76.037

Exhibit 5-B

L_{eq} For Each Case

Base

Year	SSF	SD	UR	DU	VDU
1976	44.288	48.802	56.911	63.154	67.464
1977	44.366	48.880	56.989	63.232	67.542
1978	43.972	48.486	56.613	62.875	67.224
1979	43.595	48.110	56.256	62.539	66.928
1980	43.212	47.727	55.894	62.199	66.630
1981	42.848	47.365	55.554	61.881	66.354
1982	42.368	46.885	55.105	61.463	65.995
1983	41.927	46.445	54.697	61.087	65.678
1984	41.529	46.048	54.332	60.754	65.401
1985	41.462	45.981	54.274	60.704	65.367
1986	41.398	45.918	54.219	60.658	65.335
1987	41.338	45.857	54.167	60.614	65.306
1988	41.280	45.800	54.118	60.573	65.279
1989	41.327	45.847	54.165	60.620	65.326
1990	41.362	45.882	54.200	60.655	65.361
1991	41.397	45.917	54.235	60.690	65.396
1992	41.432	45.952	54.270	60.725	65.431
1993	41.467	45.987	54.305	60.760	65.466
1994	41.502	46.022	54.340	60.795	65.501
1995	41.532	46.052	54.370	60.825	65.531
1996	41.562	46.081	54.400	60.855	65.561
1997	41.591	46.111	54.430	60.885	65.591
1998	41.621	46.141	54.460	60.915	65.621
1999	41.651	46.171	54.490	60.945	65.650
2000	41.681	46.201	54.519	60.974	65.680

Option 1

Year	SSF	SD	UR	DU	VDU
1976	44.288	48.802	56.911	63.154	67.464
1977	44.366	48.880	56.989	63.232	67.542
1978	43.972	48.486	56.613	62.875	67.224
1979	43.554	48.091	56.176	62.460	66.782
1980	43.146	47.665	55.753	62.077	66.321
1981	42.740	47.262	55.340	61.604	65.853
1982	41.949	46.473	54.519	60.769	64.965
1983	41.158	45.694	53.695	59.932	64.070
1984	40.357	44.855	52.875	59.055	63.198
1985	39.991	44.520	52.470	58.660	62.691
1986	39.662	44.190	52.140	58.321	62.343
1987	39.345	43.871	51.821	57.993	62.008
1988	39.038	43.563	51.512	57.670	61.684
1989	39.085	43.610	51.559	57.722	61.730
1990	39.120	43.645	51.594	57.757	61.765
1991	39.155	43.680	51.629	57.792	61.800
1992	39.190	43.715	51.664	57.827	61.835
1993	39.225	43.750	51.699	57.862	61.870
1994	39.260	43.785	51.734	57.897	61.905
1995	39.290	43.815	51.764	57.927	61.935
1996	39.320	43.844	51.794	57.957	61.965
1997	39.350	43.874	51.824	57.987	61.995
1998	39.379	43.904	51.854	58.017	62.025
1999	39.409	43.934	51.883	58.047	62.055
2000	39.439	43.964	51.913	58.077	62.085

Exhibit 5-B

L_{eq} For Each Case

Option 3

YEAR	SSF	SD	UR	DU	VDU
1976	44.288	48.802	56.911	63.154	67.464
1977	44.366	48.880	56.989	63.232	67.542
1978	43.572	48.486	56.613	62.875	67.224
1979	43.595	48.110	56.256	62.539	66.929
1980	43.212	47.727	55.894	62.199	66.630
1981	42.848	47.365	55.554	61.881	66.354
1982	42.270	46.789	54.952	61.291	65.732
1983	41.712	46.235	54.386	60.715	65.119
1984	41.175	45.702	53.925	60.154	64.512
1985	40.985	45.514	53.574	59.900	64.184
1986	40.795	45.327	53.363	59.649	63.959
1987	40.604	45.139	53.133	59.398	63.539
1988	40.414	44.951	52.903	59.148	63.222
1989	40.461	44.999	52.950	59.195	63.270
1990	40.496	45.033	52.985	59.230	63.305
1991	40.531	45.068	53.020	59.265	63.340
1992	40.566	45.103	53.055	59.300	63.375
1993	40.601	45.138	53.090	59.335	63.410
1994	40.636	45.173	53.125	59.370	63.445
1995	40.666	45.203	53.155	59.400	63.475
1996	40.696	45.233	53.185	59.429	63.504
1997	40.725	45.263	53.215	59.459	63.534
1998	40.755	45.293	53.244	59.489	63.564
1999	40.785	45.323	53.274	59.519	63.594
2000	40.815	45.352	53.304	59.549	63.624

Option 5

YEAR	SSF	SD	UR	DU	VDU
1976	44.288	48.802	56.911	63.154	67.464
1977	44.366	48.880	56.989	63.232	67.542
1978	43.572	48.486	56.613	62.875	67.224
1979	43.595	48.110	56.256	62.539	66.929
1980	43.212	47.727	55.894	62.199	66.630
1981	42.848	47.365	55.554	61.881	66.354
1982	42.058	46.576	54.731	61.041	65.447
1983	41.267	45.786	53.909	60.202	64.543
1984	40.477	45.000	53.087	59.363	63.641
1985	40.092	44.615	52.659	58.902	63.095
1986	39.724	44.248	52.255	58.468	62.588
1987	39.373	43.898	51.873	58.059	62.118
1988	39.038	43.563	51.512	57.676	61.684
1989	39.085	43.610	51.559	57.722	61.730
1990	39.120	43.645	51.594	57.757	61.765
1991	39.155	43.680	51.629	57.792	61.800
1992	39.190	43.715	51.664	57.827	61.835
1993	39.225	43.750	51.699	57.862	61.870
1994	39.260	43.785	51.734	57.897	61.905
1995	39.290	43.815	51.764	57.927	61.935
1996	39.320	43.844	51.794	57.957	61.965
1997	39.350	43.874	51.824	57.987	61.995
1998	39.379	43.904	51.854	58.017	62.025
1999	39.409	43.934	51.883	58.047	62.055
2000	39.439	43.964	51.913	58.077	62.085

Exhibit 5-B

L_{eq} For Each Case

Option 7

YEAR	SSF	SD	UR	DU	VDU
1976	44.238	48.902	56.911	63.154	67.464
1977	44.366	49.389	56.983	63.232	67.542
1978	43.972	48.485	55.513	62.875	67.224
1979	43.495	48.001	56.109	62.363	66.670
1980	42.576	47.474	55.579	61.226	66.091
1981	42.469	46.950	55.051	61.290	65.511
1982	41.676	46.199	54.232	60.458	64.627
1983	40.884	45.408	53.414	59.626	63.746
1984	40.091	44.617	52.595	58.794	62.866
1985	39.740	44.266	52.216	58.390	62.407
1986	39.504	44.030	51.979	58.150	62.164
1987	39.270	43.796	51.745	57.912	61.922
1988	39.038	43.563	51.512	57.676	61.684
1989	39.085	43.610	51.559	57.722	61.730
1990	39.120	43.645	51.594	57.757	61.765
1991	39.155	43.680	51.629	57.792	61.800
1992	39.190	43.715	51.664	57.827	61.835
1993	39.225	43.750	51.699	57.862	61.870
1994	39.260	43.785	51.734	57.897	61.905
1995	39.290	43.815	51.764	57.927	61.935
1996	39.320	43.844	51.794	57.957	61.965
1997	39.350	43.874	51.824	57.987	61.995
1998	39.379	43.904	51.854	58.017	62.025
1999	39.409	43.934	51.883	58.047	62.055
2000	39.439	43.964	51.913	58.077	62.085

Silent

YEAR	SSF	SD	UR	DU	VDU
1976	43.125	47.635	55.575	61.641	65.56[illegible]
1977	43.203	47.712	55.657	61.719	65.64[illegible]
1978	42.652	47.162	55.106	61.168	65.09[illegible]
1979	42.102	46.611	54.555	60.618	64.54[illegible]
1980	41.526	46.036	53.910	60.042	63.56[illegible]
1981	40.951	45.460	53.405	59.467	63.391
1982	40.147	44.656	52.600	58.663	62.5[illegible]
1983	39.343	43.852	51.796	57.859	61.783
1984	38.539	43.048	50.992	57.055	60.979
1985	38.357	42.866	50.810	56.873	60.797
1986	38.175	42.684	50.629	56.691	60.615
1987	37.993	42.502	50.447	56.509	60.433
1988	37.811	42.320	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	50.605	56.668	60.593
1999	38.182	42.692	50.636	56.698	60.622
2000	38.212	42.721	50.666	56.728	60.652

Exhibit 5-C

L_{dn} For Each Case

Base

Year	SSF	SD	UR	DU	VDU
1976	44.790	50.679	61.870	70.369	74.679
1977	44.868	50.757	61.948	70.446	74.757
1978	44.474	50.362	61.572	70.090	74.439
1979	44.097	49.986	61.216	69.754	74.143
1980	43.714	49.604	60.854	69.414	73.845
1981	43.351	49.241	60.513	69.095	73.569
1982	42.870	48.761	60.064	68.678	73.209
1983	42.430	48.322	59.657	68.302	72.892
1984	42.031	47.924	59.291	67.968	72.616
1985	41.965	47.858	59.234	67.919	72.581
1986	41.901	47.794	59.179	67.872	72.550
1987	41.840	47.734	59.127	67.829	72.520
1988	41.783	47.676	59.078	67.788	72.494
1989	41.829	47.723	59.125	67.835	72.541
1990	41.864	47.758	59.160	67.870	72.576
1991	41.899	47.793	59.195	67.905	72.611
1992	41.934	47.828	59.230	67.940	72.646
1993	41.969	47.863	59.265	67.975	72.681
1994	42.005	47.898	59.300	68.010	72.716
1995	42.034	47.928	59.330	68.040	72.746
1996	42.064	47.958	59.360	68.070	72.776
1997	42.094	47.988	59.389	68.100	72.805
1998	42.124	48.018	59.419	68.129	72.835
1999	42.154	48.047	59.449	68.159	72.865
2000	42.184	48.077	59.479	68.189	72.895

Option 1

Year	SSF	SD	UR	DU	VDU
1976	44.790	50.679	61.870	70.369	74.679
1977	44.868	50.757	61.948	70.446	74.757
1978	44.474	50.362	61.572	70.090	74.439
1979	44.067	49.754	61.135	69.674	73.998
1980	43.645	49.541	60.723	69.242	73.535
1981	43.243	49.139	60.400	68.819	73.078
1982	42.452	48.350	59.479	67.982	72.186
1983	41.651	47.551	58.658	67.146	71.292
1984	40.870	46.772	57.839	66.311	70.403
1985	40.494	46.392	57.430	65.875	69.906
1986	40.166	46.066	57.079	65.536	69.558
1987	39.848	45.748	56.780	65.207	69.222
1988	39.541	45.439	56.472	64.890	68.898
1989	39.585	45.486	56.519	64.937	68.945
1990	39.622	45.521	56.554	64.972	68.980
1991	39.659	45.556	56.589	65.007	69.015
1992	39.693	45.591	56.624	65.042	69.050
1993	39.726	45.626	56.659	65.077	69.085
1994	39.763	45.661	56.694	65.112	69.120
1995	39.793	45.691	56.724	65.142	69.150
1996	39.823	45.721	56.753	65.172	69.180
1997	39.853	45.751	56.783	65.202	69.210
1998	39.883	45.781	56.813	65.232	69.240
1999	39.913	45.811	56.843	65.262	69.269
2000	39.942	45.840	56.873	65.291	69.299

Exhibit 5-C

L_{dn} For Each Case

YEAR	SSF	SD	UR	DU	VDU
Option 3					
1976	44.790	50.679	61.870	70.365	74.675
1977	44.868	50.757	61.949	70.446	74.757
1978	44.474	50.362	61.572	70.090	74.439
1979	44.097	49.986	61.216	69.754	74.143
1980	43.714	49.604	60.854	69.414	73.845
1981	43.351	49.241	60.513	69.095	73.569
1982	42.773	48.666	59.922	68.506	72.947
1983	42.215	48.111	59.345	67.930	72.333
1984	41.678	47.578	58.785	67.358	71.727
1985	41.489	47.391	58.553	67.115	71.358
1986	41.297	47.203	58.322	66.863	71.074
1987	41.107	47.015	58.092	66.612	70.754
1988	40.917	46.828	57.863	66.363	70.438
1989	40.963	46.874	57.909	66.409	70.484
1990	40.999	46.910	57.944	66.444	70.519
1991	41.034	46.945	57.980	66.479	70.554
1992	41.069	46.980	58.015	66.514	70.589
1993	41.104	47.015	58.050	66.549	70.624
1994	41.139	47.050	58.085	66.584	70.660
1995	41.169	47.080	58.114	66.614	70.689
1996	41.198	47.109	58.144	66.644	70.719
1997	41.228	47.139	58.174	66.674	70.749
1998	41.258	47.169	58.204	66.704	70.779
1999	41.288	47.199	58.234	66.734	70.809
2000	41.318	47.229	58.264	66.764	70.839

YEAR	SSF	SD	UR	DU	VDU
Option 5					
1976	44.790	50.679	61.870	70.365	74.675
1977	44.868	50.757	61.949	70.446	74.757
1978	44.474	50.362	61.572	70.090	74.439
1979	44.097	49.986	61.216	69.754	74.143
1980	43.714	49.604	60.854	69.414	73.845
1981	43.351	49.241	60.513	69.095	73.569
1982	42.550	48.453	59.671	68.255	72.662
1983	41.770	47.664	58.869	67.417	71.758
1984	40.980	46.876	58.047	66.578	70.856
1985	40.595	46.492	57.619	66.117	70.310
1986	40.227	46.125	57.214	65.692	69.802
1987	39.876	45.774	56.833	65.274	69.333
1988	39.541	45.439	56.472	64.890	68.899
1989	39.588	45.486	56.518	64.937	68.945
1990	39.623	45.521	56.554	64.972	68.980
1991	39.658	45.556	56.589	65.007	69.015
1992	39.693	45.591	56.624	65.042	69.050
1993	39.728	45.626	56.659	65.077	69.085
1994	39.763	45.661	56.694	65.112	69.120
1995	39.793	45.691	56.724	65.142	69.150
1996	39.823	45.721	56.753	65.172	69.180
1997	39.853	45.751	56.783	65.202	69.210
1998	39.883	45.781	56.813	65.232	69.240
1999	39.913	45.811	56.843	65.262	69.269
2000	39.942	45.840	56.873	65.291	69.299

Exhibit 5-C

Ldn For Each Case

Option 7

YEAR	BSF	SD	UR	DU	VDU
1976	44.790	50.673	61.870	70.369	74.675
1977	44.868	50.757	61.948	70.446	74.757
1978	44.474	50.362	61.572	70.090	74.439
1979	43.997	49.877	61.067	69.578	73.995
1980	43.478	49.370	60.539	69.041	73.305
1981	42.571	48.865	60.011	68.505	72.726
1982	42.179	48.075	59.192	67.673	71.842
1983	41.386	47.294	58.373	66.841	70.960
1984	40.594	46.494	57.555	66.009	70.081
1985	40.243	46.143	57.175	65.605	69.622
1986	40.007	45.906	56.939	65.365	69.379
1987	39.774	45.672	56.705	65.127	69.137
1988	39.541	45.439	56.472	64.890	68.899
1989	39.588	45.486	56.518	64.927	68.945
1990	39.623	45.521	56.554	64.972	68.980
1991	39.658	45.556	56.589	65.007	69.015
1992	39.693	45.591	56.624	65.042	69.050
1993	39.728	45.626	56.659	65.077	69.085
1994	39.763	45.661	56.694	65.112	69.120
1995	39.793	45.691	56.724	65.142	69.150
1996	39.823	45.721	56.753	65.172	69.180
1997	39.853	45.751	56.783	65.202	69.210
1998	39.883	45.781	56.813	65.232	69.240
1999	39.913	45.811	56.843	65.262	69.269
2000	39.942	45.840	56.873	65.291	69.299

Silent

YEAR	BSF	SD	UR	DU	VDU
1976	43.627	49.511	60.539	68.956	72.790
1977	43.705	49.589	60.616	69.034	72.868
1978	43.154	49.039	60.066	68.383	72.307
1979	42.604	48.487	59.515	67.833	71.757
1980	42.029	47.912	58.940	67.257	71.181
1981	41.452	47.337	58.364	66.682	70.606
1982	40.650	46.533	57.560	65.878	69.802
1983	39.848	45.729	56.755	65.074	68.998
1984	39.042	44.925	55.952	64.269	68.194
1985	38.860	44.743	55.770	64.088	68.012
1986	38.679	44.561	55.588	63.906	67.830
1987	38.497	44.379	55.406	63.724	67.648
1988	38.315	44.197	55.224	63.542	67.466
1989	38.362	44.244	55.271	63.588	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	38.537	44.419	55.446	63.764	67.688
1995	38.567	44.449	55.476	63.794	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

$L_{dn}A$ For Each Case

Base

Year	SSF	SD	UR	DU	VDU
1976	54.492	55.660	62.527	70.468	74.716
1977	54.500	55.685	62.594	70.544	74.793
1978	54.459	55.562	62.272	70.196	74.478
1979	54.423	55.451	61.971	69.868	74.185
1980	54.389	55.346	61.669	69.537	73.889
1981	54.359	55.252	61.388	69.228	73.616
1982	54.323	55.137	61.025	68.823	73.261
1983	54.292	55.040	60.701	68.460	72.948
1984	54.268	54.958	60.416	68.139	72.675
1985	54.264	54.945	60.372	68.092	72.641
1986	54.260	54.933	60.330	68.047	72.610
1987	54.256	54.921	60.290	68.005	72.581
1988	54.253	54.910	60.253	67.966	72.555
1989	54.256	54.919	60.288	68.011	72.601
1990	54.258	54.926	60.315	68.044	72.636
1991	54.260	54.932	60.342	68.078	72.670
1992	54.262	54.939	60.369	68.112	72.705
1993	54.264	54.946	60.396	68.145	72.739
1994	54.266	54.953	60.423	68.179	72.774
1995	54.268	54.959	60.446	68.208	72.803
1996	54.270	54.965	60.469	68.237	72.833
1997	54.271	54.971	60.492	68.265	72.862
1998	54.273	54.977	60.515	68.294	72.892
1999	54.275	54.983	60.539	68.323	72.921
2000	54.277	54.989	60.562	68.352	72.951

Option 1

Year	SSF	SD	UR	DU	VDU
1976	54.492	55.660	62.527	70.468	74.716
1977	54.500	55.685	62.594	70.544	74.793
1978	54.459	55.562	62.272	70.196	74.478
1979	54.420	55.443	61.920	69.790	74.041
1980	54.383	55.330	61.550	69.370	73.534
1981	54.359	55.227	61.215	68.957	73.131
1982	54.294	55.046	60.562	68.152	72.249
1983	54.246	54.895	59.926	67.352	71.372
1984	54.206	54.753	59.340	66.559	70.501
1985	54.190	54.695	59.055	66.148	70.015
1986	54.176	54.648	58.821	65.830	69.677
1987	54.164	54.605	58.619	65.524	69.351
1988	54.153	54.566	58.420	65.230	69.037
1989	54.154	54.572	58.450	65.274	69.092
1990	54.156	54.576	58.472	65.306	69.116
1991	54.157	54.581	58.495	65.339	69.150
1992	54.158	54.585	58.517	65.371	69.194
1993	54.159	54.590	58.540	65.403	69.219
1994	54.161	54.594	58.563	65.436	69.252
1995	54.162	54.599	58.582	65.464	69.281
1996	54.163	54.602	58.602	65.491	69.310
1997	54.164	54.606	58.621	65.519	69.339
1998	54.165	54.610	58.641	65.547	69.358
1999	54.166	54.613	58.660	65.575	69.397
2000	54.167	54.617	58.680	65.603	69.426

Exhibit 5-D

$L_{dn}A$ For Each Case

Option 3

YEAR	SSF	SD	UR	DU	VDU
1976	54.492	55.660	62.527	70.458	74.716
1977	54.500	55.685	62.594	70.544	74.793
1978	54.459	55.562	62.272	70.196	74.478
1979	54.423	55.451	61.971	69.868	74.185
1980	54.389	55.346	61.669	69.537	73.849
1981	54.359	55.252	61.398	69.228	73.515
1982	54.316	55.115	60.911	68.657	73.002
1983	54.279	54.996	60.458	68.102	72.396
1984	54.247	54.892	60.031	67.564	71.799
1985	54.237	54.858	59.858	67.322	71.477
1986	54.227	54.825	59.688	67.082	71.158
1987	54.219	54.793	59.522	66.844	70.845
1988	54.209	54.762	59.358	66.608	70.535
1989	54.211	54.769	59.391	66.652	70.581
1990	54.212	54.775	59.416	66.695	70.615
1991	54.214	54.781	59.441	66.719	70.649
1992	54.215	54.787	59.466	66.751	70.684
1993	54.217	54.793	59.491	66.784	70.719
1994	54.219	54.798	59.516	66.818	70.752
1995	54.221	54.803	59.538	66.845	70.781
1996	54.222	54.808	59.559	66.874	70.811
1997	54.224	54.814	59.581	66.903	70.840
1998	54.225	54.819	59.602	66.931	70.869
1999	54.227	54.824	59.624	66.959	70.898
2000	54.228	54.829	59.646	66.988	70.929

Option 5

YEAR	SSF	SD	UR	DU	VDU
1976	54.492	55.660	62.527	70.458	74.716
1977	54.500	55.685	62.594	70.544	74.793
1978	54.459	55.562	62.272	70.196	74.478
1979	54.423	55.451	61.971	69.868	74.185
1980	54.385	55.346	61.665	69.537	73.899
1981	54.359	55.262	61.388	69.228	73.616
1982	54.301	55.058	60.728	68.415	72.720
1983	54.252	54.908	60.094	67.610	71.830
1984	54.211	54.770	59.489	66.811	70.944
1985	54.174	54.710	59.186	66.375	70.410
1986	54.178	54.656	58.909	65.968	69.915
1987	54.165	54.605	58.634	65.595	69.459
1988	54.153	54.566	58.420	65.230	69.037
1989	54.154	54.572	58.450	65.274	69.082
1990	54.155	54.575	58.472	65.305	69.115
1991	54.157	54.591	58.495	65.339	69.150
1992	54.158	54.585	58.517	65.371	69.184
1993	54.159	54.590	58.540	65.403	69.218
1994	54.161	54.594	58.563	65.436	69.252
1995	54.162	54.598	58.582	65.464	69.281
1996	54.163	54.602	58.602	65.491	69.310
1997	54.164	54.606	58.621	65.519	69.339
1998	54.165	54.610	58.641	65.547	69.369
1999	54.166	54.613	58.660	65.575	69.397
2000	54.167	54.617	58.680	65.603	69.426

