N-96-01
II-A-57

EPA 550/9-77-250

NOISE EMISSION STANDARDS
FOR CONSTRUCTION EQUIPMENT

PROPOSED WHEEL AND CRAWLER TRACTOR NOISE EMISSION REGULATION

PART 1.
DRAFT ENVIRONMENTAL IMPACT STATEMENT
ECONOMIC IMPACT STATEMENT

PART 2.
BACKGROUND DOCUMENT

JUNE 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 wheel and crawler tractors. The proposed regulation has been published pursuant to the mandate of Congress as expressed in the Noise Control Act of 1972 (86 Stat.1234).

EPA 550/9-77-250

NOISE EMISSION STANDARDS FOR
CONSTRUCTION EQUIPMENT

PROPOSED WHEEL AND CRAWLER TRACTOR NOISE EMISSION REGULATION

PART 1

DRAFT ENVIRONMENTAL IMPACT STATEMENT

ECONOMIC IMPACT STATEMENT

JUNE 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: Noise Emission Regulation for Wheel and Crawler Tractors in Construction Site Activities. This is an Administrative Action.

2. Description of Action: The Environmental Protection Agency's proposed regulation is intended to reduce the level of noise emissions from wheel and crawler tractors used in construction activities for loading and dozing operations. 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 wheel and crawler tractor manufacturing industry. The recommended action proposes to establish noise emission standards for newly manufactured wheel and crawler tractors and to establish enforcement procedures to ensure that this equipment complies with the standard.

The proposed regulation is based on health and welfare benefits to the public which are anticipated to result from reducing noise emissions from wheel and crawler tractors. In arriving at the proposed regulation, the Environmental Protection Agency investigated in detail the wheel and crawler tractor industry, noise control technology, noise measurement methodologies, and costs of compliance. Four major issues were identified which required resolution: (1) identification of machines to be regulated, (2) measurement methodology to be employed, (3) noise levels and effective dates, and (4) accoustical assurance period.

Three types of machines were included as subject to the proposed regulation: crawler tractors, wheel loaders, and wheel tractors. Studies show that the size of the large machines (crawler tractors over 450 horsepower and wheel loaders over 500 horsepower) essentially precludes their transport to and use in areas where significant population noise impact would result. Therefore, these horsepower levels were adopted as upper bounds for machines subject to the proposed regulation.

It was concluded that incremental reductions in equipment noise levels were preferable to a one-step requirement that all equipment meet the most stringent levels achievable and desirable. Identical effective dates were set for all equipment subject to the standaard in order to minimize market impacts from substitution of unregulated machines and to discourage possible shifts in horsepower ratings at the breakpoints of 200 and 250 horsepower.

3. Environmental Impact: Compliance with the proposed standards should, on the average, reduce noise emissions from wheel and crawler tractors by 5 dBA. In terms of reduced impact on the nations' population, the 5 dBA reduction, when considered in combination the portable air compressor and truck regulations, should result in a reduction of approximately 37 percent in the severity and extensiveness of construction site noise impact by the year 1991 (when all trucks, compressors and wheel and crawler tractors in the field will be quieted units). This represents an increase of approximately 10 percent over the benefits that are anticipated from current Federal noise regulation of construction equipment.

Air quality, water quality, land use, solid waste disposal requirements and energy consumption are not expected to be significantly impacted by the noise levels proposed.

4. Economic Impact: List price increases to quiet new wheel and crawler tractors are estimated to range from 2.3 to 7.2 percent, depending on machine type and size. The average list price increase for all machines is estimated to be 4.6 percent.

An economic analysis of the wheel and crawler tractor manufacturing industry indicates a significant price elasticity of demand. Demand could decrease by 3 to 5 percent as a result of the proposed regulation, but total revenues should remain constant as a result of price increases.

Annualized costs to users of wheel and crawler tractors, beginning in 1978 through the year 2000, are expected to increase about $228 million as a result of tractor manufacturer cost pass through plus normal mark-ups, an increase of about 3.4 percent. Compared to projected $189 billion annual construction receipts for the year 1976, this represents a potential increase of 0.12 percent in construction costs per year commencing in 1978.

Employment, regional economics, foreign trade and national GNP will not b e significantly effected by the regulation.

The proposed regulation will support the efforts of the Federal Trade Commission and other organizations to inform and protect consumers.

TABLE OF CONTENTS

PART 1

DRAFT ENVIRONMENTAL IMPACT STATEMENT AND ECONOMIC IMPACT STATEMENT

PART 2

BACKGROUND DOCUMENT

WHEEL AND CRAWLER TRACTOR

ENVIRONMENTAL AND INFLATIONARY

IMPACT STATEMENTS

ABSTRACT

These Environmental and Economic Impact Statements address a proposed noise emission regulation for wheel and crawler tractors. In arriving at the proposed regulation, the Agency carried out detailed investigations of wheel and crawler tractor 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".

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 construction equipment is one.

It has been estimated that over 30 million people located in urban, suburban, and rural areas in the United States are exposed to materials handling, earthmoving, road building, impact and/or special function construction equipment noise levels that jeopardize their health or welfare during the usage of equipment in the following construction activities:

- Domestic housing - including residences for one or several families

- Nonresidential buildings - including offices, public buildings, hotels, hospitals, and schools

  Industrial - including industrial buildings, religious and recreational centers, stores and service and repair facilities

  Public works - including roads, streets, water mains, and sewers

Inasmuch as a number of different types of construction equipment operate at the same time the quieting of only one product type is often not in itself sufficient to adequately reduce the noise from construction sites to a level requistite to protect health and welfare. Accordingly, the EPA's noise regulatory program has effected a coordinated aproach to control overall construction site noise in which pieces of construction equipment, alone or in combination, are evaluated to asses their contribution to construction site noise and attendant impact on the nation's population.

Pursuant to the mandate of the NCA and EPA's approach to the control of construction site noise, noise emission regulations were promulgated on January 14, 1976, for portable air compressors (41 FR 2162) and on April 13, 1976, for medium and heavy trucks (41 FR 15538).

To furthur control construction site noise, noise emission standards for wheel and crawler tractors are being proposed at this time.

Wheel and Crawler Tractors

The Agency determined that regulation of the following machine types is requisite to protect the public health or welfare:

1. crawler tractor - tractor which moves on tracks with or without dozer blades, loader buckets or other attachments

2. wheel loader - tractor with articulated steering and integral bucket apparatus

3. wheel tractor - tractor with rigid frame and integral or non-integral loader bucket or dozer blade and other non-integral apparatus.

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

Machines excluded from this regulation because they have minimal impact on public health and welfare or are not primarily used for loading and dozing operations in construction activities include:

1. wheel loaders with integral backhoes

2. wheel tractors with integral dozer blade linkage

3. skid steer loaders

4. wheel and crawler tractors with attachments - other than bucket or blade apparatus - integral to the machine frame

5. machines manufactured primarily for agricultural, mining or logging operations

6. trenching equipment - self propelled machines used exclusively to produce a continuous trench by means of a digging chain or similar device.