Exhibit 5-D

$L_{dn}A$ For Each Case

Option 7

YEAR	SSF	SD	UR	DU	VDU
1976	54.492	55.550	62.527	70.459	74.715
1977	54.500	55.695	62.594	70.544	74.734
1978	54.455	55.562	62.272	70.150	74.478
1979	54.413	55.421	61.846	69.696	73.929
1980	54.369	55.295	61.409	69.175	73.355
1981	54.330	55.161	60.992	68.557	72.764
1982	54.277	54.998	60.340	67.855	71.915
1983	54.232	54.839	59.726	67.051	71.047
1984	54.194	54.710	59.142	66.274	70.137
1985	54.175	54.659	58.892	65.895	69.739
1986	54.170	54.626	58.724	65.671	69.503
1987	54.161	54.595	58.570	65.449	69.269
1988	54.153	54.566	58.429	65.230	69.047
1989	54.154	54.572	58.450	65.274	69.082
1990	54.156	54.576	58.472	65.306	69.116
1991	54.157	54.581	58.495	65.339	69.150
1992	54.158	54.585	58.517	65.371	69.184
1993	54.159	54.590	58.540	65.403	69.218
1994	54.161	54.594	58.563	65.436	69.252
1995	54.162	54.598	58.592	65.454	69.291
1996	54.163	54.602	58.602	65.491	69.310
1997	54.164	54.606	58.621	65.519	69.339
1998	54.165	54.610	58.641	65.547	69.368
1999	54.166	54.613	58.660	65.575	69.397
2000	54.167	54.617	58.680	65.603	69.425

Silent

YEAR	SSF	SD	UR	DU	VDU
1976	54.391	55.322	61.409	68.996	72.837
1977	54.388	55.342	61.473	69.071	72.914
1978	54.343	55.202	61.026	68.539	72.371
1979	54.304	55.076	60.590	68.009	71.829
1980	54.257	54.955	60.147	67.459	71.264
1981	54.235	54.848	59.719	66.910	70.700
1982	54.196	54.716	59.145	66.151	69.914
1983	54.164	54.603	58.603	65.400	69.133
1984	54.136	54.507	58.095	64.660	68.356
1985	54.131	54.487	57.985	64.494	68.191
1986	54.126	54.468	57.877	64.329	68.006
1987	54.121	54.450	57.770	64.164	67.831
1988	54.115	54.432	57.665	63.997	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

ENI and RCI Results For Each Case

Base

	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	0.0	0.0	418350.8	901951.2	300586.8	1620888.0	0.0
1977	0.0	0.0	429985.6	971079.8	306536.6	1707601.0	-5.3
1978	0.0	0.0	384519.7	919891.5	271473.2	1575884.0	2.8
1979	0.0	0.0	376927.3	867673.7	274972.6	1519573.0	6.3
1980	0.0	0.0	318680.1	789614.8	262442.1	1370736.0	15.4
1981	0.0	0.0	263744.9	748061.3	244685.6	1256491.0	22.5
1982	0.0	0.0	272365.2	694496.8	229019.1	1195881.0	26.2
1983	0.0	0.0	224641.6	592881.2	222079.2	1039601.9	35.9
1984	0.0	0.0	176269.9	604281.1	206230.1	986781.1	39.1
1985	0.0	0.0	179293.9	602517.4	204530.4	986341.7	39.1
1986	0.0	0.0	181733.3	599829.6	203019.1	984582.0	39.3
1987	0.0	0.0	183633.8	596322.8	201684.4	981641.1	39.4
1988	0.0	0.0	185052.6	588598.4	200512.4	974163.4	39.9
1989	0.0	0.0	183708.6	596852.1	202604.4	983165.1	39.3
1990	0.0	0.0	182477.5	599647.7	204255.2	986380.5	39.1
1991	0.0	0.0	181065.1	601810.8	205974.3	988850.2	39.0
1992	0.0	0.0	179478.2	603395.2	207755.5	990628.9	38.9
1993	0.0	0.0	177717.2	604434.9	209605.4	991757.6	38.8
1994	0.0	0.0	175789.8	604966.9	211518.7	992275.4	38.8
1995	0.0	0.0	174014.1	605038.1	213199.3	992251.5	38.8
1996	0.0	0.0	172120.9	604778.4	214921.1	991820.4	38.8
1997	0.0	0.0	170113.8	604200.2	216690.9	991004.9	38.9
1998	0.0	0.0	203616.4	603319.2	218500.5	1025436.1	36.7
1999	0.0	0.0	205903.6	602146.1	220357.5	1028407.2	36.6
2000	0.0	0.0	208296.8	600697.4	222257.2	1031251.5	36.4

Exhibit 5-E

ENI and RCI Results for Each Case

Option 1

	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	0.0	0.0	419350.8	901951.2	300586.9	1620888.0	0.0
1977	0.0	0.0	429985.5	971079.8	306536.6	1707601.0	-5.3
1978	0.0	0.0	394519.7	919891.5	271473.2	1575884.0	2.8
1979	0.0	0.0	365778.4	846974.3	272349.7	1485000.0	8.4
1980	0.0	0.0	302592.2	741940.5	242887.9	1287310.0	20.5
1981	0.0	0.0	274176.2	726790.1	228466.5	1229432.0	24.2
1982	0.0	0.0	208299.3	604587.7	190107.8	1002994.8	38.1
1983	0.0	0.0	174910.7	482115.3	156419.5	813445.5	49.8
1984	0.0	0.0	115185.3	412946.9	135228.2	663360.4	59.1
1985	0.0	0.0	118379.2	386411.4	127674.4	632465.1	61.0
1986	0.0	0.0	100644.4	356824.7	115705.6	573255.7	64.6
1987	0.0	0.0	84652.1	323152.9	105610.2	513415.2	68.3
1988	0.0	0.0	63269.4	304515.1	104864.9	472549.3	70.8
1989	0.0	0.0	62008.7	303962.6	105389.6	471361.8	70.9
1990	0.0	0.0	60981.6	303289.9	105677.9	469949.3	71.0
1991	0.0	0.0	59891.0	302404.1	105881.9	468177.0	71.1
1992	0.0	0.0	78586.7	301316.4	106006.7	485909.9	70.0
1993	0.0	0.0	79842.8	300035.2	106057.2	485935.3	70.0
1994	0.0	0.0	81156.2	298562.9	106037.4	485757.5	70.0
1995	0.0	0.0	82322.9	297158.4	105957.9	485459.2	70.0
1996	0.0	0.0	83530.4	295646.5	105852.0	485029.3	70.1
1997	0.0	0.0	84782.3	322690.2	105691.6	513164.2	68.3
1998	0.0	0.0	85075.3	325216.7	105499.1	515792.2	68.1
1999	0.0	0.0	87413.0	327852.6	105245.0	520510.6	67.9
2000	0.0	0.0	88792.4	330595.1	104961.2	524348.6	67.7

Exhibit 5-E

ENI and RCI Results For Each Case

Option 3

	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	0.0	0.0	418350.8	901951.2	300586.8	1620888.0	0.0
1977	0.0	0.0	429955.5	971079.0	306536.5	1707501.0	-5.3
1978	0.0	0.0	384519.7	919891.5	271473.2	1575884.0	2.8
1979	0.0	0.0	376927.3	867673.7	274972.6	1519573.0	6.3
1980	0.0	0.0	218660.1	789614.8	262442.1	1270726.0	15.4
1981	0.0	0.0	263744.9	748061.3	244685.0	1256491.0	22.5
1982	0.0	0.0	255508.4	660430.0	225599.9	1141538.0	29.5
1983	0.0	0.0	173040.0	603014.4	188867.7	964922.2	40.5
1984	0.0	0.0	184817.4	518112.8	176531.0	879461.2	45.7
1985	0.0	0.0	165225.2	483380.1	154939.9	803545.3	50.4
1986	0.0	0.0	146872.9	483351.2	157015.4	787239.6	51.4
1987	0.0	0.0	132582.1	451893.3	147646.6	732122.0	54.8
1988	0.0	0.0	114430.9	418740.1	136235.1	669406.1	58.7
1989	0.0	0.0	112865.7	424281.5	137677.2	674824.4	58.4
1990	0.0	0.0	111559.1	428646.5	138816.9	679022.9	58.1
1991	0.0	0.0	110146.1	433175.0	140005.7	683326.8	57.8
1992	0.0	0.0	108623.2	437879.6	141241.4	687744.2	57.6
1993	0.0	0.0	106995.7	442750.7	142521.7	692268.2	57.3
1994	0.0	0.0	132171.5	447772.2	143849.9	723793.7	55.3
1995	0.0	0.0	133779.7	452189.8	145014.8	730984.4	54.9
1996	0.0	0.0	135455.9	456725.7	146215.3	738397.0	54.4
1997	0.0	0.0	137200.9	461365.9	147447.7	746014.4	54.0
1998	0.0	0.0	139015.0	466126.1	148707.2	753848.3	53.5
1999	0.0	0.0	140894.7	471000.1	150001.9	761896.7	53.0
2000	0.0	0.0	142844.3	475977.5	151327.2	770149.1	52.5

Exhibit 5-E

ENI and RCI Results for Each Case

Option 5

	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	0.0	0.0	418350.9	901951.2	300586.3	1620888.0	0.0
1977	0.0	0.0	429995.6	971079.0	306536.0	1707601.0	-5.3
1978	0.0	0.0	384519.7	919891.5	271473.2	1575884.0	2.8
1979	0.0	0.0	376927.3	867673.7	274972.6	1519573.0	6.3
1980	0.0	0.0	318650.1	799614.8	252442.1	1370735.0	15.4
1981	0.0	0.0	263744.9	748061.3	244685.6	1256491.0	22.5
1982	0.0	0.0	228199.6	596512.2	208593.1	1033305.0	36.3
1983	0.0	0.0	196572.9	524735.7	178023.7	899336.4	45.1
1984	0.0	0.0	107127.7	446936.2	152102.4	706066.4	56.4
1985	0.0	0.0	119182.1	382620.6	128374.4	630177.1	61.1
1986	0.0	0.0	107617.9	375690.3	124011.1	607319.3	62.5
1987	0.0	0.0	96939.1	328992.6	104599.1	520530.7	67.9
1988	0.0	0.0	63269.4	304515.1	104864.7	472649.3	70.8
1989	0.0	0.0	62008.7	303962.6	105389.6	471361.8	70.9
1990	0.0	0.0	60981.6	303289.9	105677.9	469949.3	71.0
1991	0.0	0.0	59891.0	302494.1	105801.9	468177.0	71.1
1992	0.0	0.0	76566.7	301315.4	106005.7	483909.9	70.0
1993	0.0	0.0	79642.8	300035.2	106057.3	485935.3	70.0
1994	0.0	0.0	81156.2	298562.9	106037.4	485757.5	70.0
1995	0.0	0.0	82322.9	297158.4	105957.9	485439.2	70.0
1996	0.0	0.0	83530.4	295646.9	105852.0	485029.3	70.1
1997	0.0	0.0	84782.3	322690.2	105691.6	513164.2	68.3
1998	0.0	0.0	86075.3	325215.7	105489.1	516782.2	68.1
1999	0.0	0.0	87413.0	327852.6	105245.0	520510.6	67.9
2000	0.0	0.0	88792.4	330595.1	104961.2	524348.6	67.7

Exhibit 5-E

ENI and RCI Results For Each Case

Option 7

	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	0.0	0.0	419350.6	901951.2	300586.8	1621888.0	0.0
1977	0.0	0.0	429385.6	971079.8	306535.5	1707001.0	-5.3
1978	0.0	0.0	384519.7	915891.5	271473.2	1571884.0	2.9
1979	0.0	0.0	350596.1	823647.7	265398.7	1439642.0	11.2
1980	0.0	0.0	261878.1	745071.9	228223.6	1235173.0	23.6
1981	0.0	0.0	267629.7	660296.6	212086.4	1140012.0	29.7
1982	0.0	0.0	191184.9	555375.2	182323.4	929883.4	42.5
1983	0.0	0.0	150569.7	492301.0	155699.6	798570.3	51.3
1984	0.0	0.0	119389.0	385950.0	129403.2	634742.2	59.8
1985	0.0	0.0	105182.1	365420.3	117745.7	588348.1	63.7
1986	0.0	0.0	92001.9	337759.4	110943.1	540704.4	66.6
1987	0.0	0.0	81574.6	297909.0	106002.8	485486.4	70.0
1988	0.0	0.0	63265.4	304515.1	104864.7	472645.2	70.8
1989	0.0	0.0	62098.7	303963.6	105299.5	471361.8	70.9
1990	0.0	0.0	50591.5	303299.9	105577.9	459469.3	71.0
1991	0.0	0.0	59891.0	302404.1	105881.9	468177.0	71.1
1992	0.0	0.0	78586.7	301316.4	106006.7	485909.9	70.0
1993	0.0	0.0	79842.8	300035.2	106057.3	485935.3	70.0
1994	0.0	0.0	81156.2	298553.9	106037.4	485747.5	70.0
1995	0.0	0.0	82322.9	297169.4	105967.2	485459.2	70.0
1996	0.0	0.0	83530.4	295645.5	105852.0	485028.3	70.1
1997	0.0	0.0	84782.3	322590.2	105791.5	513164.2	68.3
1998	0.0	0.0	86076.3	325216.7	105489.1	516782.2	69.1
1999	0.0	0.0	87413.0	327852.6	105245.0	520510.6	67.9
2000	0.0	0.0	88792.4	330595.1	104961.2	524348.6	67.7

Exhibit 5-E

ENI and RCI Results For Each Case

Silent

	SSF	SD	UR	DU	VDU	TOTAL	RCI
1976	0.0	0.0	261973.0	735988.8	215192.8	1213054.0	0.0
1977	0.0	0.0	255323.3	743812.8	219517.7	1219054.0	-0.5
1978	0.0	0.0	272431.9	635806.7	193214.0	1101451.0	9.2
1979	0.0	0.0	211324.5	596649.9	177994.5	985959.4	18.7
1980	0.0	0.0	185539.7	475744.5	157175.3	818458.2	32.4
1981	0.0	0.0	149899.3	462566.1	141834.5	754291.9	37.8
1982	0.0	0.0	119389.4	386441.8	123985.9	629817.1	48.1
1983	0.0	0.0	93538.9	300176.5	105770.5	499605.2	59.5
1984	0.0	0.0	68825.8	263127.7	85944.4	417901.9	65.5
1985	0.0	0.0	65894.7	229173.2	86319.1	381386.0	68.5
1986	0.0	0.0	58398.1	235182.4	84992.2	378572.7	68.8
1987	0.0	0.0	51683.8	236736.1	80526.7	368946.6	69.6
1988	0.0	0.0	46310.1	232544.2	76255.7	355110.0	70.7
1989	0.0	0.0	47681.0	234256.5	77231.8	359169.3	70.4
1990	0.0	0.0	48699.8	235263.5	77996.2	361959.5	70.2
1991	0.0	0.0	49790.3	235980.6	78787.6	364558.5	69.9
1992	0.0	0.0	50895.6	236485.4	79604.8	366985.7	69.7
1993	0.0	0.0	52046.2	236751.0	80445.1	369253.3	69.5
1994	0.0	0.0	53231.2	236829.4	81314.2	371374.7	69.4
1995	0.0	0.0	54269.5	236731.6	82072.7	373073.8	69.2
1996	0.0	0.0	55333.4	236496.1	82850.7	374680.2	69.1
1997	0.0	0.0	56422.9	236125.7	83646.4	376198.5	69.0
1998	0.0	0.0	57537.7	235636.9	84460.1	377634.6	68.9
1999	0.0	0.0	58679.9	235013.8	85085.3	378796.0	68.8
2000	0.0	0.0	59849.5	234285.5	85429.1	379564.6	68.7

Exhibit 5-F

SEL For Each Case

BASE

Year	SSF	SD	UR	DU	VDU
1976	98.88	98.85	102.82	104.59	105.23
1977	98.88	98.85	102.83	104.59	105.23
1978	98.33	98.30	102.32	104.09	104.77
1979	97.82	97.79	101.84	103.63	104.35
1980	97.34	97.31	101.39	103.20	103.97
1981	96.91	96.87	100.99	102.80	103.62
1982	96.31	96.28	100.44	102.27	103.15
1983	95.80	95.76	99.96	101.81	102.75
1984	95.36	95.32	99.56	101.43	102.41
1985	95.13	95.09	99.35	101.22	102.23
1986	94.92	94.87	99.15	101.03	102.07
1987	94.73	94.68	98.98	100.86	101.92
1988	94.55	94.50	98.82	100.71	101.79
1989	94.48	94.43	98.75	100.65	101.74
1990	94.41	94.36	98.69	100.59	101.68
1991	94.35	94.30	98.63	100.53	101.63
1992	94.35	94.30	98.63	100.53	101.63
1993	94.35	94.30	98.63	100.53	101.63
1994	94.35	94.30	98.63	100.53	101.63
1995	94.35	94.30	98.63	100.53	101.63
1996	94.35	94.30	98.63	100.53	101.63
1997	94.35	94.30	98.63	100.53	101.63
1998	94.35	94.30	98.63	100.53	101.63
1999	94.35	94.30	98.63	100.53	101.63
2000	94.35	94.30	98.63	100.53	101.63

OPTION 1

Year	SSF	SD	UR	DU	VDU
1976	98.88	98.85	102.83	104.59	105.23
1977	98.88	98.85	102.83	104.59	105.23
1978	98.33	98.30	102.32	104.09	104.77
1979	97.74	97.71	101.67	103.46	104.09
1980	97.17	97.15	101.10	102.84	103.43
1981	96.64	96.62	100.53	102.26	102.79
1982	95.63	95.61	99.46	101.18	101.63
1983	94.64	94.62	98.43	100.12	100.51
1984	93.69	93.68	97.43	99.11	99.42
1985	92.57	92.55	96.57	98.22	98.55
1986	92.33	92.33	96.03	97.68	97.92
1987	91.71	91.70	95.40	97.05	97.28
1988	91.03	91.01	94.79	96.43	96.55
1989	90.85	90.84	94.64	96.27	96.52
1990	90.81	90.80	94.51	96.16	96.40
1991	90.69	90.67	94.39	96.03	96.29
1992	90.69	90.67	94.39	96.03	96.29
1993	90.68	90.67	94.39	96.03	96.28
1994	90.68	90.67	94.39	96.03	96.29
1995	90.68	90.67	94.39	96.03	96.29
1996	90.68	90.67	94.39	96.03	96.28
1997	90.69	90.67	94.39	96.03	96.29
1998	90.69	90.67	94.39	96.03	96.28
1999	90.69	90.67	94.39	96.03	96.29
2000	90.69	90.67	94.39	96.03	96.29

Exhibit 5-F

SEL for each case

Option 3

Year	SSF	SD	UR	DU	VDU
1976	98.88	98.85	102.83	104.59	105.23
1977	98.88	98.85	102.83	104.59	105.23
1978	98.33	98.30	102.32	104.09	104.77
1979	97.82	97.79	101.84	103.63	104.35
1980	97.34	97.31	101.39	103.20	103.97
1981	96.91	96.87	100.99	102.80	103.62
1982	96.15	96.11	100.20	102.00	102.76
1983	95.45	95.42	99.46	101.24	101.95
1984	94.81	94.78	98.70	100.54	101.19
1985	94.28	94.26	98.29	100.03	100.59
1986	93.96	93.94	97.82	99.53	100.01
1987	93.56	93.55	97.36	99.05	99.44
1988	93.17	93.16	96.92	98.58	98.89
1989	93.09	93.08	96.83	98.50	98.81
1990	93.00	92.99	96.75	98.42	98.73
1991	92.92	92.91	96.67	98.34	98.66
1992	92.92	92.91	96.67	98.34	98.66
1993	92.92	92.91	96.67	98.34	98.66
1994	92.92	92.91	96.67	98.34	98.66
1995	92.92	92.91	96.67	98.34	98.66
1996	92.92	92.91	96.67	98.34	98.66
1997	92.92	92.91	96.67	98.34	98.66
1998	92.92	92.91	96.67	98.34	98.66
1999	92.92	92.91	96.67	98.34	98.66
2000	92.92	92.91	96.67	98.34	98.66

Option 5

Year	SSF	SD	UR	DU	VDU
1976	90.88	98.85	102.83	104.59	105.[illegible]
1977	90.88	90.85	102.83	104.59	105.[illegible]
1978	98.33	98.30	102.32	104.09	104.[illegible]
1979	97.82	97.79	101.84	103.63	104.[illegible]
1980	97.34	97.31	101.39	103.20	103.[illegible]
1981	96.91	96.87	100.99	102.80	103.[illegible]
1982	95.88	95.85	99.91	101.70	102.[illegible]
1983	94.89	94.86	98.86	100.63	101.[illegible]
1984	93.93	93.91	97.85	99.60	100.[illegible]
1985	93.20	93.18	97.05	98.77	99.[illegible]
1986	92.48	92.46	96.27	97.97	98.[illegible]
1987	91.77	91.76	95.51	97.18	97.[illegible]
1988	91.09	91.08	94.78	96.43	96.[illegible]
1989	90.95	90.94	94.64	96.29	96.[illegible]
1990	90.81	90.80	94.51	96.16	96.[illegible]
1991	90.68	90.67	94.38	96.03	96.[illegible]
1992	90.68	90.67	94.38	96.03	96.[illegible]
1993	90.68	90.67	94.38	96.03	96.[illegible]
1994	90.68	90.67	94.38	96.03	96.[illegible]
1995	90.68	90.67	94.38	96.03	96.[illegible]
1996	90.68	90.67	94.38	96.03	96.[illegible]
1997	90.68	90.67	94.38	96.03	96.[illegible]
1998	90.68	90.67	94.38	96.03	96.[illegible]
1999	90.68	90.67	94.38	96.03	96.[illegible]
2000	90.68	90.67	94.38	96.03	96.[illegible]

Exhibit 5-F

SEL For Each Case

Option 7

Year	SSF	SD	UR	DU	VDU
1976	98.86	98.85	102.93	104.59	105.23
1977	98.86	98.85	102.83	104.59	105.23
1978	98.33	98.30	102.32	104.09	104.77
1979	97.64	97.61	101.59	103.34	103.96
1980	96.96	96.94	100.96	102.60	103.16
1981	96.30	96.29	100.17	101.89	102.38
1982	95.28	95.26	99.09	100.80	101.22
1983	94.29	94.27	98.05	99.74	100.18
1984	93.32	93.31	97.05	98.72	99.01
1985	92.52	92.51	96.30	97.95	98.17
1986	92.10	92.09	95.79	97.43	97.66
1987	91.59	91.58	95.28	96.93	97.15
1988	91.09	91.08	94.79	96.43	96.66
1989	90.95	90.94	94.64	96.29	96.52
1990	90.81	90.80	94.51	96.15	96.40
1991	90.68	90.67	94.39	96.03	96.28
1992	90.68	90.67	94.38	96.03	96.28
1993	90.68	90.67	94.39	96.03	96.28
1994	90.68	90.67	94.39	96.03	96.28
1995	90.68	90.67	94.38	96.03	96.28
1996	90.68	90.67	94.39	96.03	96.28
1997	90.68	90.67	94.39	96.03	96.28
1998	90.68	90.67	94.38	96.03	96.28
1999	90.68	90.67	94.39	96.03	96.28
2000	90.68	90.67	94.39	96.03	96.28

Silent

Year	SSF	SD	UR	DU	VDU
1976	97.25	97.25	100.84	102.45	102.5
1977	97.25	97.25	100.84	102.45	102.5
1978	96.45	96.45	100.05	101.65	101.7
1979	95.68	95.68	99.29	100.89	100.9
1980	94.92	94.92	98.51	100.12	100.2
1981	94.17	94.17	97.77	99.37	99.4
1982	93.07	93.07	96.67	98.27	98.3
1983	92.01	92.01	95.61	97.22	97.3
1984	91.01	91.01	94.61	96.21	96.3
1985	90.42	90.42	94.02	95.62	95.7
1986	89.84	89.84	93.44	95.05	95.1
1987	89.27	89.27	92.87	94.48	94.5
1988	88.72	88.72	92.32	93.93	94.0
1989	88.49	88.49	92.08	93.69	93.7
1990	88.25	88.25	91.85	93.45	93.5
1991	88.01	88.01	91.61	93.22	93.3
1992	88.01	88.01	91.61	93.22	93.3
1993	88.01	88.01	91.61	93.22	93.3
1994	88.01	88.01	91.61	93.22	93.3
1995	88.01	88.01	91.61	93.22	93.3
1996	88.01	88.01	91.61	93.22	93.3
1997	88.01	88.01	91.61	93.22	93.3
1998	88.01	88.01	91.61	93.22	93.3
1999	88.01	88.01	91.61	93.22	93.3
2000	88.01	88.01	91.61	93.22	93.3

Exhibit 5-G

Sleep Disruption

Base

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RCI
1976	1022262.06	2070597.00	12852092.0	14434003.0	3695528.00	34074464.0	0.0
1977	1040758.37	2107953.00	13075998.0	14640425.0	3735261.00	34600368.0	-1.54
1978	933799.12	1890094.00	11917510.0	13607555.0	3504942.00	31853872.0	6.52
1979	844592.50	1708606.00	10942364.0	12723070.0	3306841.00	29525456.0	13.35
1980	765956.37	1548676.00	10067214.0	11914748.0	3126662.00	27423248.0	19.52
1981	700608.25	1415771.00	9333212.00	11226018.0	2972396.00	25647984.0	24.73
1982	618181.25	1248350.00	8391655.00	10325654.0	2771032.00	23354864.0	31.46
1983	555701.56	1121410.00	7669313.00	9621567.00	2612488.00	21580464.0	36.67
1984	508311.75	1025202.06	7116566.00	9074562.00	2488594.00	20213232.0	40.68
1985	486810.37	981403.69	6866524.00	8825349.00	2431314.00	19591392.0	42.50
1986	468412.06	944022.87	6652679.00	8610933.00	2381850.00	19057888.0	44.07
1987	452753.75	912188.81	6471231.00	8427958.00	2339409.00	18603536.0	45.40
1988	439483.00	885187.37	6317367.00	8272295.00	2303169.00	18217488.0	46.54
1989	436842.50	879764.31	6292682.00	8248716.00	2296519.00	18154512.0	46.72
1990	433377.94	872673.75	6255964.00	8212180.00	2287301.00	18061488.0	46.99
1991	430248.31	866259.87	6223161.00	8179705.00	2279021.00	17970384.0	47.24
1992	433724.62	873250.44	6271394.00	8230376.00	2289289.00	18098032.0	46.89
1993	437227.44	880295.12	6319988.00	8281263.00	2299560.00	18218320.0	46.53
1994	440770.87	887394.94	6368936.00	8332369.00	2309845.00	18339312.0	46.18
1995	443819.69	893495.81	6410942.00	8376098.00	2318617.00	18442960.0	45.87
1996	446881.00	899631.12	6453213.00	8419988.00	2327398.00	18547104.0	45.57
1997	449958.31	905814.94	6495752.00	8464038.00	2336186.00	18651744.0	45.26
1998	453060.19	912037.69	6538557.00	8508239.00	2344981.00	18756864.0	44.95
1999	456187.87	918304.50	6581624.00	8552603.00	2353777.00	18862496.0	44.64
2000	459334.31	924613.50	6624970.00	8597118.00	2362584.00	18968608.0	44.33

Exhibit 5-G

Sleep Disruption

Option 1

YEAR	SUBURBAN SINGLE-FAMILY OFTACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RCI
1976	1022262.06	2070597.00	12852092.0	14434003.0	3695520.00	34074464.0	0.0
1977	1040759.37	2107953.00	13075998.0	14540425.0	3735261.00	34600369.0	-1.54
1978	933799.12	1990094.00	11917510.0	13607555.0	3504942.00	31853872.0	6.52
1979	828592.62	1678000.00	10604747.0	12343035.0	3164984.00	28519344.0	16.01
1980	735274.75	1491832.00	9441220.00	11198453.0	2859432.00	25727200.0	24.50
1981	659128.44	1336268.00	8458737.00	10209571.0	2593812.00	23257520.0	31.75
1982	527016.12	1069295.00	6808053.00	8520505.00	2159457.00	19084320.0	43.99
1983	424252.12	861628.75	5513687.00	7146240.00	1806375.00	15752282.0	53.77
1984	344256.00	695559.69	4496273.00	6026869.00	1519160.00	13086117.0	61.60
1985	294575.19	599040.44	3849455.00	5286085.00	1324719.00	11352895.0	66.68
1986	256618.06	521864.19	3364647.00	4758217.00	1197808.00	10119154.0	70.30
1987	223967.62	455470.62	2981396.00	4287750.00	1084227.00	9032811.00	73.49
1988	195843.37	398274.87	2630709.00	3859039.00	982633.75	8076499.00	76.30
1989	191557.19	389596.37	2579499.00	3807857.00	967175.06	7935713.00	76.71
1990	187105.81	380452.62	2525319.00	3742866.00	951205.37	7785749.00	77.15
1991	182922.25	371918.37	2474703.00	3681927.00	936188.31	7647558.00	77.56
1992	184400.00	374720.44	2493921.00	3704892.00	940476.06	7698609.00	77.41
1993	185889.19	377945.19	2513281.00	3728050.00	944758.05	7749943.00	77.25
1994	187396.06	380993.31	2532784.00	3751330.00	949064.50	7801567.00	77.10
1995	188651.94	383613.25	2549524.00	3771247.00	952730.12	7845806.00	76.97
1996	189994.12	386247.37	2566367.00	3791234.00	956379.75	7890240.00	76.84
1997	191202.00	388903.00	2583319.00	3811295.00	960070.31	7934889.00	76.71
1998	192621.06	391574.69	2600376.00	3831429.00	963744.75	7979744.00	76.58
1999	193950.75	394265.31	2617541.00	3851637.00	967421.81	8024815.00	76.45
2000	195289.62	396974.06	2634815.00	3871919.00	971101.50	8070097.00	76.32

Exhibit 5-G

Sleep Disruption

Option 3

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN FOR APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	KC
1976	1022262.06	2070597.00	12852092.0	14434003.0	3695528.00	34074464.0	0.
1977	1040758.37	2107353.00	13075999.0	14640425.0	3735251.00	34600358.0	-1.
1978	933799.12	1890094.00	11917510.0	13607555.0	3504942.00	31853372.0	6.
1979	844592.50	1708600.00	10942364.0	12723070.0	3306041.00	29525455.0	13.
1980	765956.37	1548576.00	10067214.0	11914748.0	3126662.00	27423243.0	19.
1981	700608.25	1415771.00	9332212.00	11226018.0	2972396.00	25647994.0	24.
1982	594848.62	1202749.00	7566776.00	9840839.00	2600477.00	22205595.0	34.
1983	512193.06	1036210.37	6880670.00	9705350.00	2291709.00	19426304.0	42.
1984	447066.81	905136.75	6011642.00	7770494.00	2034611.00	17160944.0	49.
1985	408782.94	828295.31	5466735.00	7159145.00	1855295.00	15718244.0	53.
1986	375041.94	760625.37	4586752.00	6612151.00	1695473.00	14430053.0	57.
1987	345251.81	700863.12	4562607.00	6121897.00	1552973.00	13283591.0	61.
1988	318930.75	648011.91	4108186.00	5582505.00	1425871.00	12263605.0	64.0
1989	315835.12	641680.19	4154269.00	5645593.00	1415737.00	12173114.0	64.2
1990	312219.12	634329.94	4113410.00	5600883.00	1404364.00	12065206.0	64.5
1991	308930.12	627557.06	4076151.00	5559528.00	1393874.00	11966442.0	64.9
1992	311425.54	632623.87	4107765.00	5594535.00	1400203.00	12046552.0	64.6
1993	313941.19	637726.87	4139622.00	5629290.00	1406535.00	12127115.0	64.4
1994	316465.81	642869.94	4171704.00	5664194.00	1412873.00	12208126.0	64.1
1995	318674.31	647291.00	4199246.00	5694067.00	1418281.00	12277559.0	63.9
1996	320873.37	651734.69	4226955.00	5724049.00	1423691.00	12347303.0	63.7
1997	323082.31	656215.81	4254841.00	5754134.00	1429110.00	12417383.0	63.5
1998	325310.06	660725.44	4282857.00	5784331.00	1434529.00	12487792.0	63.3
1999	327555.69	665263.94	4311130.00	5814635.00	1439954.00	12558537.0	63.1
2000	329815.19	669835.06	4339553.00	5845050.00	1445382.00	12629535.0	62.9

Exhibit 5-G

Sleep Disruption

Option 5

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RCI
1976	1022262.05	2070597.00	12852092.0	14434003.0	3575525.00	34074454.0	0.
1977	1040758.37	2107952.00	13075958.0	14640425.0	3735261.00	34600363.0	-1.
1978	923755.12	1890094.00	11917510.0	13607555.0	3504942.00	31855872.0	6.
1979	844592.50	1709505.00	10942354.0	12722070.0	3206841.00	29525456.0	13.
1980	765956.37	1545676.00	10067214.0	11914748.0	3126662.00	27423248.0	19.
1981	700606.25	1415771.00	9332212.00	11226018.0	2972325.00	25547994.0	24.
1982	559533.05	1131724.00	7494617.00	9347460.00	2465756.00	20999056.0	38.
1983	449861.87	910686.44	6052744.00	7818293.00	2053740.00	17285312.0	49.
1984	364279.56	738120.62	4919262.00	6571951.00	1718473.00	14312095.0	58.
1985	310468.81	627693.69	4182371.00	5727296.00	1494431.00	12334260.0	63.
1986	265368.67	539760.00	3560732.00	5006926.00	1267508.00	10667294.0	68.
1987	227565.87	462425.25	3057213.00	4392521.00	1121985.00	9261609.00	72.
1988	155843.27	399274.87	2630709.00	3969039.00	992633.72	8076493.00	76.
1989	191567.19	389596.37	2579498.00	3807557.00	957175.05	7935713.00	75.
1990	187105.81	390452.62	2525315.00	3742566.00	951206.57	7786949.00	77.
1991	182922.25	371918.37	2474703.00	3681827.00	936133.31	7647553.00	77.
1992	184400.00	374920.44	2493921.00	3704492.00	940476.05	7698503.00	77.
1993	185889.19	377945.19	2512281.00	3728060.00	944769.06	7749943.00	77.
1994	187396.06	380993.31	2532784.00	3751330.00	949064.50	7801567.00	77.
1995	188591.94	383513.25	2549524.00	3771247.00	952730.12	7945905.00	75.
1996	189994.12	386247.37	2566367.00	3791234.00	956399.75	7370243.00	76.
1997	191202.00	388905.00	2583319.00	3811295.00	960070.31	7934999.00	76.
1998	192621.05	391574.59	2600375.00	3831429.00	963744.75	7979744.00	76.
1999	193550.75	394265.31	2617541.00	3851637.00	967421.51	8024315.00	76.
2000	195288.62	396974.06	2634815.00	3871919.00	971101.50	9070077.00	75.

Exhibit 5-G

Sleep Disruption

Option 7

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN 2C+ APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	PC
1976	1022262.06	2070597.00	12852092.0	14434003.0	3675928.00	34074604.0	0.
1977	1040758.37	2107953.00	13075792.0	14640475.0	3735261.00	34600368.0	-1.
1978	933799.12	1890094.00	11917510.0	13507555.0	3504942.00	31853872.0	5.
1979	809775.81	1640188.00	10357676.0	12099314.0	3077759.00	28003704.0	17.
1980	701045.06	1420909.00	8984858.00	10738672.0	2735206.00	24581664.0	27.
1981	609479.81	1236137.00	7823357.00	9550911.00	2425579.00	21653456.0	36.
1982	485551.75	986422.25	6284993.00	7969999.00	2017066.00	17743360.0	47.
1983	350355.50	792931.75	5082512.00	6676795.00	1697247.00	14530091.0	57.
1984	316105.62	642517.69	4140221.00	5627690.00	1419493.00	12146025.0	64.3
1985	271115.00	551552.50	3554940.00	4950119.00	1242399.00	10570174.0	68.9
1986	242813.44	493850.05	3210155.00	4553510.00	1147529.00	9547758.00	71.5
1987	217856.25	443069.25	2903258.00	4194662.00	1061189.00	8820035.00	74.1
1988	195843.37	390274.87	2630705.00	3869039.00	982033.75	9076499.00	75.3
1989	191587.19	385595.37	2579479.00	3907857.00	957175.05	7935713.00	76.7
1990	187105.81	380452.62	2525315.00	3742866.00	951206.37	7796749.00	77.1
1991	182922.25	371918.37	2474703.00	3681827.00	936189.31	7647558.00	77.5
1992	184400.00	374920.44	2493921.00	3704892.00	940476.06	7699509.00	77.4
1993	188889.19	377945.19	2513281.00	3729060.00	944769.06	7749943.00	77.2
1994	187356.06	380993.31	2532784.00	3751330.00	949054.50	7801557.00	77.1
1995	188691.94	383613.75	2549524.00	3771247.00	952730.12	7845906.00	76.9
1996	189994.12	386247.37	2566367.00	3791234.00	956398.75	7890240.00	76.8
1997	191202.00	388703.00	2583319.00	3911295.00	960070.31	7934899.00	75.7
1998	192621.06	391574.69	2600376.00	3831429.00	963744.75	7979744.00	76.5
1999	193950.75	394265.31	2617541.00	3851637.00	967421.01	8024315.00	76.4
2000	195298.62	396974.06	2634815.00	3871919.00	971101.50	8071397.00	76.3

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Exhibit 5-G

Sleep Disruption

Silent

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RCI
1976	701423.31	1429320.00	8389582.00	9917381.00	2378900.00	22816592.0	0.0
1977	714113.55	1455108.00	9335795.00	10059604.0	2404592.00	23167216.0	-1.5
1978	605624.06	1233911.00	7331073.00	9385420.00	2134102.00	20190112.0	11.5
1979	514877.81	1049018.00	6210842.00	7851873.00	1897209.00	17533808.0	22.7
1980	436522.94	885364.00	5416814.00	6939305.00	1694175.00	15565890.0	32.6
1981	371340.37	756511.37	4663454.00	6139151.00	1498469.00	13428925.0	41.1
1982	291075.59	592915.50	3719501.00	5102087.00	1257306.00	10952935.0	51.9
1983	230241.50	469066.94	2991746.00	4268765.00	1061727.00	9021546.00	60.4
1984	184151.31	375183.94	2430054.00	3599944.00	903363.69	7492676.00	67.1
1985	162109.75	330242.37	2157442.00	3265590.00	823185.50	6739559.00	70.4
1986	143057.62	291479.81	1919941.00	2967303.00	751401.75	6073132.00	73.3
1987	126579.94	257860.31	1712883.00	2701795.00	687173.37	5486291.00	73.9
1988	112359.75	228984.31	1521833.00	2465455.00	629724.31	4969256.00	78.2
1989	107278.50	218534.19	1467103.00	2379503.00	609208.75	4780626.00	79.0
1990	102211.37	208206.00	1402505.00	2292567.00	595712.62	4592201.00	79.8
1991	97437.81	198479.31	1341051.00	2209741.00	566194.25	4412903.00	80.6
1992	98225.00	200081.56	1351495.00	2223731.00	568830.56	4442352.00	80.5
1993	99018.25	201695.00	1361955.00	2237785.00	571469.81	4471954.00	80.4
1994	99820.87	203322.87	1372585.00	2251900.00	574112.19	4501740.00	80.2
1995	100511.25	204721.19	1381674.00	2263982.00	576366.44	4527254.00	80.1
1996	101204.87	206127.19	1390819.00	2276110.00	578622.81	4552882.00	80.0
1997	101901.50	207544.62	1400024.00	2288294.00	580881.06	4578635.00	79.9
1998	102604.12	208970.69	1409285.00	2300503.00	583141.25	4604503.00	79.8
1999	103312.44	210405.94	1418606.00	2312766.00	585403.37	4630494.00	79.7
2000	104025.06	211852.87	1427986.00	2325077.00	587667.00	4656007.00	79.5

Exhibit 5-H

Sleep Awakening

Base

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBRBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RC
1976	893691.31	1810972.00	11283769.0	12949207.0	3405434.00	30343056.0	0.
1977	909907.44	1843657.00	11481362.0	13139761.0	3444061.00	30818720.0	-1.
1978	816341.12	1653171.00	10465176.0	12217213.0	3233434.00	28385312.0	6.
1979	738406.19	1494461.00	9609839.00	11427367.0	3052333.00	26322384.0	13.
1980	669650.81	1354609.00	8841891.00	10703900.0	2887052.00	24457088.0	19.
1981	612532.94	1238389.00	8197804.00	10087608.0	2745595.00	22881904.0	24.
1982	540502.31	1091973.00	7371342.00	9280630.00	2560471.00	20844896.0	31.
1983	485900.37	980966.25	6737313.00	8649833.00	2414827.00	19268816.0	36.
1984	444469.62	896829.81	6252230.00	8160020.00	2301126.00	18054672.0	40.
1985	425644.62	858523.69	6032914.00	7937730.00	2248906.00	17503712.0	42.
1986	409600.31	825838.81	5845405.00	7746672.00	2203885.00	17031392.0	43.
1987	395895.94	798000.31	5686309.00	7583873.00	2165346.00	16629424.0	45.
1988	384301.81	774395.06	5551457.00	7445569.00	2132519.00	16288241.0	46.
1989	381994.31	769655.37	5530104.00	7426216.00	2127105.00	16235074.0	46.
1990	378964.00	763458.94	5498070.00	7394718.00	2119124.00	16154334.0	46.
1991	376220.12	757855.19	5469503.00	7366870.00	2112005.00	16082453.0	47.
1992	379253.19	763971.62	5512141.00	7413986.00	2122088.00	16191439.0	46.
1993	382351.37	770138.75	5555093.00	7461319.00	2132186.00	16301088.0	46.2
1994	385434.31	776353.00	5598367.00	7508872.00	2142298.00	16411324.0	45.9
1995	388082.12	781691.56	5635511.00	7549581.00	2150933.00	16505798.0	45.6
1996	390785.25	787067.94	5672904.00	7590450.00	2159572.00	16600779.0	45.2
1997	393452.87	792477.62	5710510.00	7631480.00	2168227.00	16696147.0	44.9
1998	396172.37	797925.06	5748374.00	7672670.00	2176893.00	16792032.0	44.6
1999	398917.00	803411.06	5786465.00	7714018.00	2185565.00	16888368.0	44.3
2000	401658.00	808936.00	5824805.00	7755528.00	2194245.00	16985168.0	44.0

Exhibit 5-H

Sleep Awakening

Option 1

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RCI
1976	893691.31	1810972.00	11283769.0	12949207.0	3405434.00	30343035.0	0.0
1977	909907.44	1843657.00	11481262.0	13139761.0	3444061.00	30818720.0	-1.5
1978	816341.12	1653171.00	10465176.0	12217213.0	3233434.00	28385312.0	6.4
1979	724420.62	1467695.00	9213342.00	11085824.0	2921302.00	25512575.0	15.9
1980	643705.44	1304895.00	8292145.00	10060012.0	2640128.00	22940880.0	24.3
1981	576292.06	1168859.00	7429803.00	9173650.00	2395639.00	20744224.0	31.6
1982	460808.31	935372.55	5980444.00	7557104.00	1994734.00	17028555.0	43.8
1983	371072.37	752761.50	4542873.00	6422960.00	1669101.00	14060767.0	53.6
1984	301045.52	612014.44	3950436.00	5417559.00	1403974.00	11685009.0	61.4
1985	257594.81	524095.81	3381553.00	4752185.00	1224459.00	10139897.0	66.5
1986	224423.31	456599.62	2974232.00	4278198.00	1107384.00	9040836.00	70.2
1987	195878.87	398527.87	2620083.00	3855626.00	1002554.50	8072569.00	73.4
1988	171293.37	345504.31	2312078.00	3479517.00	900771.50	7220163.00	76.2
1989	167572.00	340911.87	2267205.00	3425255.00	894762.00	7095709.00	76.62
1990	163653.19	332916.44	2219694.00	3357331.00	880192.55	6953735.00	77.03
1991	159992.50	325453.62	2175305.00	3312951.00	866497.55	6840203.00	77.46
1992	161282.19	328080.56	2192294.00	3334357.00	870704.61	6886717.00	77.30
1993	162599.87	330729.55	2209405.00	3355855.00	874918.44	6933519.00	77.15
1994	163910.94	333399.75	2226047.00	3377476.00	879135.81	6980570.00	76.99
1995	165036.81	335691.37	2241445.00	3395975.00	882740.94	7020889.00	76.86
1996	166188.55	338030.05	2256338.00	3414553.00	885347.87	7061424.00	76.73
1997	167320.94	340323.75	2271326.00	3433205.00	889959.37	7102134.00	76.59
1998	168477.37	342663.19	2286409.00	3451928.00	893574.94	7143051.00	76.45
1999	169644.62	345019.59	2301588.00	3470730.00	897194.87	7184176.00	76.32
2000	170810.31	347392.12	2316965.00	3489603.00	900819.12	7225489.00	76.19

Exhibit 5-H

Sleep Awakening

Option 3

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	P.C.
1976	853691.31	1910972.00	11283759.0	12949207.0	3405434.00	30343056.0	0.(
1977	909907.44	1843657.00	11481352.0	13139751.0	3444051.00	30813720.0	-1.5
1978	816341.12	1653171.00	10465176.0	12217213.0	3233434.00	28385312.0	6.4
1979	738406.19	1494461.00	9609839.00	11427367.0	3052333.00	26322384.0	13.2
1980	559550.91	1354509.00	8841891.00	10703900.0	2837052.00	24457098.0	19.4
1981	612532.94	1238389.00	8157804.00	10087609.0	2745595.00	22891904.0	24.5
1982	520166.12	1052091.00	6998179.00	8844615.00	2402780.00	19817744.0	34.6
1983	447854.55	906451.31	6044615.00	7825549.00	2110256.00	17342720.0	42.8
1984	390928.87	791813.69	5281619.00	6996515.00	1890983.00	15331963.0	49.4
1985	357433.54	724612.12	4803211.00	6437959.00	1715533.00	14038858.0	53.7
1986	327968.87	665442.87	4281785.00	5947159.00	1569234.00	12890569.0	57.5
1987	301913.62	613166.00	4009385.00	5507133.00	1436778.00	11868375.0	60.8
1988	278907.75	555948.64	3580529.00	5112859.00	1319495.00	10958940.0	63.8
1989	276202.37	561412.19	3651040.00	5080793.00	1310569.00	10880016.0	64.1
1990	273029.54	554986.50	3615301.00	5041462.00	1300370.00	10785159.0	54.4
1991	270158.19	549067.87	3582717.00	5005503.00	1290988.00	10699434.0	64.7
1992	272336.00	553498.94	3610665.00	5037658.00	1297200.00	10771357.0	64.50
1993	274560.54	557968.19	3638817.00	5069957.00	1303419.00	10844722.0	54.2
1994	276774.69	562470.81	3667184.00	5102412.00	1309650.00	10918491.0	64.02
1995	278676.00	566338.12	3691532.00	5130197.00	1314970.00	10981713.0	63.81
1996	280617.19	570233.25	3716030.00	5158092.00	1320293.00	11045265.0	53.50
1997	282532.75	574152.67	3740692.00	5186093.00	1325626.00	11109096.0	63.39
1998	284465.56	578099.12	3765505.00	5214210.00	1330960.00	11173259.0	63.18
1999	286455.37	582075.75	3790475.00	5242435.00	1335304.00	11237747.0	62.96
2000	288424.69	586077.87	3815609.00	5270770.00	1341654.00	11302535.0	62.75

Exhibit 5-H

Sleep Awakening

Option 5

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	PCT
1976	893591.31	1910972.00	11283755.0	12947207.0	3405434.00	30343056.0	0.0
1977	909907.44	1942657.00	11481362.0	13139761.0	3444961.00	30918720.0	-1.9
1978	816241.12	1633171.00	10465176.0	12217213.0	3233434.00	28395312.0	6.4
1979	738405.19	1494451.00	9605839.00	11427467.0	3052322.00	26322534.0	13.2
1980	669650.91	1354609.00	8641991.00	10703900.0	2897052.00	24457099.0	19.4
1981	612532.54	1238399.00	8197804.00	10037609.0	2745575.00	22831934.0	24.5
1982	489232.25	939770.69	6583469.00	9400861.00	2278155.00	13741680.0	38.2
1983	393374.44	776667.19	5317372.00	7027543.00	1897931.00	15432887.0	49.1
1984	318550.67	643740.47	4322012.00	5908020.00	1589416.00	12732737.0	57.9
1985	271489.06	550909.12	3674895.00	5149277.00	1372516.00	11018932.0	63.6
1986	232094.12	471377.12	3135972.00	4502077.00	1170441.00	9531951.00	68.5
1987	199024.75	404509.81	2585558.00	3949961.00	1037435.25	9277729.00	72.7
1988	171293.37	349504.21	2312079.00	3479517.00	909771.50	7220163.00	76.2
1989	167572.00	340911.87	2267209.00	3422255.00	894762.00	7095707.00	75.5
1990	163653.19	332916.44	2219574.00	3367531.00	890192.55	6963796.00	77.0
1991	159592.50	325453.62	2175309.00	3312951.00	866497.56	6940293.00	77.4
1992	161282.19	329080.56	2192294.00	3334357.00	970704.91	6989717.00	77.3
1993	162599.87	330729.56	2209406.00	3355866.00	974913.44	6933519.00	77.1
1994	163910.94	333398.75	2226047.00	3377476.00	879158.61	6990370.00	76.9
1995	165036.81	335591.37	2241445.00	3395976.00	892740.94	7020939.00	75.8
1996	166186.56	338000.06	2256338.00	3414553.00	836347.87	7061424.00	76.7
1997	167320.94	340323.75	2271326.00	3433205.00	839759.37	7102134.00	76.5
1998	168477.37	342553.19	2286405.00	3451928.00	993574.94	7143091.00	76.4
1999	169644.62	345019.69	2301598.00	3470730.00	597194.87	7183176.00	76.3
2000	170810.21	347392.12	2316865.00	3485603.00	900819.12	7225437.00	75.1

Exhibit 5-H

Sleep Awakening

Option 7

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN 3C APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	PCI
1976	893691.31	1810772.00	11283769.0	12949207.0	3405434.00	30343056.0	0.0
1977	909907.44	1843657.00	11481362.0	13139761.0	3444061.00	30818720.0	-1.57
1978	816341.12	1553171.00	10455175.0	12217213.0	3233434.00	28385312.0	6.45
1979	707571.67	1434626.00	9096252.00	10869932.0	2959397.00	24764272.0	17.73
1980	612910.44	1242968.00	7891355.00	9646705.00	2526252.00	21920090.0	27.75
1981	532874.81	1091285.00	6971765.00	8570434.00	2238303.00	19314540.0	36.35
1982	424947.06	962994.06	5521026.00	7161024.00	1863264.00	15533155.0	47.82
1983	341365.12	693676.25	4469128.00	6000866.00	1559995.00	13059750.0	56.96
1984	276435.31	562124.50	3637667.00	5059391.00	1211739.00	10946256.0	64.25
1985	237137.50	492561.00	3123678.00	4449852.00	1148253.00	9441436.00	68.88
1986	212363.61	432096.50	2820930.00	4094003.00	1050921.00	8520214.00	71.59
1987	190535.87	387681.56	2551427.00	3771952.00	981213.62	7492799.00	74.02
1988	171273.37	349504.21	2312078.00	3479517.00	509771.50	7220163.00	75.20
1989	167572.00	340911.87	2257205.00	3425255.00	974752.00	7075709.00	76.62
1990	163653.19	322916.44	2219694.00	3367331.00	890192.55	6963786.00	77.05
1991	159992.50	325453.62	2179505.00	3312951.00	866497.56	6840203.00	77.45
1992	161292.17	328090.55	2192294.00	3334257.00	870704.81	6886717.00	77.30
1993	162599.87	330729.56	2209406.00	3355966.00	874919.44	6933919.00	77.15
1994	163910.94	333398.75	2226647.00	3377476.00	879138.81	6980570.00	76.99
1995	165035.81	335691.27	2241445.00	3395976.00	882740.94	7020397.00	76.86
1996	166186.56	339000.06	2256338.00	3414553.00	886347.87	7061424.00	76.73
1997	167220.94	340323.75	2271325.00	3433205.00	889759.37	7102134.00	76.59
1998	168477.37	342663.17	2286409.00	3451928.00	893574.94	7143051.00	76.46
1999	169644.62	345019.69	2301508.00	3470730.00	897194.87	7184176.00	76.32
2000	170810.31	347392.12	2316865.00	3489503.00	900919.12	7225499.00	76.19

Exhibit 5-II

Sleep Awakening

Silent

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	%C
1976	612231.21	1250167.00	7266166.00	8895524.00	2191662.00	20316335.0	0.
1977	624355.31	1272734.00	7435190.00	9026542.00	2216405.00	20635232.0	-1.
1978	523492.87	1079310.00	6438025.00	7975457.00	1967998.00	17990272.0	11.
1979	450185.50	917616.69	5542697.00	7058729.00	1750349.00	15719757.0	22.
1980	281688.81	777993.12	4757893.00	6231365.00	1554202.00	13703131.0	32.
1981	324701.81	661910.00	4096515.00	5513996.00	1383173.00	11980195.0	41.
1982	254501.52	518729.00	3257743.00	4582945.00	1160735.00	9794534.00	51.
1983	201367.12	410407.94	2628567.00	3824695.00	990291.12	8055330.00	60.
1984	161068.62	328292.69	2135283.00	3234076.00	834150.19	6692970.00	67.
1985	141766.81	283981.05	1895934.00	2934010.00	750225.00	6020706.00	70.
1986	125141.21	255032.37	1697320.00	2666266.00	694037.25	5427776.00	73.2
1987	110729.50	225668.75	1505469.00	2427928.00	634799.75	4904594.00	75.5
1988	98296.75	200322.57	1346455.00	2215754.00	591798.12	4442626.00	78.1
1989	93854.25	191269.31	1289645.00	2139977.00	562069.69	4275713.00	78.9
1990	89423.00	182235.62	1232921.00	2050955.00	542799.44	4107824.00	79.7
1991	85247.50	173727.75	1178962.00	1986709.00	522407.94	3949053.00	80.5
1992	85934.62	175130.12	1188192.00	1999667.00	525990.25	3974903.00	80.4
1993	86635.75	176544.31	1197471.00	2012590.00	528577.56	4001917.00	80.3
1994	87235.31	177969.31	1206831.00	2025774.00	531168.62	4029077.00	80.1
1995	87935.12	179193.25	1214862.00	2036977.00	533380.62	4052348.00	80.0
1996	88547.87	180425.75	1222949.00	2048225.00	535595.62	4075743.00	79.9
1997	89152.19	181666.31	1231096.00	2059523.00	537813.44	4099240.00	79.8
1998	89768.44	182915.19	1239274.00	2070865.00	540034.12	4122955.00	79.7
1999	90390.37	184173.25	1247516.00	2082251.00	542257.50	4146597.00	79.5
2000	91011.44	185439.81	1255909.00	2093699.00	544493.81	4170431.00	79.4

Exhibit 5-I

Outdoor Speech Interference

Base

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RCI
1976	9881050.00	3062542.00	11244948.0	5206902.00	1117825.00	30513248.0	0.0
1977	9989892.00	3099036.00	11365350.0	5253379.00	1127168.00	30834816.0	-1.05
1978	8913123.00	2789072.00	10404140.0	4905906.00	1064145.00	28076368.0	7.99
1979	7976451.00	2519163.00	9561809.00	4597107.00	1008198.81	25662704.0	15.90
1980	7135493.00	2275426.00	8794129.00	4311001.00	956111.00	23472128.0	23.08
1981	6405604.00	2063747.00	8123477.00	4057879.00	910074.50	21560768.0	29.34
1982	5546880.00	1813856.00	7324897.00	3751446.00	854211.31	19291280.0	36.78
1983	4840681.00	1608290.00	6663343.00	3493733.00	807340.81	17413376.0	42.93
1984	4260528.00	1439414.00	6116371.00	3277976.00	768211.06	15862500.0	48.01
1985	4147137.00	1407288.00	6014705.00	3238921.00	761592.69	15569643.0	48.97
1986	4039750.00	1376863.00	5918497.00	3201999.00	755372.00	15292481.0	49.88
1987	3938273.00	1348137.00	5827704.00	3167206.00	749539.44	15030859.0	50.74
1988	3842358.00	1320969.00	5741891.00	3134340.00	744072.69	14783630.0	51.55
1989	3873699.00	1331307.00	5779507.00	3151383.00	747795.37	14883691.0	51.22
1990	3897536.00	1339140.00	5807989.00	3164297.00	750608.06	14959570.0	50.97
1991	3921444.00	1346993.00	5836514.00	3177227.00	753421.37	15035599.0	50.72
1992	3945502.00	1354885.00	5865179.00	3190211.00	756242.94	15112019.0	50.47
1993	3969708.00	1362819.00	5893972.00	3203244.00	759072.56	15188815.0	50.22
1994	3994065.00	1370794.00	5922900.00	3216329.00	761910.25	15265998.0	49.97
1995	4014946.00	1377625.00	5947661.00	3227523.00	764335.56	15332090.0	49.75
1996	4035938.00	1384485.00	5972519.00	3238756.00	766766.50	15398464.0	49.54
1997	4057038.00	1391376.00	5997473.00	3250027.00	769203.44	15465117.0	49.32
1998	4078252.00	1398296.00	6022532.00	3261334.00	771645.94	15532059.0	49.10
1999	4099574.00	1405248.00	6047689.00	3272679.00	774094.31	15599284.0	48.88
2000	4121007.00	1412230.00	6072937.00	3284064.00	776548.69	15666786.0	48.66

Exhibit 5-I

Outdoor Speech Interference

Option 1

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	PCI
1976	5881050.00	3062542.00	11244948.0	5206902.00	1117025.00	30513248.0	0.0
1977	9569852.00	3099036.00	11365350.0	5253379.00	1127158.00	30934815.0	-1.0
1978	8913123.00	2789072.00	10404140.0	4905906.00	1064145.00	28076368.0	7.9
1979	7911624.00	2511252.00	9435749.00	4532174.00	984003.12	25364784.0	16.8
1980	7006651.00	2239578.00	8543635.00	4180435.00	907973.31	22878352.0	25.0
1981	6213354.00	2010354.00	7750193.00	3861052.00	838260.31	20673200.0	32.2
1982	4907332.00	1629025.00	6433746.00	3308928.00	718933.44	16997952.0	44.2
1983	3825139.00	1312550.00	5332905.00	2832782.00	615320.00	13919719.0	54.3
1984	2928236.00	1049955.00	4412147.00	2422165.00	528057.37	11340560.0	62.8
1985	2548751.00	930873.56	4005115.00	2228181.00	483579.75	10204500.0	65.5
1986	2354487.00	852058.75	3695634.00	2085606.00	454212.31	9454997.00	69.0
1987	2079155.00	771047.00	3422925.00	1955775.00	427417.00	8656321.00	71.6
1988	1823206.00	698392.94	3174106.00	1837281.00	402919.81	7935305.00	73.9
1989	1840679.00	704496.37	3195724.00	1847632.00	404994.81	7993715.00	73.9
1990	1854224.00	709109.62	3212092.00	1855469.00	405563.94	8037455.00	73.6
1991	1867611.00	713739.37	3228495.00	1863310.00	408132.00	8081281.00	73.52
1992	1881087.00	718395.31	3244961.00	1871181.00	409704.69	8125329.00	73.37
1993	1894652.00	723077.56	3261512.00	1879084.00	411281.94	8169606.00	73.23
1994	1908309.00	727784.94	3278137.00	1887017.00	412863.69	8214110.00	73.09
1995	1920027.00	731817.50	3292369.00	1893903.00	414215.37	8252226.00	72.96
1996	1931800.00	735869.69	3306655.00	1900814.00	415570.50	8290509.00	72.83
1997	1943545.00	739939.87	3321000.00	1907446.00	416725.69	8329757.00	72.70
1998	1955559.00	744027.37	3335401.00	1914302.00	418290.12	8367579.00	72.58
1999	1967536.00	748135.50	3349857.00	1921181.00	419654.94	8405355.00	72.45
2000	1979584.00	752262.12	3364371.00	1928093.00	421022.69	8445322.00	72.32

Exhibit 5-I

Outdoor Speech Interference

Option 3

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN LOW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	PCI
1976	5981050.00	3062542.00	11244948.0	5206902.00	1117925.00	30513248.0	0.0
1977	9989852.00	3099036.00	11365350.0	5253379.00	1127168.00	30834915.0	-1.0
1978	8913123.00	2789072.00	10404140.0	4905906.00	1064145.00	28076369.0	7.9
1979	7976451.00	2519163.00	9561909.00	4597107.00	1009199.81	25662704.0	15.9
1980	7135493.00	2275426.00	8794129.00	4311001.00	955111.00	23472128.0	23.0
1981	6405604.00	2063747.00	8123477.00	4057879.00	910074.50	21560763.0	29.3
1982	5392632.00	1769513.00	7097408.00	3637262.00	817440.37	19714240.0	38.6
1983	4538699.00	1521351.00	5217705.00	3255526.00	734370.25	15279272.0	49.9
1984	3817057.00	1311503.00	5461775.00	2939501.00	661246.56	14191082.0	53.4
1985	3568400.00	1240139.00	5165176.00	2798372.00	623700.06	13395787.0	56.1
1986	3331644.00	1172103.00	4884555.00	2654255.00	598598.62	12641157.0	58.5
1987	3106244.00	1107213.00	4619011.00	2536740.00	555776.94	11924984.0	60.9
1988	2891545.00	1045301.81	4367606.00	2415489.00	525064.87	11245005.0	63.1
1989	2917280.00	1053805.00	4396661.00	2428839.00	527729.94	11324313.0	62.8
1990	2936823.00	1060249.00	4418667.00	2438907.00	529745.12	11384391.0	62.6
1991	2956408.00	1066706.00	4440708.00	2449017.00	531759.19	11444598.0	62.4
1992	2976117.00	1073158.00	4462844.00	2459160.00	533779.00	11505106.0	62.2
1993	2995947.00	1079725.00	4485086.00	2469358.00	535804.69	11565920.0	62.1
1994	3015900.00	1086285.00	4507432.00	2479585.00	537835.05	11627037.0	61.90
1995	3033005.00	1091903.00	4526554.00	2488339.00	539572.00	11679373.0	61.72
1996	3050201.00	1097546.00	4545755.00	2497121.00	541312.44	11731935.0	61.55
1997	3067487.00	1103213.00	4565035.00	2505931.00	543056.81	11784722.0	61.38
1998	3084865.00	1108905.00	4584383.00	2514772.00	544805.31	11837730.0	61.20
1999	3102332.00	1114623.00	4603813.00	2523641.00	546558.19	11890957.0	61.03
2000	3119891.00	1120366.00	4623319.00	2532540.00	548314.94	11944430.0	60.85

Exhibit 5-I

Outdoor Speech Interference

Option 5

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RC
1976	9861050.00	3062542.00	11244948.0	5206902.00	1117825.00	30517249.0	0.
1977	9569892.00	3095035.00	11365350.0	5253379.00	1127169.00	30834816.0	-1.
1978	8913123.00	2799072.00	10404140.0	4905906.00	1064145.00	28076359.0	7.
1979	7976451.00	2519163.00	9561809.00	4597107.00	1009198.81	25552704.0	15.
1980	7125493.00	2273426.00	8794129.00	4311001.00	956111.00	23472129.0	23.
1981	6405604.00	2063747.00	8123477.00	4057979.00	910071.50	21560756.0	29.
1982	5067670.00	1573529.00	5743780.00	3475579.00	779179.55	17740912.0	41.
1983	3959771.00	1343850.00	5590255.00	2975853.00	656556.12	14541729.0	52.
1984	3039615.00	1001101.00	4626068.00	2544126.00	570430.17	11901340.0	61.
1985	2541550.00	954591.25	4191342.00	2325797.00	518198.94	10635769.0	65.
1986	2418343.00	865748.06	3797447.00	2143256.00	473086.62	9697480.00	69.
1987	2101825.00	777252.69	3464484.00	1930297.00	435631.37	8759499.00	71.
1988	1823306.00	699352.54	3174105.00	1837291.00	402717.91	7936006.00	73.
1989	1840575.00	704486.37	3195724.00	1847632.00	404794.81	7993715.00	73.
1990	1854224.00	709108.62	3212092.00	1855459.00	405553.94	8037455.00	73.
1991	1867611.00	713739.47	3228485.00	1863310.00	408432.00	8081281.00	73.
1992	1881087.00	718395.31	3244961.00	1871191.00	409704.69	8125328.00	73.
1993	1894652.00	723077.55	3261512.00	1879094.00	411291.94	8157505.00	73.
1994	1908309.00	727794.94	3278137.00	1887017.00	412963.69	8214110.00	73.
1995	1920022.00	731817.50	3292369.00	1893803.00	414215.57	8252226.00	72.
1996	1931800.00	735869.59	3306555.00	1900514.00	415570.50	8290509.00	72.
1997	1943645.00	739930.87	3321000.00	1907446.00	416920.69	8328957.00	72.
1998	1955559.00	744027.37	3335401.00	1914302.00	418270.12	8367577.00	72.
1999	1967539.00	748135.50	3349857.00	1921181.00	419654.94	8406365.00	72.
2000	1979584.00	752262.12	3364371.00	1928093.00	421022.69	8445322.00	72.

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Exhibit 5-I

Outdoor Speech Interference

Option 7

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RC
1976	5881050.00	3052542.00	11244944.0	5205902.00	1117825.00	30513249.0	0.
1977	9989892.00	3099036.00	11365350.0	5253379.00	1127168.00	30934914.0	-1.
1978	8912122.00	2739072.00	10404140.0	4905906.00	1064145.00	28076358.0	7.5
1979	7741555.00	2451157.00	9255681.00	4454528.00	965611.06	24868650.0	19.5
1980	6683129.00	2144252.00	8204369.00	4032379.00	873631.00	21937729.0	29.1
1981	5751337.00	1873809.00	7270555.00	3549283.00	790184.12	19235264.0	35.5
1982	4527230.00	1514913.00	6035436.00	3128375.00	678635.94	15879594.0	47.9
1983	3504056.00	1217241.00	5001996.00	2678816.00	592353.50	12984706.0	57.4
1984	2660625.00	970304.62	4137292.00	2290962.00	499751.44	10558944.0	65.4
1985	2453213.00	875963.62	3778750.00	2119115.00	460535.25	9687576.00	69.2
1986	2229160.00	812860.75	3564852.00	2020303.00	440372.06	9067547.00	70.2
1987	2019556.00	753777.05	3363595.00	1925450.00	421190.17	8484573.00	72.1
1988	1823308.00	698392.94	3174106.00	1837281.00	402917.31	7936006.00	73.9
1989	1840879.00	704486.37	3195724.00	1847632.00	404994.81	7993715.00	73.9
1990	1854224.00	709109.62	3212092.00	1855469.00	405563.94	8037456.00	73.6
1991	1867611.00	713739.37	3228489.00	1863310.00	408132.09	8081281.00	73.5
1992	1881097.00	718395.21	3244951.00	1871191.00	409704.57	8125323.00	73.3
1993	1894652.00	723077.56	3261512.00	1879084.00	411281.94	8169606.00	73.2
1994	1908309.00	727784.94	3278137.00	1887017.00	412863.69	8214110.00	73.0
1995	1920022.00	731817.50	3292369.00	1893903.00	414215.37	8252226.00	72.9
1996	1931900.00	735967.69	3306656.00	1900614.00	415570.59	8290509.00	72.8
1997	1943645.00	739938.67	3321000.00	1907446.00	416928.67	8328957.00	72.7
1998	1955559.00	744027.37	3335401.00	1914302.00	418290.12	8367579.00	72.5
1999	1967538.00	748135.50	3349857.00	1921191.00	419654.94	8406365.00	72.4
2000	1979584.00	752262.12	3364371.00	1928083.00	421022.57	8445322.00	72.3

Exhibit 5-I

Outdoor Speech Interference

Silent

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN 5Ch APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RCI
1976	7226347.00	2285719.00	9400062.00	3973296.00	813916.37	22699312.0	0.0
1977	7309612.00	2312608.00	8490786.00	4009079.00	820778.55	22943840.0	-1.0
1978	6206737.00	1994960.00	7472140.00	3612620.00	744697.37	20031136.0	11.7
1979	5243838.00	1716236.00	6571638.00	3253901.00	675440.25	17461104.0	23.0
1980	4384719.00	1456424.00	5755559.00	2920823.00	610752.94	15138297.0	33.3
1981	3636458.00	1248649.00	5036424.00	2620237.00	552034.25	13093802.0	42.3
1982	2759254.00	992587.19	4179884.00	2251846.00	479545.69	10663116.0	53.0
1983	2155171.00	784365.19	3450995.00	1932301.00	416139.81	8749766.00	61.4
1984	1723541.00	619455.44	2857483.00	1655068.00	360670.56	7216217.00	68.2
1985	1576273.00	580813.00	2726687.00	1593865.00	349351.55	6926099.00	69.9
1986	1435155.00	543933.37	2601307.00	1534722.00	336422.94	6452540.00	71.5
1987	1302571.00	508733.12	2481124.00	1477582.00	324872.44	6094882.00	73.1
1988	1402216.00	492412.87	2365890.00	1422343.00	313684.62	5996545.00	73.5
1989	1413327.00	496612.50	2382474.00	1430545.00	315328.69	6038296.00	73.4
1990	1421782.00	499800.17	2395029.00	1436755.00	316570.81	6069936.00	73.2
1991	1430258.00	502997.05	2407508.00	1442957.00	317813.05	6101643.00	73.1
1992	1438756.00	506214.00	2420244.00	1449203.00	319059.12	6133516.00	72.9
1993	1447396.00	509450.94	2432940.00	1455463.00	320308.75	6165557.00	72.8
1994	1455059.00	512709.62	2445693.00	1461750.00	321562.00	6197772.00	72.7
1995	1463492.00	515501.44	2456611.00	1467126.00	322632.81	6225362.00	72.5
1996	1470572.00	518309.44	2467571.00	1472527.00	323706.55	6253030.00	72.4
1997	1478457.00	521131.87	2478514.00	1477936.00	324782.62	6280920.00	72.3
1998	1486070.00	523968.01	2489621.00	1483360.00	325861.25	6308898.00	72.2
1999	1493685.00	526821.25	2500711.00	1488817.00	326942.55	6336980.00	72.0
2000	1501354.00	529688.87	2511844.00	1494285.00	328026.37	6365197.00	71.9

Exhibit 5-J

Indoor Speech Interference

Base

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBRBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RC
1976	349396.31	147772.81	221239.62	159781.69	42176.96	920367.37	0.
1977	355560.44	150272.25	224704.25	161898.62	42561.07	934996.62	-1.
1978	321804.19	135990.62	205029.69	150757.62	40020.18	853602.25	7.
1979	292121.12	123450.81	187901.44	140893.19	37761.85	782128.37	15.
1980	264956.94	111988.75	171888.25	131537.31	35659.66	716030.87	22.
1981	241144.81	101954.00	157900.50	123317.37	33798.72	658115.37	28.
1982	212949.62	90072.31	141249.25	113198.44	31540.40	589010.00	36.
1983	189575.50	80233.00	127349.12	104698.87	29646.82	531503.31	42.
1984	170620.44	72240.31	116023.00	97651.25	28062.76	484597.75	47.
1985	167333.44	70837.12	114057.61	96492.37	27790.45	476511.19	48.
1986	164223.06	69509.00	112199.56	95399.06	27533.52	468864.19	49.
1987	161288.94	68256.62	110448.12	94372.00	27291.65	461657.31	49.
1988	158520.87	67073.44	108794.69	93404.31	27064.02	454857.31	50.
1989	160186.37	67749.44	109811.00	94136.62	27206.19	459089.62	50.
1990	161452.87	68262.44	110581.19	94690.69	27313.19	462300.37	49.
1991	162726.50	68777.81	111354.12	95245.62	27419.84	465523.87	49.
1952	164009.94	69296.87	112131.56	95802.56	27526.42	468767.31	49.
1993	165303.12	69819.50	112913.56	96361.19	27632.96	472030.31	48.
1994	166606.25	70345.75	113700.06	96921.87	27739.41	475313.31	48.
1995	167724.87	70797.31	114374.06	97401.19	27830.10	478127.50	48.
1996	168850.94	71251.44	115051.31	97882.06	27920.73	480956.44	47.
1997	169984.19	71708.25	115732.00	98364.19	28011.30	483799.87	47.
1998	171124.87	72167.75	116416.00	98847.69	28101.82	486658.12	47.
1999	172273.00	72630.00	117103.31	99332.56	28192.27	489531.12	46.
2000	173428.69	73095.00	117793.94	99818.69	28282.66	492418.94	46.

Exhibit 5-J

Indoor Speech Interference

Option 1

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	PC
1976	349296.31	147772.81	221229.62	155781.69	42176.96	920367.37	0.0
1977	355560.44	150272.25	224704.25	161898.62	42561.07	934996.62	-1.5
1978	321804.19	135990.52	205029.59	150757.52	40020.18	853502.25	7.2
1979	289914.37	122576.00	185157.00	139703.06	35794.92	773175.31	15.9
1980	260555.69	110238.87	166512.62	127129.44	33716.29	698152.87	24.1
1981	234553.37	99337.31	150034.55	115663.21	30902.72	631501.25	31.3
1982	191031.81	81011.31	122139.44	98307.81	26094.89	519575.25	43.6
1983	154996.87	65026.75	99020.87	82505.44	21947.40	424295.81	53.9
1984	125202.19	53260.80	79787.81	68944.27	18391.63	345496.75	62.4
1985	112694.06	47969.54	71462.54	62510.15	16602.35	311257.94	66.1
1986	102843.69	43757.00	65092.73	57924.23	15415.97	284744.44	69.0
1987	93825.12	39932.27	59376.71	53634.38	14341.10	261109.50	71.6
1988	85743.37	36497.36	54390.83	49742.09	13352.21	239725.75	73.9
1989	85548.31	35858.01	54709.28	50149.71	13429.85	242004.06	73.1
1990	87335.50	37149.40	55302.39	50458.04	13496.63	243731.87	73.5
1991	88026.50	37432.06	55676.76	50766.82	13564.15	245455.50	73.2
1992	88722.81	37715.71	56093.93	51076.82	13601.76	247211.94	73.1
1993	89424.50	38003.38	56493.33	51388.04	13659.30	249308.44	72.9
1994	90131.62	38292.06	56855.16	51700.53	13715.87	250735.12	72.7
1995	90738.56	38539.77	57239.61	51967.80	13765.91	252251.50	72.5
1996	91349.56	38788.93	57595.81	52236.00	13814.96	253775.12	72.4
1997	91964.35	39039.60	57933.85	52504.99	13854.00	255305.81	72.2
1998	92583.62	39291.80	58293.68	52774.97	13913.02	256846.94	72.0
1999	93206.81	39545.50	58635.29	53045.75	13962.03	258395.25	71.9
2000	93834.00	39800.48	58998.57	53317.39	14011.04	259951.62	71.1

Exhibit 5-J

Indoor Speech Interference

Option 3

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	PC
1976	349396.31	147772.81	221235.62	155781.69	42176.96	920367.37	0.
1977	355560.44	150272.25	224704.25	161998.62	42561.07	934996.62	-1.
1978	321804.19	135990.62	205029.59	150757.62	40020.18	853502.25	7.
1979	292121.12	123450.81	187901.44	140993.19	37761.85	782128.37	15.
1980	264956.94	111988.75	171888.25	131537.31	35659.66	716030.87	22.
1981	241144.81	101956.00	157900.50	123317.37	33798.72	658115.37	29.
1982	207656.37	87896.06	136362.25	109336.06	30058.89	571309.62	37.
1983	179208.00	75967.44	117938.06	97074.81	26724.07	495912.37	45.
1984	155370.25	65959.31	101984.75	86199.12	23752.32	433265.75	52.9
1985	147378.00	62615.10	95923.75	81634.06	22234.10	409684.94	55.4
1986	139575.44	59505.57	90136.69	77225.62	20818.07	387662.37	57.8
1987	132666.87	56445.55	84601.62	73031.87	19490.55	366236.37	60.2
1988	125684.37	53520.34	79359.00	69108.75	18248.48	345920.87	62.4
1989	127008.37	54061.21	80107.37	69661.81	18348.89	349187.62	62.0
1990	128014.19	54471.62	80674.87	70079.06	18424.54	351664.19	61.7
1991	129025.06	54883.99	81244.12	70497.81	18499.90	354150.81	61.5
1992	130043.75	55299.30	81815.81	70918.00	18575.24	356653.00	61.2
1993	131070.25	55717.41	82392.94	71339.87	18650.54	359170.94	60.9
1994	132104.56	56138.58	82972.50	71763.19	18725.83	361704.62	60.7
1995	132992.50	56499.84	83469.12	72125.25	18789.96	363876.62	60.4
1996	133886.31	56863.32	83968.31	72490.50	18854.09	366060.50	60.2
1997	134765.94	57228.83	84470.00	72852.62	18918.17	368255.50	59.9
1998	135691.44	57596.59	84974.25	73218.00	18982.22	370462.44	59.7
1999	136602.81	57966.51	85481.00	73584.44	19046.26	372681.00	59.5
2000	137520.12	58338.62	85990.19	73952.00	19110.25	374911.12	59.2

Exhibit 5-J

Indoor Speech Interference

Option 5

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN RCH APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	RCI
1976	349396.31	147772.81	221239.62	159701.65	42176.96	920367.37	0.0
1977	355560.44	150272.25	224704.25	151890.62	42561.07	934795.52	-1.5
1978	321804.19	135990.62	205025.69	150757.62	40020.19	853602.25	7.2
1979	292121.12	123450.81	187901.44	140893.19	37751.65	782120.37	15.0
1980	264955.94	111989.75	171885.25	131537.31	35559.65	715030.87	22.2
1981	241144.81	101954.00	157900.50	123317.37	33799.72	658115.37	28.4
1982	196819.19	83195.31	126776.54	103909.62	28515.04	540916.06	41.2
1983	159564.37	57549.00	104511.62	87258.19	23983.66	442956.81	51.8
1984	128999.25	54778.91	84324.19	72938.69	20097.14	351138.12	60.7
1985	115853.94	49234.66	75028.69	65918.56	17987.51	324025.37	54.7
1986	104620.59	44480.07	67177.50	59754.[illegible]	16499.25	292231.50	64.2
1987	84572.69	40232.89	60250.07	54454.79	14670.74	264181.06	71.3
1988	85743.37	36497.35	54390.63	49742.09	13352.21	239725.75	73.9
1989	86648.31	36869.01	54769.28	50149.71	13428.86	242004.06	73.7
1990	87335.50	37149.40	55302.39	50458.04	13495.65	243731.87	73.5
1991	88026.50	37432.05	55652.55	50755.92	13544.19	245466.50	73.2
1992	88722.81	37716.71	56093.93	51076.82	13601.76	247211.94	73.1
1993	89424.50	38003.30	56493.33	51358.04	13637.30	248968.44	72.9
1994	90121.62	38292.05	56895.15	51700.53	13716.97	250736.12	72.7
1995	90738.56	38539.77	57239.61	51967.80	13765.91	252251.50	72.5
1996	91249.56	38788.93	57585.81	52235.00	13814.95	253775.12	72.4
1997	91764.56	39039.60	57923.65	52504.98	13864.00	255306.81	72.2
1998	92583.62	39291.90	58283.68	52774.97	13913.02	256846.94	72.0
1999	93206.81	39545.50	58539.29	53045.75	13962.03	258395.25	71.9
2000	93834.00	39800.68	58988.67	53217.25	14011.04	259951.62	71.7

Exhibit 5-J

Indoor Speech Interference

Option 7

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN RCH APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	PCI
1976	349356.31	147772.81	221239.62	159791.69	42176.96	920357.37	0.0
1977	355550.44	150272.25	224704.25	161378.62	42561.07	934496.62	-1.59
1978	321804.19	135990.62	205029.69	150757.67	40020.18	853602.25	7.25
1979	284130.00	120132.12	181335.94	135094.94	35344.55	757727.50	17.57
1980	249513.25	105571.06	155239.44	122172.44	32330.12	669846.31	27.33
1981	218993.00	92733.81	139747.75	109513.87	28962.62	589851.00	35.90
1982	177873.87	75431.75	113775.12	92220.25	24453.00	483754.00	47.44
1983	144045.06	61175.20	92139.06	77327.25	20590.57	395276.12	57.05
1984	116101.94	49386.90	73979.00	64517.30	17258.12	321243.12	65.10
1985	105347.00	44824.89	65685.12	58851.11	15676.34	291394.37	68.24
1986	98286.31	41967.14	62277.59	55718.86	14951.27	273111.06	70.33
1987	91862.62	39096.30	58131.44	52654.50	14091.13	255335.94	72.20
1988	85743.37	36457.36	54290.82	49742.08	13352.21	239725.75	73.95
1989	86649.31	36869.01	54909.29	50149.71	13428.96	242004.06	73.71
1990	87335.50	37147.40	55302.39	50458.04	13495.53	243731.87	73.52
1991	88026.60	37432.06	55696.56	50766.92	13544.19	245466.50	73.33
1992	88722.81	37716.71	56093.93	51076.82	13601.75	247211.94	73.14
1993	89424.50	38003.38	56493.33	51389.04	13559.30	248955.44	72.95
1994	90121.62	38292.06	56895.16	51700.53	13716.37	250736.12	72.76
1995	90738.56	38539.77	57239.61	51967.80	13755.91	252251.50	72.59
1996	91349.55	38789.93	57595.91	52236.00	13814.76	253775.12	72.43
1997	91564.56	39039.60	57933.85	52504.99	13864.00	255306.81	72.26
1998	92583.62	39291.80	58283.68	52774.97	13713.02	255945.94	72.09
1999	93205.81	39545.50	58635.29	53045.75	13762.03	258395.25	71.92
2000	93834.00	39800.69	58989.67	53317.39	14011.04	259751.62	71.76

Exhibit 5-J

Indoor Speech Interference

Silent

YEAR	SUBURBAN SINGLE-FAMILY DETACHED	SUBURBAN DUPLEXES	URBAN ROW APARTMENTS	DENSE URBAN APARTMENTS	VERY DENSE URBAN APARTMENTS	TOTAL	%CI
1976	261360.75	110557.06	161175.44	118694.75	29917.35	691705.31	0.0
1977	265915.56	112431.06	163716.62	120291.19	30197.72	692612.12	-1.6
1978	230655.05	97522.31	142842.52	107473.81	27133.28	605528.06	11.1
1979	199868.62	84514.19	124211.94	95956.62	24343.31	528794.62	22.4
1980	171911.94	72720.87	107323.31	84897.56	21734.44	458598.12	32.7
1981	147312.44	62356.52	92328.37	75073.00	19370.21	396440.56	41.8
1982	118459.00	50205.94	74600.06	62987.19	16455.43	322748.56	52.6
1983	94792.62	40206.78	59837.49	52552.64	13910.89	261300.31	61.5
1984	75334.69	31990.79	41576.28	43558.55	11691.05	210151.19	69.1
1985	71225.75	30250.86	44935.12	41594.80	11192.92	199199.25	70.7
1986	67297.81	28587.87	42404.21	39595.22	10710.55	188596.69	72.3
1987	63543.70	26958.51	40141.36	37860.96	10243.77	178788.19	73.7
1988	60174.95	25563.19	37809.39	36085.09	9791.58	169424.94	75.1
1989	60811.04	25923.87	39173.99	35388.73	9850.55	171048.06	74.9
1990	61294.10	26021.76	38450.50	36618.00	9895.00	172279.25	74.7
1991	61775.85	26220.60	38728.07	36847.55	9939.34	173515.31	74.5
1992	62269.33	26420.85	39007.38	37078.08	9983.70	174759.25	74.3
1993	62762.61	26622.53	39298.46	37309.61	10028.06	176011.12	74.1
1994	63259.73	26825.65	39571.30	37542.10	10072.43	177271.06	74.0
1995	63665.43	26999.95	39812.75	37741.05	10110.26	178351.37	73.9
1996	64116.06	27175.28	40057.51	37940.70	10148.11	179437.56	73.6
1997	64548.36	27351.71	40302.59	38141.07	10185.95	180329.62	73.5
1998	64983.62	27529.18	40548.57	38342.14	10223.80	181627.56	73.3
1999	65421.74	27707.73	40796.62	38543.92	10261.65	182731.50	73.1
2000	65862.69	27887.37	41045.61	38746.39	10299.52	183841.50	73.0

Section 6

NOISE CONTROL TECHNOLOGY

INTRODUCTION

There are four main sources of noise on a garbage compactor truck. These are:

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

The control of truck chassis noise in not addressed by this study, but the garbage truck manufacturer has control over its 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 garbage trucks produces an obtrusive whine. Alternative designs and types of PTO will be discussed so that this whine can be greatly reduced or eliminated. 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 makes 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 when compared with the noise from the rest of the truck (less than 60 dBA at 7 m). 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-off 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 fitted. Typically, truck engines at present run between 1200 and 1800 rpm and employ a pump of about 5 cubic inches/revolution displacement (20 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 control 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 a electronic governor. 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. This is already installed on most compactor trucks, except for the front loaders and thus, only these will require them to be installed. They are not installed at present 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. 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 has been 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 up 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. Most truck engines rated at 200 hp or more are capable to 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 very much less speed loss. However, the diagnostic measurements showed that there was no noise difference between the case when the engine was closely regulated to 1050 rpm with or without load and the case when the engine was set to 1200 rpm under no load and its speed allowed to drop under load. Accordingly, there is little to be gained from a noise point of view by installing the better governor. However, it can help in preventing the engine from stalling under load.

Noise levels

Table 3-2 in Section 3 presented the mean sound levels of 27 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 regulation, all trucks are

TABLE 6-1
OVERALL NOISE LEVELS UNDER STAGE 1 OF NOISE CONTROL (TRANSMISSION PTO = 74 dBA at 7m)

Truck	Fuel	RPM	Unreg.	Overall Noise Levels at 7 m Chassis Regulation dBA			
				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	75	74.5	74.5	74

*This assumes actual truck-noise level 2.5 below reg level

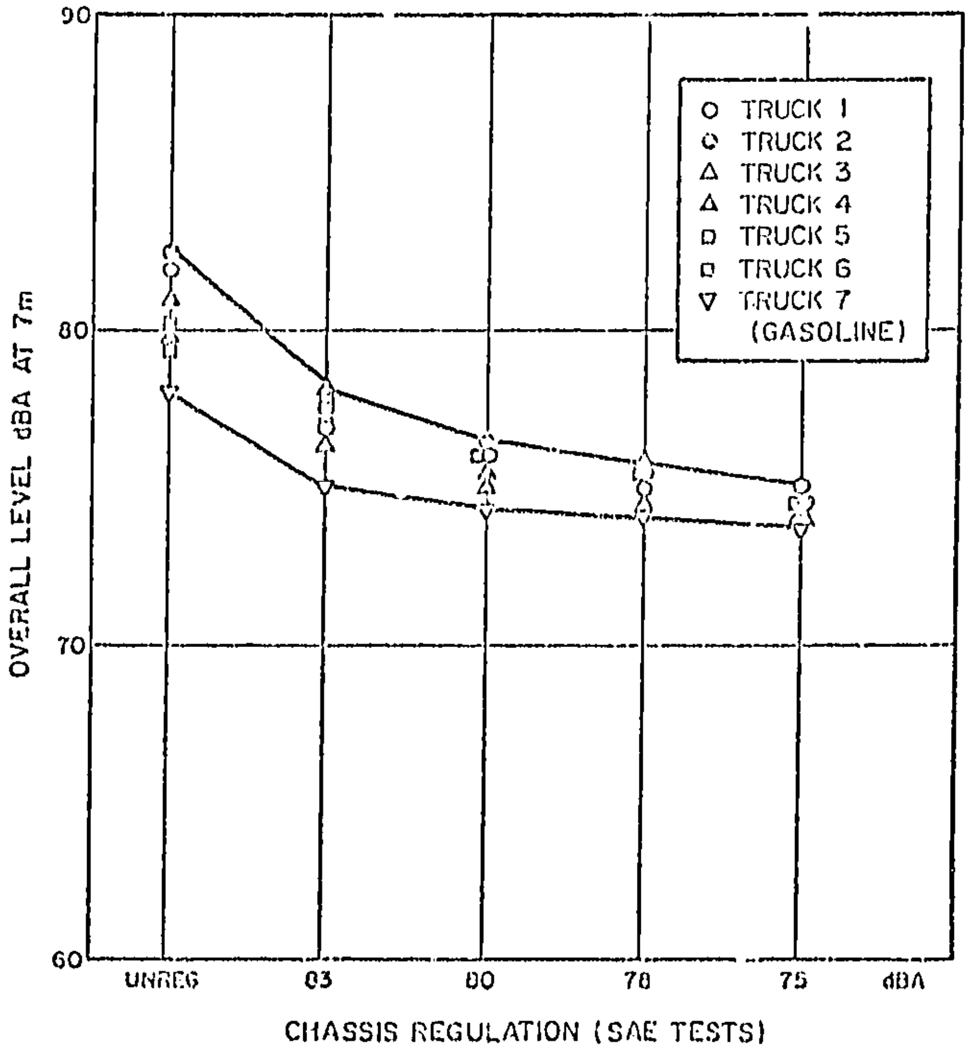


Figure 6-1. Overall Noise Level Under Stage 1 of Noise Control

quieter than 76 dBA at 7 m. Figure 6-1 illustrates these quieted noise levels further.

Four trucks have already been measured which incorporated this noise control method. They all meet 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 takeoff instead of the noisier transmission power takeoff. 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 by an EPA contractor 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	Developed hp	Standard rpm	Reduced rpm	Fuel Savings gal/hr
Gasoline	200	20	1800	1200	0.33
Diesel	200	20	1500	1000	0.55

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 garbage compactor truck primarily by slowing the engine down to 1200 rpm or less. This requires an automatic engine throttle control which exists on most garbage 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 required 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

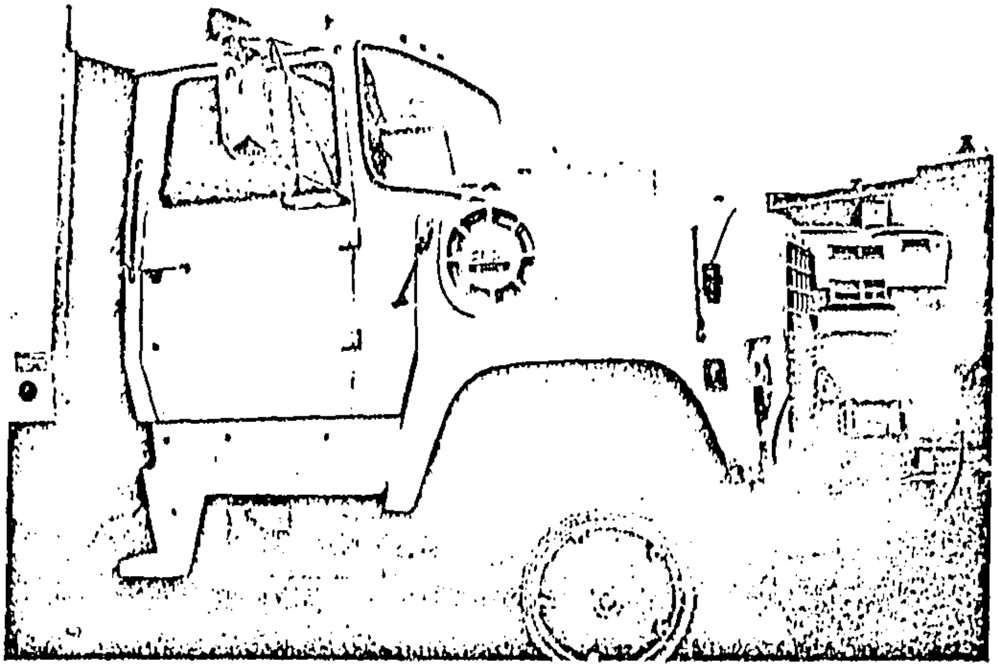
In order to reduce the noise of compacting garbage truck below that of Stage 1, in addition to reducing the speed of the engine, the power take-off noise must be reduced. Under Stage 1, the overall noise was dominated by the transmission power take-off gear at 74 dBA. There does not appear to be any 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 means of reducing the noise. It is therefore not considered to be a practical means of reducing PTO noise by enclosing it in a sound absorbing enclosure.

One manufacturer of automatic transmissions for trucks, is currently undertaking a test program into the source and means of reducing the noise from transmission PTO's. The tooth design of the PTO goes back over 40 years and is very stubby by modern standards. Accordingly, 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 is 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:

Front Power Takeoff

One such power takeoff which has been tried by a number of manufacturers is the "Front Power Takeoff." 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 driver 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 about 2,800 rpm.

Company E reported that they had reliability problems with an electric clutch on a front power takeoff when installed on trucks. This was also confirmed by Co. F. However, Co. G claims very good reliability for their pneumatic-hydraulic clutch (Figure 6-2). This clutch comes in several gear ratios:



GEAR MOUNTED ON A TRUCK WITH A REFUSE PACKER

Figure 6-2. Front Power Take-Off

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 Co. H. This will disconnect the pump should the engine exceed a certain preset rpm.

Front power takeoffs have been used on front, rear, and side loaders. There do not appear to be any inherent problems in the use of front PTO's. 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, Co. I, is offering front power takeoffs on their "quieted" trucks.

A problem with a front power takeoff 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. Co. J offers a front PTO option on two of its lines of trucks. However, it is what they call a "Limited Production Option" which requires a long lead time and special tooling charges. Co. E and Co. K (private communication) are also planning to offer a front PTO option on some of their medium trucks later this year.

Flywheel Power Takeoff

An alternative, and very successful, type of power takeoff is the "Flywheel Power Takeoff" (Figure 6-3). This is a PTO inserted between the engine crankcase and transmission. It is about 8-1/2 inches long

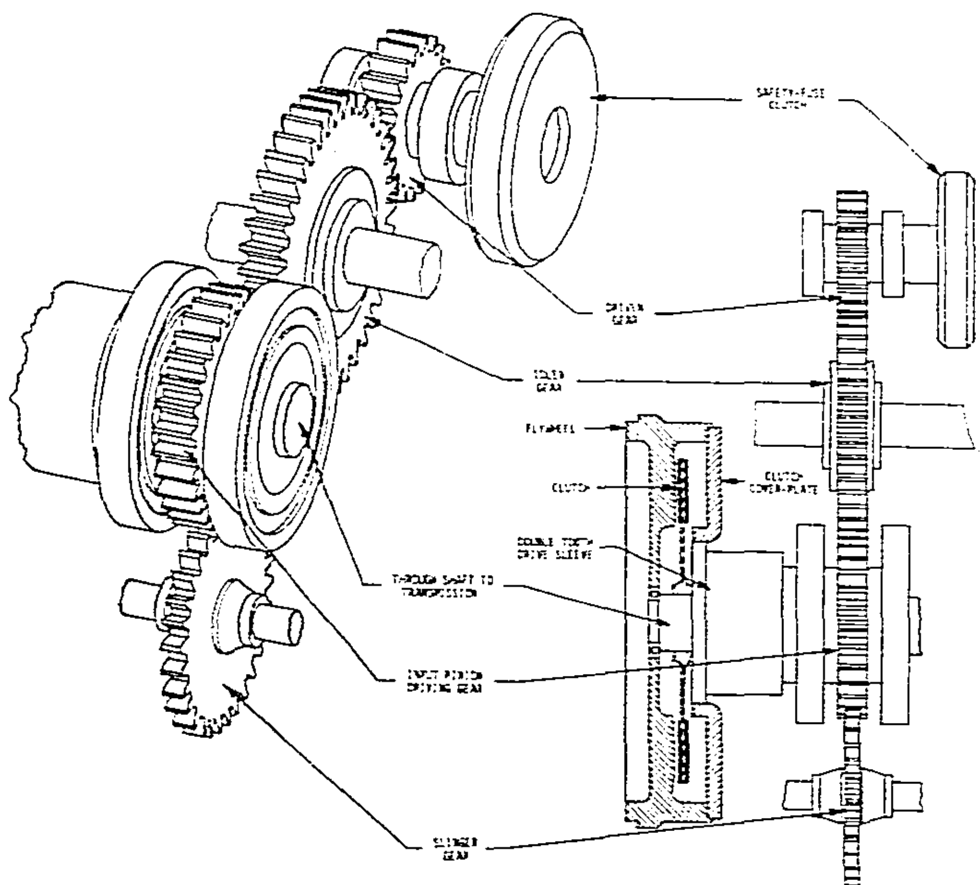


Figure 6-3. "Flywheel Power Take-Off."

and weighs 180 lbs. It is currently available only on Co. 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 PTO's. This is presumably because the gears are all mounted in one integral housing and are correctly aligned. Thus, a garbage truck manufacturer who employs a Co. L chassis need not employ any special hardware to achieve a Stage 2 truck other than to employ a quieted version of the chassis and regulate the engine speed, during compaction, on the engine's own governor.

Co. K has also supplied a flywheel power takeoff on a number of their chassis. It is not currently available, but they have supplied it on Co. M gasoline engines and Co. 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 noise comes from the chassis, with some from the hydraulic pump. In the diagnostic study, the noise level of a Co. O pump at 1,000 rpm was 64 dBA at 7 m.

Table 6-3 shows the chassis noise levels of unregulated and regulated chassis. The unregulated trucks are all well over 75 dBA at 7 m, but under an 80 dBA regulation, all trucks generate less than 72 dBA

TABLE 6-3.
OVERALL NOISE LEVELS UNDER STAGE 2 OF NOISE CONTROL (HYDRAULIC PUMP = 64 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	74.5	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

at 7 m, with the gasoline trucks 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 Co. D side loader with a Co. N diesel engine. The levels are also illustrated in Figure 6-4.

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 Level 2 of noise control treatment. This was a Co. I truck with the quieted option and a Co. 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 garbage 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.

Now, if the truck chassis is 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 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.

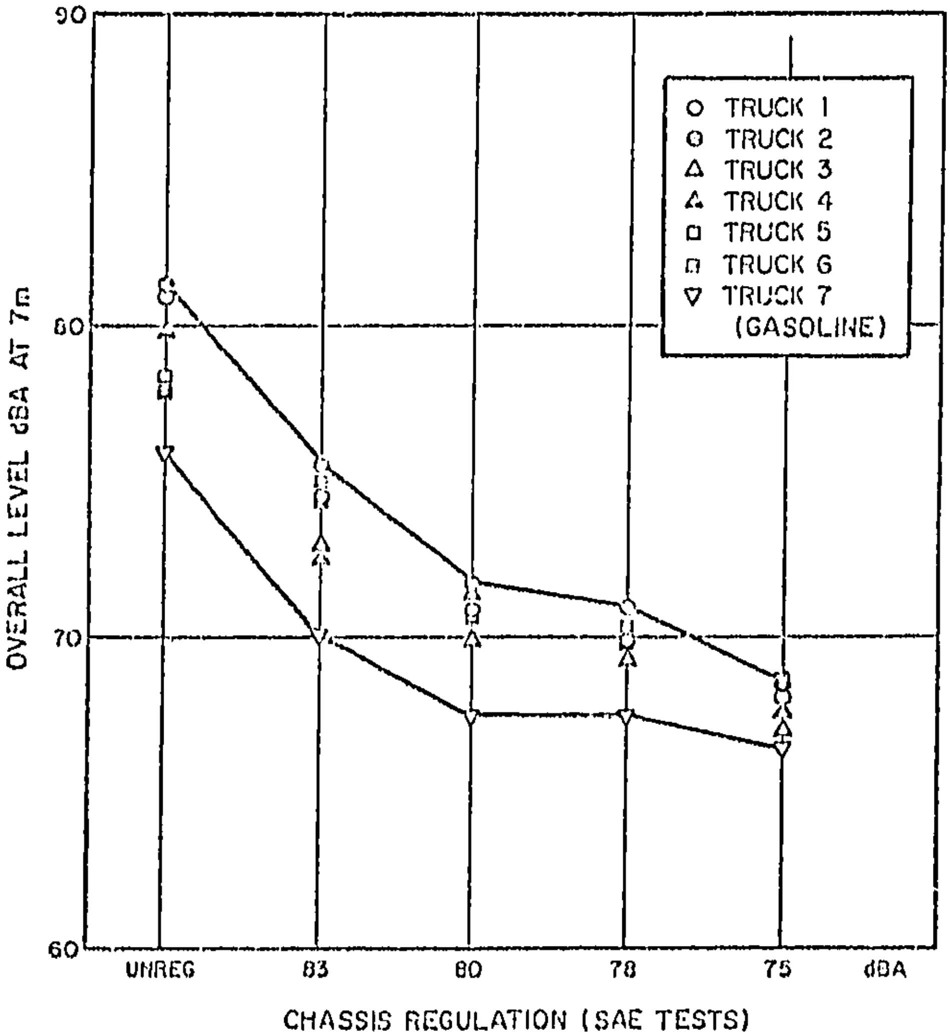


Figure 6-4. Overall Noise Level Under Stage 2 of Noise Control

Quiet Pumps

There are a number of proprietary pumps on the market. One very successful design is a German patent being marketed by Co. P (Figure 6-5). This design uses a 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. Co. 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 vibration isolated from the chassis frame. This technique should give at least 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 of noise control treatment. Significant differences with Stage 2 only occur when the Stage 3 treatment is 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. This data is illustrated in Figure 6-6.

Auxiliary Engines

A number of garbage trucks drive their hydraulic systems from auxiliary gasoline engines mounted on the truck body, rather than using

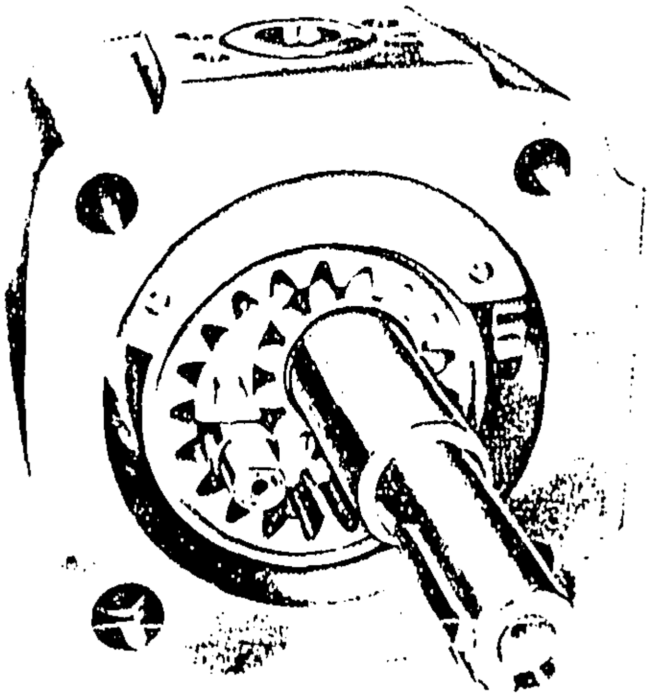


Figure 6-5. A Quiet Hydraulic Pump Design

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 Noise Regulation 83	80	78	75
1	Diesel	1200	81	74	70	69	66.5
2	Diesel	1000	81	75	71	70	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

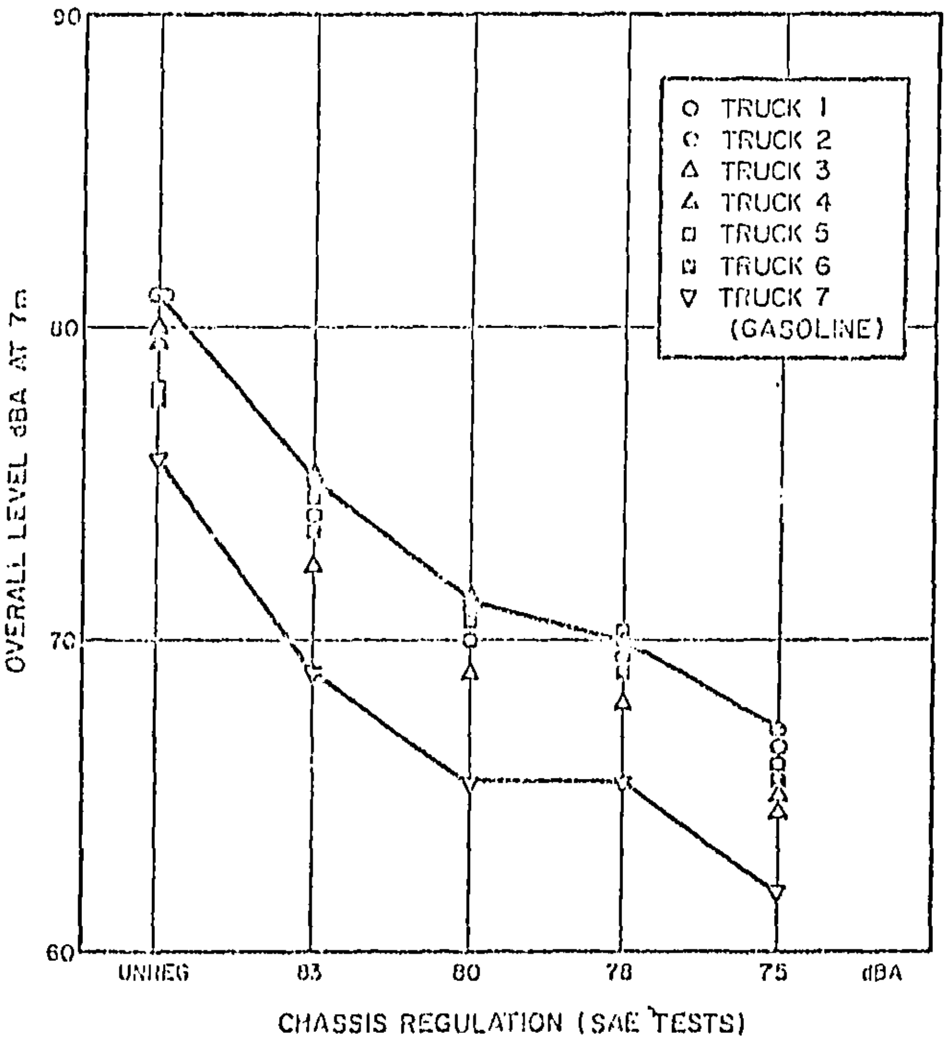


Figure 6-6. Overall Noise Level Under Stage 3 of Noise Control

the main truck engine. These engines are typically water cooled, four cylinder engines and run on the same fuel as the main truck engine. They typically are between 100 and 172 cubic inches displacement 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.

Quieting of Impact Noise

There are a number of sources of impact noises which occur during the loading and compacting cycles. Garbage cans impact on 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 improvement.

Garbage can impacts - rear and side loaders

This noise can be minimized by covering the edge of the loading hopper with a 1/2 inch thick rubber strip.

Hydraulic cylinder bottoming - rear loaders

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 90-100 dBA is typically 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 6-7 shows a cutaway view of a hydraulic cylinder with these cushions installed. The cushions are standard items and are recommended by the manufacturer for all applications with piston speeds in excess of 20-25 ft/min (manufacturer's literature).

Co. 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 are only required on rear loading garbage trucks.

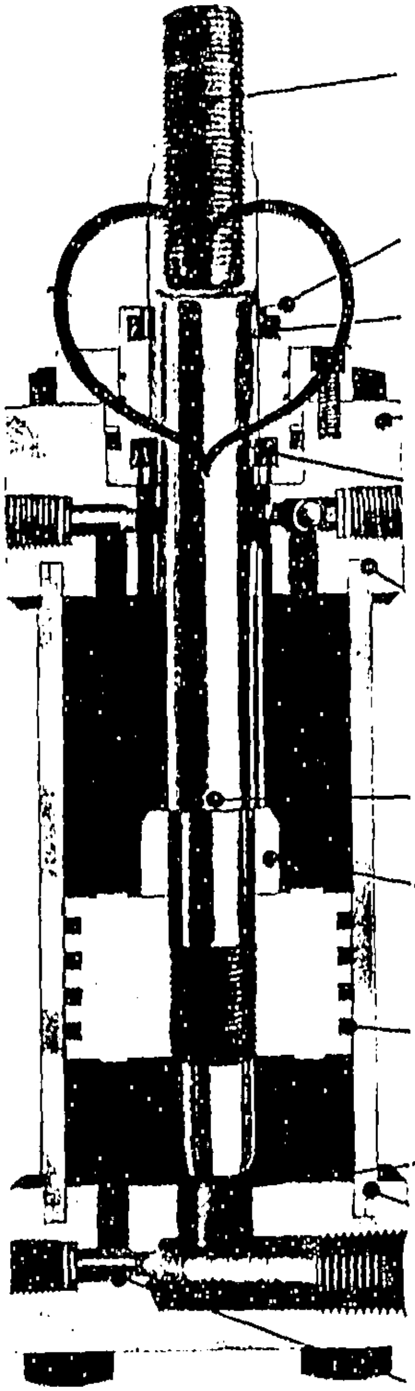


Figure 6-7. Hydraulic Cylinder with Cushions.

There are two compacting cylinders on each truck, requiring a cushion at each end. Thus four cushions are required on each truck. The hydraulic cylinders which require the cushions are between 3 inches and 5-1/2 inches bore, depending on truck model.

Banging of containers - front loaders

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 this respect, some noise reduction might be obtained by coating the front loader arms with an epoxy damping material, which although not producing much damping, may lessen the impacts themselves. It is not clear, however, how durable such an epoxy compound would be under such severe service.

Banging of hopper lid - front loader

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.

There is a great deal which can be done to lessen impact noise on garbage trucks: Hydraulic cushions, rubber edgings or stops and damping compound.

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 takeoff noise. Most rear and side loading trucks already have automatic engine speed, but front loaders do not. They 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 currently available) or different types of power take off 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 (and associated fan modifications) is available from some truck chassis manufacturers with some engine combinations. A "flywheel power takeoff" is available on all Co. L diesel engines and Co. K has engineered a design for Co. M gasoline and Co. N diesel engines. This design can be adapted to other engines.

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 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 both the level of noise control for 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 take place with garbage cans or container lids can be covered with rubber sheets and the noise appropriately reduced.

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. The proposed rule focuses on an option which requires Stage 2 quieting. The cost and economic impacts resulting from the adoption of this proposed regulatory option will be examined in a later part of section 7.

COST ANALYSIS*

Estimates of the costs incurred to achieve 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.,

* 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 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 front 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. Co. 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 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 Co.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.

* 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 Co. 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 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 cylinder 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 not significantly increase 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 fiberglas, 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 economies 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 economies will amount to 0.008 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	90
Rear Loader	90

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 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 7-2
SUMMARY OF ESTIMATED
DIRECT LABOR AND MATERIAL COST
FOR NOISE ABATEMENT*
(COST PER UNIT)

Treatment	Front Loader High	Front Loader Low	Front Loader Expected	Side Loader High	Side Loader Low	Side Loader Expected	Rear Loader High	Rear Loader Low	Rear Loader Expected
Stage 1	$1,050	$600	$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
OVERHEAD COSTS FOR
NOISE ABATEMENT*
(COST PER UNIT)

Treatment	Front Loader High	Front Loader Low	Front Loader Expected	Side Loader High	Side Loader Low	Side Loader Expected	Rear Loader High	Rear Loader Low	Rear Loader 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 preceeding Stages and the Impact Noise costs.

TABLE 7-4
SUMMARY OF TOTAL ESTIMATED
COST FOR NOISE ABATEMENT*

Treatment	Front Loader High	Front Loader Low	Front Loader Expected	Side Loader High	Side Loader Low	Side Loader Expected	Rear Loader High	Rear Loader Low	Rear Loader Expected
Stage 1	$1,740	$ 885	$1,215	$ 705	$ 460	$ 320	$ 690	$ 445	$ 520
Stage 2	2,985	1,920	2,310	2,750	1,560	1,930	2,735	1,545	1,915
Stage 3	3,345	1,970	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.

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

The EPA contractor 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 CONTRACTOR 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 Contractor Estimates:			
- Expected	1,215	2,310	2,500
- High	1,740	2,985	3,345
- Low	885	1,920	1,970

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 Contractor 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.

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*Manufacturer #1 estimate is based on a front mount, direct drive pump. The EPA contractor estimate assumes the flywheel PTO option on a Co. L chassis.

**Stage 1: Manufacturer #1 estimates include the cost of an improved speed control device. The EPA contractor 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	$ -90	$ -90
Stage 2	0	60	60	-114	-90	-90
Stage 3	10-15	10-15	10-15	-114	-90	-90
Impact	40-50	15-20	15-20			
Auxiliary	15-20	15-20	15-20			

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 impacts 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 impacted 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, 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.

Dynamics:

*Adjusting to a Known Future

The dynamics associated with the adoption of noise emission standards reflect econmic 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 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 is assumed to be effective on January 1, 1979; Stage 2 on January 1, 1982; and Stage 3 on January 1, 1985.

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 impact since it becomes reflected in other impacts such as production employment, activity in downstream channels of distribution and impacts transmitted to upstream component suppliers.

2. Base Line 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.

TABLE 7-8

BASELINE FORECAST BY YEAR AND COMPACTOR BODY TYPE
1979-1993

				BASELINE FORECAST(1)		
	Total	Front	Side	Rear Loader		
Year	Units	Loader	Loader	Total	Quieted(2)	Standard
1979	13,344	1,524	3,660	8,160	816	7,344
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 exhibit 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 MANUFACTURER'S 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%

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 and 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 increased, the migration of higher income families to houses with larger yards and increases in the quantity of yard waste in the suburbs, and to 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 will 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 be increased replacement of rear loaders by side 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 will be substituted for rear loaders for non-residential applications and side loaders will be substituted for rear loaders for residential applications.

The latter is supported by data presented in a recent study which are summarized in the following table:

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 Magazine, 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.), the overall higher efficiency of one-man crews (side loaders) under a number of application environments is clear, as 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 enhancements 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 (constant 1974 dollars) will be three percent per year between 1974 and 1985, and that unit shipments will increase at the two percent level.

Industry shipment levels, which reflect these growth rates, are shown in Table 7-12. In 1985, unit shipments are expected to be at the 15,000 level and value of shipments are expected to be at the $173 million level.

Projected unit shipments for the time frame up to 1995 are required to evaluate the economic impact of 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 are equal at 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 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 presented separately since these treatments have not been associated with a particular level. The estimated cost related to impact noise 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%

Consideration 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 giving 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	11,580	1,095		12,675		9.5
	2-3		190			12,865	1.5

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	—**	9.5	1.5

* 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.

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 of 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.

For the major cost elements, operating (or fuel) costs, maintenance costs, and equipment costs (direct labor and materials) estimates have been developed and are summarized in Table 7-17. Table 7-18 shows the percentage cost increase 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.

The regulatory option which has been proposed for rulemaking is option 7, which requires the noise level of truck mounted solid waste compactor bodies to reach a maximum of 78 dBA in 1979 and 75 dBA in 1982. To achieve the 78 dBA level, Stage 2 technology is assumed for all compactor body types. To reach the overall 75 dBA level, there will be a 3 dBA noise reduction in the truck itself due to noise regulation which EPA has promulgated for medium and heavy duty trucks (41 FR 15538).

The costs for this proposed regulatory option are exactly equal to those costs imposed 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 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. Taking the price of the truck chassis into consideration, the effective percentage increase in price for the complete units are about one-half of these figures, or about 6.4 percent for front loaders, 12.8 percent for side loaders, and 9.8 percent for rear loaders. 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	1979	80	Stage 1	Front Loader	-114.00	45.00	1,290.00
				Side Loader	- 90.00	17.50	560.00
				Rear Loader	- 90.00	17.50	860.00
1	1982	75	Stage 2	Front Loader	-114.00	45.00	2,385.00
				Side Loader	- 90.00	77.50	1,955.00
				Rear Loader	- 90.00	77.50	2,255.00
3	1982	79	Stage 1	Front Loader	-114.00	45.00	1,290.00
				Side Loader	- 90.00	17.50	560.00
				Rear Loader	- 90.00	17.50	860.00
5	1982	75	Stage 2	Front Loader	-114.00	45.00	2,385.00
				Side Loader	- 90.00	77.50	1,955.00
				Rear Loader	- 90.00	77.50	2,255.00
7	1979	78	Stage 2	Front Loader	-114.00	45.00	2,385.00
				Side Loader	- 90.00	77.50	1,955.00
				Rear Loader	- 90.00	77.50	2,255.00
7	1982	75	Stage 2	Front Loader	-114.00	45.00	2,385.00
				Side Loader	- 90.00	77.50	1,955.00
				Rear Loader	- 90.00	77.50	2,255.00
a	1979	80	Stage 1	Front Loader	-114.00	45.00	1,290.00
				Side Loader	- 90.00	17.50	560.00
				Rear Loader	- 90.00	17.50	860.00
a	1982	79	Stage 1	Front Loader	-114.00	45.00	1,290.00
				Side Loader	- 90.00	17.50	560.00
				Rear Loader	- 90.00	17.50	860.00
b	1979	78	Stage 2	Front Loader	-114.00	45.00	2,385.00
				Side Loader	- 90.00	77.50	1,955.00
				Rear Loader	- 90.00	77.50	2,255.00
b	1982	74	Stage 3	Front Loader	-114.00	57.50	2,575.00
				Side Loader	- 90.00	90.00	2,145.00
				Rear Loader	- 90.00	90.00	2,445.00

*Not to Exceed

TABLE 7-18

REGULATORY OPTIONS AND COST IMPACTS

Option No.	1979		1982		Equivalent Annual Costs $(Millions)
	Regulatory Level	%Cost Increase	Regulatory Level	%Cost Increase	
Baseline	New truck 83 dBA @ 50 feet	0	New truck 80 dBA @ 50 feet	0	0
1	80	3.7	75	6.2*	14.53
3	(not regulated)	0	79	3.7	1.63
5	(not regulated)	0	75	9.9	12.29
7	78	9.9	75	0	18.72

*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 changes are expected to decline by $114.00 while side and rear loader trash compactors will each reduce fuel expenses about $90.00 per year.

It should be noted however that percentage price increases are based on the cost of the compactor body alone, not the price of the complete operational unit which also includes the truck chassis and cab. The 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.

The equivalent annualized costs for adoption of the Option 7 regulatory scenario is $18.72 million when the regulatory scenario begins in 1979 and quieting costs are computed through 1993.

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 impacting on the quantity demanded as prices change from present levels.

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* Mathematically, the price elasticity (e) of demand can be defined as:

$$e = \frac{\text{Percentage Change in Quantity Demanded (q)}}{\text{Percentage Change in Price (p)}}$$

$e = \underline{dq/q} = \underline{dq} \cdot \underline{p}$

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 sevices to the consumer.

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%

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 are 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. Lease of compactor bodies will not materially change at 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. Prebuying will occur somewhat 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 annualized costs of regulation for the trial scenario are $15.5 million. This scenario assumes: 1) A regulatory process in which Stage 1 technology is adopted in 1979, Stage 2 in 1982, and Stage 3 in 1985 for all body types; 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 change in price (of the magnitude discussed here.)

The equivalent annualized costs of regulation assuming an elasticity of -1.0 are $13.1 million; assuming an elasticity of 0, the equivalent annualized costs are $17.1 million. In these two cases, the equivalent annualized costs of regulation vary from the original case, decreasing 15.5% or increasing 10.3% from the original estimate of $15.5 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 times 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 January 1, 1979.

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.

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 1979-87 are shown in Table 7-22.

Table 7-23 summarizes the estimated Stage 1 reduction in unit volume in 1979:

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	1.5	—	—	—

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 producted 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 to apply 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 (1979 - 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
1979	186	13,158	21	1,503	55	3,605	110	8,050
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 forecase 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, 1979

Compactor Body Type	Reduction in Annual Volume Units	Reduction in Annual Volume Percent
Front loader	21	1.4%
Side loader	55	1.5
Rear loader	110	1.5
Total	186	1.5

The reduction in unit volume resulting from the adoption of the Stage 1 standard ranges from 21 to 110 units depending on compactor body category, and the total unit reduction is about 1.5 percent of baseline shipments. The largest unit reduction occurs in rear loaders, and the smallest unit and percentage reduction occurs in front loaders. Stage 1 does not reduce industry volume below the 1978 baseline forecast shipment level.

Stage 2

The analysis of the Stage 2 economic impact is based on the regulation taking effect January 1, 1982. However, to facilitate subsequent analysis of proposed regulatory options, adjusted forecasts of demand include the years 1979-1981 in parentheses.

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 1979-90 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]

Compactor Body Type	STANDARD UNITS Elasticity	Percent Price Increase	Percent Decrease in Demand	QUIETED UNITS[2] 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 (1979 - 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
1979(3)	527	12,817	38	1,486	187	3,473	286	7,058	16	800
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.

(3) The years 1979, 1980, and 1981 are separated from other years by a horizontal line. Although they need not be included in a general discussion of Stage 2 technology, proposed Option 7 requires Stage 2 technology to begin in 1979 and thus, the table shows volume impacts for that particular option.

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%

The total reduction in unit volume resulting from the adoption of a Stage 2 standard is about 9.0 percent and ranges from 101 to 668 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.

Option 7 which requires a 78 dBA noise level in 1979 and a 75 dBA level in 1982 requires Stage 2 technology to be implemented in 1979. Table 7-27 shows the volume impacts (annual volume reduction) which would follow from adoption of Option 7.

* 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]

Compactor Body Type	STANDARD UNITS Elasticity	Percent Price Increase	Percent Decrease in Demand	QUIETED UNITS[2] 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.

Stage 3

The analysis of economic impact is based on Stage 3 regulations taking effect January 1, 1985.

Table 7-28 provides the estimated price increases related 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*

	Reduction in Annual Volume	
Compactor Body Type	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.

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 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 cost 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		
	State 1 1978	State 2 1981	Stage 3 1984
Front Loader	9	0	0
Side Loader	0	0	0
Rear Loader	20*	20*	20*

* Exhibit V-13 shows estimated 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. (Ref. 7-1).

Estimates of the excess production capacity available in the year prior to each effective date of 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)

	1978	1981	1984
Front Loader	2	0	0
Side Loader	0	0	0
Rear Loader	6	25	25

The unused capacity will allow prebuying to increase the 1978 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 operations cost.

Stage 2 price increases 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 (1978, 1981, and 1984). 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 reduction in industry volume at Stage 1 is relatively low (186 units). The impact on volume at Stages 2 and 3 is a reduction of 571 and 668 units respectively. 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 is 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 three measures:

A. The annual increase in capital cost required by end user industries in the first year of enforcement. This represents the additional capital 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, 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.

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

Stage 1

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 by the increased unit price.

Table 7-34

TOTAL ESTIMATED FIRST YEAR
INCREASED CAPITAL COSTS FOR
END USER INDUSTRIES - STAGE 1, 1979
$(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

Estimated total annual cost increases in the first year for adoption of a Stage 1 noise standard in 1979 are $1.9 million (Table 7-35).

Table 7-35

TOTAL ESTIMATED FIRST YEAR
INCREASED ANNUAL COSTS FOR
END USER INDUSTRIES - STAGE 1, 1979
$(000s)

Compactor Body Type	Increased Capital Costs Mid-Range Estimates
Front Loader	$ 383
Side Loader	196
Rear Loader	1,368
Total	$1,947

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.

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

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*
Total	$31,651

* Includes $977,000 for quieted rear loaders.

The total estimated increases in annual costs for Stage 3 are presented in Table 7-39.

Table 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

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.

* Summary

Analysis of the resource costs required to quiet solid waste compactor bodies indicates that: The capital costs associated with sound attenuation are significant. 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.

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, and truck chassis on which to mount solid waste compactors are not a major portion of the truck chassis market. Manufacturers are not expected to make design changes as a result of packer body noise attenuation.

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. EPA has established that enforcement of the standards will be at that level which mounts or assembles the compactor body on the truck chassis. An estimated 30 percent of total new bodies are mounted by distributors.

The worst case impact of noise regulation on distributors is considered by applying the following assumptions:

(1) New compactor body sales are $1.75 million (70 percent of $2.5 million).

(2) The average price of a new compactor body is $11,500 (the average list price of a rear loader) and the average distributor sells 151 bodies annually.

(3) The distributor mounts 45 of the 151 bodies sold (30 percent of 151).

(4) The revenue derived from mounting bodies is between $300 to $500 per unit. For the 45 mounted annually, total revenue is between $13,500 and $22,500.

(5) The above estimated revenue loss represents between .5 and .9 percent of current sales.

It is not believed that loss of these revenues will directly impact total net profit before taxes since costs will also be reduced.

D. End Users

The potential impact of 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 purchase of a 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 the following table that the total packer truck price increases are more moderate than previously presented:

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 expected that price increases will reduce overall demand for packer bodies in both the private hauler and municipality end user segments. 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.

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	Depre-ciation	Mainten-ance Cost	Operating Cost	Impact Mainten-ance Cost	Total	
Stage 1							
Front Loader	$129	$185	0	$-104	$45	$255	.58
Side Loader	56	80	0	- 90	18	64	.15
Rear Loader	86	123	0	- 90	18	137	.31
Stage 2							
Front Loader	$238	$342	0	$-104	$45	$521	1.19
Side Loader	196	280	$60	- 90	18	464	1.06
Rear Loader	226	323	60	- 90	18	537	1.22
Stage 3							
Front Loader	$258	$369	$13	$-104	$45	$581	1.32
Side Loader	214	307	73	- 90	18	522	1.19
Rear Loader	244	350	73	- 90	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)

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 investment levels are not expected to result from regulation.

Assessment of regulation impact on overall industry employment levels involves consideration of the expected reduction in units produced and the incremental labor required to intergrate the new technology. These factors are considered for each regulatory level in the following paragraphs.

* 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 Loaders	180	9	5.0	39	21.7	39	21.7

Note that direct labor inputs to produce units increase from 5.0 to 6.2 percent depending upon body type. A net increase in employment is expected under Stage 1.

* Stages 2 and 3

Demand reduction 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. It can be seen in Table 7-42 that these reductions are more than off-set by increases in direct labor inputs 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

*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).

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 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 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 will 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 of mix of product offering are expected.

Distributive 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 to 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 of its operations. Through adjustments in planning, future over-capacity, unemployment and other adverse conditions are avoided.

* Assessment

The adoption of the noise emission levels suggested for study will have the following probable effects:

A. Stage 1 — 1979. 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 unemployment would be anticipated.

B. Stage 2 — 1982. Adoption of a Stage 2 standard will 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 will result in an overall 4 percent decrease in domestic solid waste compactor body demand. The growth pattern of the solid waste compactor body industry will remain at the baseline average annual rate. No unemployment is anticipated.

C. Stage 3 — 1985. Compactor body price increases for Stage 3 range from 13.7 to 28.0 percent. Demand is expected to decrease by 4.3 percent. No unemployment is anticipated and the growth of the industry will 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 will occur from these changes.

Summary:

In this section, the economic impact has been assessed based on required product technology modifications provided by EPA. A brief summary of the results are:

A. Equipment prices will increase as shown in Table 7-43 and will be passed on to end users.

TABLE 7-43
SUMMARY OF ESTIMATED 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. 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 (1979)	Stage 2 (1982)	Stage 3 (1985)
Front Loader	21	44	55
Side Loader	55	231	293
Rear Loader	110	296	320
Total	186	571	668

SOURCE: Tables 7-24, 7-28 and 7-33

Stage 1 will result in an overall 1.5 percent decline in unit volume Stage 2 in an overall 4.0 percent decline in unit volume, and Stage 3 in an overall 4.4 percent decline.

C. The cost of noise abatement is presented in Table 7-45.

TABLE 7-45

SUMMARY OF THE RESOURCE COSTS ASSOCIATED WITH NOISE ABATEMENT $(000s)

	First Year of Enforcement	
Noise Standard	Capital Costs	Annual Costs
Stage 1 - 1979	$10,881	$1,947
Stage 2 - 1982	27,431	6,520
Stage 3 - 1985	31,651	6,903

The cost of noise attenuation is high in relation to the total 1974 dollar volume of the solid waste compactor body market of approximately $125 million.

D. There will be little effect on upstream component suppliers, or downstream distributors or end users.

E. There will be no effect on factory operations at any of the regulatory levels.

F. No unemployment is expected to occur at any of the regulatory levels.

G. No changes in import and export patterns will 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 is no expected disruptive impacts from adoption of noise standards.

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 estimat 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 impacted by noise regulation.
4. Collected component cost data from suppliers, manufacturers and end-users.
5. Utilized industrial engineering analysis of production and en-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 production process, the level of vertgical integration in manufacturing major components, and the nature of other products being made at these plants.

The basic manufacturing process for compactors was similar among the manufacturers though 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, Analysitcl Financial Reports for selected companies. The contractor'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 7-46

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%

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 material sourcing, 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 7-45, 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 (Reference 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 manufacturer labor versus capital intensity is considerable, the EPA contractor concluded that the proposed noise control technology would not have a significant impact on either existing manufacturing operations or labor content and thus 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 production.

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 effect the existing make versus buy mix. It can be assumed that those components presently purchased will still be purchased after quieting and that the same type of purchase economics 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 EPA contractor concluded that the proposed noise control technology would not result in any major changes or disruptions in the existing patterns of operation. Consequently, the contractor 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 7-47

ESTIMATED UNIT PRODUCTION
OF A TYPICAL COMPANY

Manufacturers of:	Typical Company Production (units/year)
Front Loader	200
Side Loader	300
Rear Loader	400

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 contractor's experience in similar industries. The following cost and profit estimates are assumed to be representative of the "typical" company:

TABLE 7-48

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.

This breakdown shows that direct material represent the largest cost element and that 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 fo 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%

REFERENCES

SECTION 7

7-1. A Study to Determine the Economic Impact of Noise Emissions Standards in the Speciality 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 Magazine, May 1975.

7-3. Residential Collection Systems, U.S. Environmental Protection Agency (530/SW-97C-1), March 1975.

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 these regulations and 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 may be present to observe any testing required by these regulations. In addition, Enforcement Officers under previously promulgated 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.

The enforcement strategy proposed in these regula tions 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 during the two year acoustical assurance period 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 that configuration's expected sound level degradation factor (SLDF) 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 in Sandusky, Ohio, or at any other site the Administrator may find appropriate. When the Administrator tests a product, that test becomes the official test for that model. The manufacturer is afforded an opportunity to invalidate any test that the Administrator conducts.

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 and any additional parameters that a manufacturer or the Administrator may select. The basic parameters for configuration identification include the types of truck engine, exhaust and transmission, compactor capacity, and power taken off type or auxiliary engine type.

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 at the end of their defined acoustical assurance period (based on tests or on engineering judgement) are consistently representative of other configurations. In such a case, that product which emits the highest noise level at the end of the defined acoustical assurance period would be the only configuration requiring verification testing.

The 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 and fuel type, compactor type, compactor power system and hydralic power system. Again, the manufacturer may designate additional categories based on additional parameters of his choice.

Within a category, the configuration estimated by the manufacturer to be emitting the greatest A-weighted sound pressure level at the end of the two year 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 at the end of the acoustical assurance period complies with the applicable standard. This can eliminate the need for a substantial amount of testing. However, it must be emphasized that the loudest configuration at the end of the acoustical assurance period must be clearly identified.

These proposed regulations also provide that the Administrator may test products at a manufacturer's facility using either Agency equipment or the manufacturer's equipment. This will provide the Administrator with an opportunity to determine that the manufacturer's test facility and equipment are technically qualified as specified in section 205.204 for conducting the tests required by this subpart. If it is determined that the equipment and/or facilities are not technically 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 must be filed by the manufacturer before any products of the configuration represented 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 minus the SLDF 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, the production verification of a configuration is automatically waived by the Administrator for a period of up to 45 consecutive days without the manufacturer's request provided that the test is performed on the first day that the manufacturer is able. This procedure will minimize disruptions to manufacturing facilities. The manufacturer may request an additonal extension of up to 45 days if it is demonstrated that weather or other uncontrollable conditions prohibited testing during the first 45 days. However, to avoid any penalties under these proposed regulations, the manufacturer must test for purposes of production verification on the first day that he is able.

If a manufacturer proposed to add a new configuration to a product line or change or deviate 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 and/or categories. The considerations that are cited in the regulations 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 is made a part of this enforcement strategy in order to determine whether production products continue to comply with the standard.

SELECTIVE ENFORCEMENT AUDITING

Selective enforcement auditing (SEA) is the term used in this regulation 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, including the acoustical assurance period 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 batch 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 randomly select the sample from the first batch of products of the specified category or configuration that is scheduled for production. (The purpose of the random selection is to ensure that a representative sample is drawn.) The Administrator also reserves the right to designate specific products for testing. Generally, a batch will be defined as the number of products produced during a time period specified in the test request. A batch defined in this manner will allow the Administrator to select batch 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.

The particular type of inspection plan which has been adopted for SEA of compactors is known as sequential batch sampling. Sequential batch sampling differs from single sampling in that small test samples are drawn from sequential batches rather than one large sample being drawn from a batch. This sampling offers the advantage of keeping the number of products tested to a minimum when the majority of products are meeting the standard.

Once the test sample of a batch has been selected from the batch sample, each item is tested to determine whether it meets the prescribed criterion; this is generally referred to as inspection by attributes. The basic criteria for acceptance or rejection of a batch is the number of sample products whose parameters meet specification rather than the average value of some parameter.

The sampling plans (A, B, C, and D) are arranged according to the size of the batch from which a sample is to be drawn. Each plan specifies the sample size and acceptance and rejection number for the established acceptance quality level (AQL). As applied to compactor noise emissions, this AQL is the maximum percentage of failing products that for purposes of sampling inspection can be considered satisfactory.

A product is considered a failure if it exceeds the noise emission standard minus the SLDF. An 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 in the batch is less than the AQL and the batch is accepted. On the other hand, if the number of failing products in the sample is equal to or greater than the rejection number, then there is a high probability that the percentage of noncomplying products in the batch is greater than the AQL and the batch fails. Since the sampling strategy involves a sequential batch sampling plan, in some instances the number of failures in a test sample may not allow acceptance or rejection of a batch so that continued testing may be required until a decision can be made to either accept or reject a batch.

Regardless of whether a batch is accepted or rejected, failed products would have to be repaired and/or adjusted and pass a retest before they can be distributed in commerce.

The proposed regulation establishes two types of inspection criteria. These are normal inspection and 100 percent testing. Normal inspection is used until a decision can be made as to whether a batch sequence is accepted or rejected. When a batch sequence is tested and accepted 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 batch sequence is tested and rejected, then the Administrator may require 100 percent testing of the compactors of that category or configuration produced at that plant. The Administrator will notify the manufacturer of the intent to require 100 percent testing. The manufacturer can request a hearing on the issue of noncompliance of the rejected category or configuration.

Subparagraph (1) of section 205.207-1(d) pertains to batches which consist of three or less compactors. The subsection requires that each compactor in that batch be tested and comply with the noise emission standard minus rhw SLDF. This subparagraph will allow testing to take place within a more reasonable period of time when a test request is issued for particular categories or configurations which are not produced in a sufficiently high volume for the normal SEA scheme to be applicable.

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 proposed approach is to establish the time limit on a test-time-per-product basis, taking transportation requirements, if any, into consideration. The manufacturer would be allowed a reasonable amount of time for transport of products to a test facility if one were not available at the assembly plant.

The Administrator estimates that the manufacturers can test a minimum of five (5) compactors per day. However, manufacturers are requested to present any data or information that may effect a revision of this estimate.

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 criminal 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 and during the two year acoustical assurance period were distributed in commerce, such 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 proposed 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 production verified, and (3) cease to distribute products for failure to test.

In addition, 40 CFR §205.4(f) provides for cease to distribute orders for substantial infractions of the regulation requiring entry to manufacturers' facilities and reasonable assistance. 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 to 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 has been used so as to avoid disruption of marketing and distribution patterns.

APPLICABILITY OF PREVIOUSLY PROMULGATED REGULATION

Manufacturers who will be subject to this regulation 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 manufacturer's actions taken in compliance with this proposed regulation and for granting exemptions from this proposed regulation for testing, pre-verification products, national security reasons, and export products.

ACOUSTICAL ASSURANCE PERIOD COMPLIANCE

The manufacturer is required to design, build, and equip compactors subject to this regulation so that the products comply with the standard during the acoustical assurance period provided that they are properly maintained, used, and repaired.

EPA does not specify what testing or analysis a manufacturer must conduct to determine that his product will be in compliance throughout the acoustial assurance period of this regulation. However, these regulations require the manufacturer to make such a determination and maintain records of the test data and other information upon which the determination was based. This determination may be based on information such as testing of critical noise producing or abatement components, rates of noise control deterioration, engineering judgements based on previous experience, and physical durability characteristics of the product.

An SLDF is the degradation (sound level increase in A-weighted decibels) which the manufacturer expects will occur on a configuration during the two year acoustical assurance period. The manufacturer must determine an SLDF for each of his product configurations.

To ensure that the products will meet the noise standard throughout the two year accoustical performance period, they must emit a time of sale sound level less than or equal to the noise standard minus the SLDF. A product is in compliance only if its measured dBA level, added to the SLDF, is less than or equal to the applicable standard. Production verification and selective enforcement audit testing both embody this principle.

All compactors must emit a sound level that is less than or equal to the standard at the time of sale, so a negative SLDF cannot be used. A product that becomes quieter during the two year accoustical performance period must still meet the standard on the day of sale; so an SLDF of 0 must be used for that configuration.

As stated above, the Agency is not requiring durabilty testing as a matter of course, however, should it be necessary, §13(a) of the Noise Act authorizes EPA to require the manufacturer to run such tests on selected compactors.

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 proposed Federal regulation of new trash compactor trucks will preempt new product standards for the local and state level* 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 reviewed available literature and conducted a survey to determine the number of existing regulations that are applicable to refuse truck noise and that may be affected by the proposed Federal regulation. In the following subsections, the findings of the review are summarized.

LOCAL LAWS APPLICABLE TO REFUSE TRUCK NOISE

This section of the report presents the results of a detailed study of nineteen local noise laws, which are specifically applicable to refuse truck noise. In this study, the sources listed below were reviewed.

- Compilation of noise laws maintained by the Technical Assistance Division of the EPA Ofice of Noise Abatement and Control
- Compilation of noise laws maintained by Dr. Clifford R. Bragdon of the Georgia Institute of Technology
- Noise publication data base maintained by Informatics for the EPA Office of Noise Abatement and Control

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*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.

- Noise abatement staff at each of the EPA Regional Offices
- State noise abatement staffs.

The study showed that there are presently nineteen city and county laws specifically applicable to truck-mounted solid waste compactor noise in the United States. These laws are summarized in Table 9-1, where it can readily be observed that there is a great deal of variation from one jurisdiction to the next. Of the nineteen laws, eight specify sound levels for the product. All the remainder have curfew provisions, usually applying only to residential areas, prohibiting night collections of garbage.

Interviews with the local people involved have revealed that five of the refuse truck noise laws have not been enforced to this date. For the remaining laws, which are in fact being enforced, the approach has generally been to try to get the cooperation of the scavenger companies through negotiation rather than to bring them into court. The study has found that there have been gargabe truck noise court prosecutions so far only on Cook County, Illinois, and Littleton, Colorado. All these prosecutions have been for curfew violations.

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 50 feet. Those regulatons which call for a different measurement distance are shown in terms of equivalent 50-foot levels, assuming 6 dB per double-distance spreading

Table 9-1

LOCAL SOLID WASTE COMPACTOR TRUCK NOISE LAWS

Jurisdiction	Regulation Applies to	Level dB(A)	Distance (ft.)	Curfew Hours	Effective Date	Administering Agency	Site of Enforcement	Penalties	Comment
Los Angeles, Calif.	Scavenger Operations	None	—	[illegible]	[illegible]	Police Department	Streets	Fine up to $500, imprisonment up to 6 mo.	Curfew only.
San Anselmo, Calif.	Compactor	75	50	None	[illegible]	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	12/31/73	Environmental Quality Dept., Noise Abatement & Control	Streets	Fine up to $500, imprisonment up to 6 mo.	Amendment of law of 1977 removed source noise level limit of 85 dB(A) @ 50 ft.
San Francisco, Calif.	Compactor	80 75	50 50	None	3/18/73 3/18/78	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 measurement of street operations of compactors by mobile enforcement units.
San Jose, Calif.	Vehicle	75	25	6 pm-6 am	10/15/75	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	76	50	None	2/75	Police Department	Streets	Fine up to $300	
Englewood, Col.	Scavenger Operations	None	—	10 pm-7 am	7/10/74	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.
Lakewood, Col.	Scavenger Operations	None	—	10 pm-7 am	8/9/73	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	—	9:30 pm-7 am	12/18/69	Police Department	Streets	Fine up to $300 for second offense	Curfew only.
Dubuque, Iowa	Scavenger Operations	None	—	9 pm-7 am	6/8/76	Police Department	Streets	Fine up to $100, imprisonment up to 30 days	Curfew only. Residential areas.
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	95	30	10 pm-7 am	3/75	Health Department	Streets	Fine up to $500, imprisonment up to 90 days	
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 $1000, 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 82 day 83 night	50	7 am-9 pm 9 pm-7 am 7 am-9 pm 9 pm-7 am	1/14/75 1/14/78	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.
Ogden, Utah	Scavenger Operations	None	—	7 pm-6 am	5/15/73	Health Dept.	Streets	Fine up to $300, imprisonment up to 30 days	Curfew only. Applies in areas zoned residential.
Salt Lake City, Utah	Scavenger Operations	None	--	[illegible] pm-7 am	8/16/72	City-County Health Dept.	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	—	8 pm-7 am	11/16/72	Dept. of Environmental Control	Streets	$25-300 fine, up to 6 mo. imprisonment	Curfew for residential zones.

of sound. It can be observed that the levels range from 87 dB(A) at 50 feet for Toledo to 75 dB(A) at 10 feet for New York City [equivalent to about 61 dB(A) at 50 feet].

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 order of discussion is cities first and then countries, with cities addressed in alphabetical order by the states in which they are located. The text of the refuse truck noise provisions for each jurisdiction is presented in Appendix A.

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 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 year-old 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, found in none of the other laws analyzed, that states the noise is "not unlawful if sound deadening devices are used

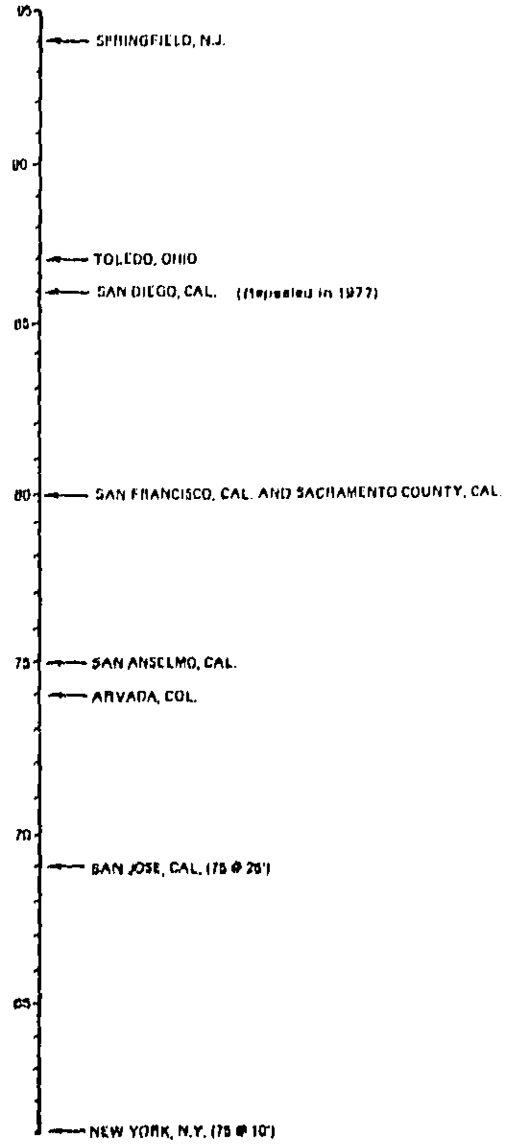

Figure 9-1. Range of Maximum Source Levels for Solid Waste Compactor Trucks in Noise Ordinances*

*All levels not measured at 50 feet have been normalized to an equivalent 50 feet level.

to the extent reasonably feasible." Nominally the law is to be enforced by the Police Department on an in-use basis, with violations of the law treated as infractions. Up to the present, however, the law has not yet been enforced, and no sound level measurements have been made on refuse trucks.

3. San Diego, California

The former San Diego noise law was one of two in the nation which had contained both a curfew provision and a maximum source level provision for refuse trucks (the other is Salt Lake County, Utah). However, an amended version of the law was adopted in March, 1977 which strikes the source level provision and leave only the curfew. The maximum source noise level provision was repealed because it was not found to be as effective as the curfew.

The noise law in San Diego is administered by the Noise Abatement and Control Administration of the Building Inspection Department. This is one of the more active noise programs in the nation. Since April 1976 they have been performing noise measurements of solid waste compactor trucks at a test site near the Chollar landfill. The measurements are made at a distance of 50 feet at four points: front, rear, and both sides. The tests are 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 are recorded for each test. Scavenger companies receive copies of the test reports on their vehicles and are required to correct vehicles found to be excessively noisy.

The garbage truck curfew provision of the San Diego noise law is also 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 presently has the most active refuse truck noise abatement program of any city in the United States. The noise standard of 80 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 conducted on the morning of November 6, 1975. After locating a refuse truck on the street, an Environmental Health man pulled his car up 50 feet to the rear of the truck. This particular truck was a rear-loader No. 3941, operated by Co. F, having a Co. I compactor and a Co. 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.

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 when trucks have been found to be over the limit. The scavengers have generally been cooperative in retrofitting their trucks when necessary to make the 80 dB(A) 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 noise law has been in effect for a year, but no enforcement actions have yet been taken against refuse trucks. Arvada has not yet made any refuse truck measurements.

The administering agency for the noise law is the Police Department. Penalties up to $300 are provided for violations.

7. Englewood, Colorado

The Englewood, Colorado, refuse truck noise provision was apparently patterned after that of Lakewood, Colorado. It calls for a 10 p.m. to 7 a.m. curfew on scavenger operations within a residential district or within 300 feet of a hotel or motel.

8. Lakewood, 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 the "soft fuzz" approach. No summonses have yet been issued to scavenger companies for curfew violations. 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.

9. Littleton, Colorado

Littleton, Colorado, is another community located near Denver with considerable noise awareness. There are 30,000 people and 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 NIMLO/EPA model ordinance. There were three or four refuse collection noise complaints per year in the years before the noise ordinance was passed in 1974, and a total of 15 since that time.

The enforcement approach is similar to Lakewood and Englewood in trying to work with the scavengers 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 and has not broken the curfew since. These two convictions represent the only examples outside Cook County, Illinois, where a speciality truck noise case has gone to court. There has not yet been a court challenge to any specialty truck noise law.

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 two convictions, Littleton appears to be receiving co-operation from the scavengers.

10. 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.

11. 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.

12. Princeton, New Jersey

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.

13. Springfield, New Jersey

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 filled in noise levels for the NIMLO/EPA model ordinance. Unfortunately, the level which they filed in 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. No refuse truck noise measurements have been made by Springfield either before or since passage of their noise law. They had one sound level meter which they borrowed from the State Department of Environmental Protection but they have since given it back.

The Springfield noise law also contains a curfew provision of 10 p.m. to 7 a.m., which is apparently not being enforced. They receive about 5 complaints per year of 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 they interfere with logistics of getting to the dump on time. No citations have been issued to the scavengers.

Besides its own difficulties, the Springfield, New Jersey, noise law is also under legal challenge for its zone-ambient noise provisions. A local quarry has been cited for noise violations and intends to fight the law in court. None of the municipal officials interviewed had information on the current status of this challenge or whether it applied to the whole law or just one provision.

Apparently the noise law had been passed primarily with the quarry in mind, with the refuse truck provisions as an afterthought. There was no input from the scavenger 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.

In summary, the Springfield, New Jersey, noise law has been unsuccessful in dealing with refuse truck noise, due both to the law itself and to its enforcement program.

14. New York, New York

The New York noise ordinance as amended provides a maximum noise level of 75 dB(A) at 10 feet for vehicles manufactured after December 31, 1974. The law as presently worded 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 75 dB(A) with the slow scale. The New York City Environmental Protection Agency has measured newly manufactured refuse vehibles which meet the relaxed requirement. However, the law contains a provision to ratchet the level back down to 70 dB(A) on December 31, 1978.

Since the law exempts the city's own fleet of garbage trucks, the only enforcement would be against newly manufactured privately operated trucks. So far the law has not been enforced against them, because of other problems affecting refuse collections in New York City and because other noise enforcement has had higher priority.

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 if one is promulgated by EPA.

15. 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 87 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. The law also contains a ratchet provision to lower the permitted daytime noise level to 82 dB(A) in 1979. 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.

16. 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.

17. 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 law are fines up to $299 and improsinment of up to 6 months.

18. 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 among all those in the nation 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 numbe. Fines of $50 are typically required. Since the law was enacted, there have only been two firms cited more than once. Generally the scavengers 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 now 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. In all the prosecutions there has never been a challenge to the law itself.

19. Sacramento County, California

The Sacramento County, California, noise ordinance was recently passed and has an effective date of July 1, 1976. The maximum refuse truck noise level provision of 80 dB(A) at 50 feet, however, has an effective date of January 1, 1977. This level is slated to ratchet down the 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.

Although the new law has a maximum penalty of a $500 fine or 6 months imprisonment, the Environmental Health Office does not plan to issue citations for refuse truck noise once that provision goes into effect. Instead the San Francisco approach will be used which is working with the scavengers in trying to get them to retrofit their trucks or buy quieter new ones.

OTHER MUNICIPAL NOISE LAWS

The nineteen noise laws discussed above were of the most immediate interest because:

- They specifically mentioned either waste compactors or garbage collection.
- They are presently in effect.

Each of the above laws was discussed in detail here and summarized in Table 9-1. The full texts of their noise provisions are provided at the end of this section.

Besides these nineteen laws there are others worthy of mention, but not of as immediate interest because they are still drafts, not yet in effect, already repealed, or do not specifically mention the product. Those laws having a motor vehicle provision usually have a general truck provision which can be used against specialty trucks when they are in motion. Of course, the non-quantitative nuisance noise laws can also be applied to refuse trucks.

Those noise laws (and draft laws) which mention refuse trucks but have not been treated in detail because they are not presently in effect are the following:

- Cape Canaveral, Florida--repealed. It had a maximum of 80 dB(A) at 50 feet, but it was never enforced. The successor noise law has no refuse truck provision.
- Kansas City, Missouri--early draft. An early draft had a provision for 70 dB(A) at 10 feet, like the original New York City Noise law. The present draft has removed the provision.
- Cleveland, Ohio--still in draft. It has a 10 p.m. to 7 a.m. curfew for scavenger operations.
- Portland, Oregon--early draft. An earlier draft had a provision of 70 dB(A) at 25 feet for newly manufactured refuse compacting vehicles. The present draft has removed this provision.
- Harrisburg, Pennsylvania--early draft. It applied to the "loading and unloading of garbage cans" rather than to the compactor or the vehicle. It called for a maximum level of 15 dB(A) above ambient as measured at the property line for 10 percent of the measurement period which must be at least 10 minutes long. The present draft has removed all mention of refuse trucks.

o Salt Lake County, Utah - early draft. It specified a maximum level of 80 dB(A) at 25 feet for solid waste compactors, measured at the rear. There was also a curfew of 9 p.m. to 7 a.m. provided for collections. Penalties called for in the law were fines up to $299 and imprisonment up to 6 months. An amended version of the Salt Lake County noise law is now being considered and may be adopted in the near future. This amended draft does not contain the maximum noise level provision.

Conclusions - Local Refuse Truck Noise Laws

The above analysis discussed in detail the nineteen local refuse truck noise law which are presently in effect and have also noted those laws that were repealed or stayed in draft form. The analysis indicated that the refuse truck laws specifying curfews have generally been more successful than those specifying maximum levels. In cases where a law specifies both a curfew and a maximum level, it has been the curfew enforcement which has reduced the number of complaints.

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 to an area, they appear to offer the best possibility of relief from refuse collection noise. A vigorous enforcement of the curfew is a necessary factor in such an approach.

STATE LAWS APPLICABLE TO REFUSE TRUCK NOISE

A search of all state noise laws has established that there are none which apply specifically to solid waste compactor truck noise. However, 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 follow below:

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 eleven local jurisdictions discussed in the previous section. As of this writing, however, none of the municipalities in Florida has yet adopted the suggested wording for its own ordinance.

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;

(b) Operate or permit 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 Ordiance, 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 way recommended in the NIMLO/EPA model ordinance. The difficulty in the above model 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. Subsequent editions of the New Jersey Model Community Ordinance will have this error corrected.

Besides the Florida and New Jersey model ordinances the only applicable state laws found were the state laws 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:

- o 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

This regulation was promulgated by EPA under authority of the Noise Control Act of 1972. Section 18 of the Noise Control Act requires the Administration 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. Maximum noise level under test conditions established by DOT is 86 dB(A) at 50 feet from 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 or 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, include 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 call for a new truck low speed acceleration passby test 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 were to be regulated under independent rules and operating conditions after the Administrator had 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. This law is more stringent that any presently in effect in the United States. It is comparable to the New York City noise ordinance level of 70 dB(A) at 10 feet which was scheduled to go into effect on January 1, 1977.

An extensive effort has been made to uncover other foreign laws relating specifically to specialty trucks; it appears that the Stockholm law is indeed the only one in existence. There appear to be no specialty truck noise laws in Australia, Japan, Switzerland, or Germany.

MODEL LOCAL SPECIALTY TRUCK NOISE ORDINANCES

This section provides model provisions for local noise laws for solid waste compactor trucks. The general problem is first discussed, then the product is defined and the model law provision is presented.

As can be observed from examining the nineteen 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 we propose here, which combines both, is patterned after the refuse truck provision 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 is as follows:

<u>Refuse Collection Vehicles.</u> No person shall:

(a) On or after (2 years) following the effective date of this ordinance, operate or permit the operation of the compacting mechansim 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;

(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;

(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 modification which we have made to the NIMLO model is to introduce some noise measurement procedures which are used in the San Francisco enforcement program.

(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 one can generate a broad and probably effective ordinance, as follows:

Refuse Collection Vehicles. No person shall:

(a) On or after (2 years) following the effective date on 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 the rear of the vehicle. Measurements shall be made with whatever load is present in the compactor at the time. The measurement shall be that of the average compaction noise level, and peaks due to transient phenomena in the load, such as cans crushing, shall be ignored.

(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 residential area or noise sesitive zones;

(c) Collect refuse with a refuse collection vehicle between the hours of ___ p.m. and ___ a.m. the following day in the residential area or noise sensitive zone.

Note in the above model provision that the noise level measurement distance and hours of the curfew have been left blank. Since this is an in-use noise law the level and distance will be community options, as long as it is consistent with EPA's new product noise law. As EPA noise levels are specified for an empty compactor, some adjustment may have to be made in the 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 curfew hours should be strictly the prerogative 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.

The provisions in the model ordinance for measurement at the rear for load condition as found on the street, and for ignoring transient peak sound levels orginating in the load are all 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, with a standard empty compactor condition. However, repeatability as a primary consideration is better suited to product certification measurements. 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.

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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 unalwful 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, trnasfer, 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 permiteed 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 colletion 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 sounddeadening devices into equipment used in rendering those services.

Notwithstanding the foregoing, it shall be unalwful 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 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.

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

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 and residential except between the hours of 7:00 a.m. and 9:00 p.m. of any day and then only a manner so as not to create a loud or excessive noise.

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 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, 1976	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 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.

<u>Ogden, Utah (5/25/72)</u>

19.9.2. <u>Prohibited acts specifically</u>. The following acts, among others, are declared to be loud, disturbing or unnecessary noises in violation of this ordinance, . . . namely:

L. <u>Garbage trucks</u>. 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.

<u>Salt Lake City, Utah (8/16/72)</u>

Section 39-9-3. <u>Noises Prohibited - Standards</u>. The following acts, among others, are declared to be in violation of this ordinance . . .:

(1) <u>Garbage collection</u>. 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.

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.

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.

SECTION 9
EXHIBIT A

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 or 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 87 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	

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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 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		

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City	Ordinance Regulates	Automobiles	Trucks	Test Procedure
Barrington (Illinois)	Manufacturers Only (Certification 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 or more		
Boulder	Operators Only	80 dbA	*88 dbA	Measured at "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		
I-45 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 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	Measured "not less" than 50 feet from center line of travel
		*Gross vehicle weight of 10,000 pounds or more		
9-46 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 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.			
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, 79 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 1/1/70, 76 dbA under 35 mph 82 dbA over 35 mph	Before 1/1/73, 88 dbA under 35 mph 90 dbA over 35 mph	Measured "not less" than 50 feet from the center line of travel
		After 1/1/70, 70 dbA under 35 mph 79 dbA over 35 mph	After 1/1/73, 86 dbA under 25 mph 90 dbA over 35 mph	
		*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		

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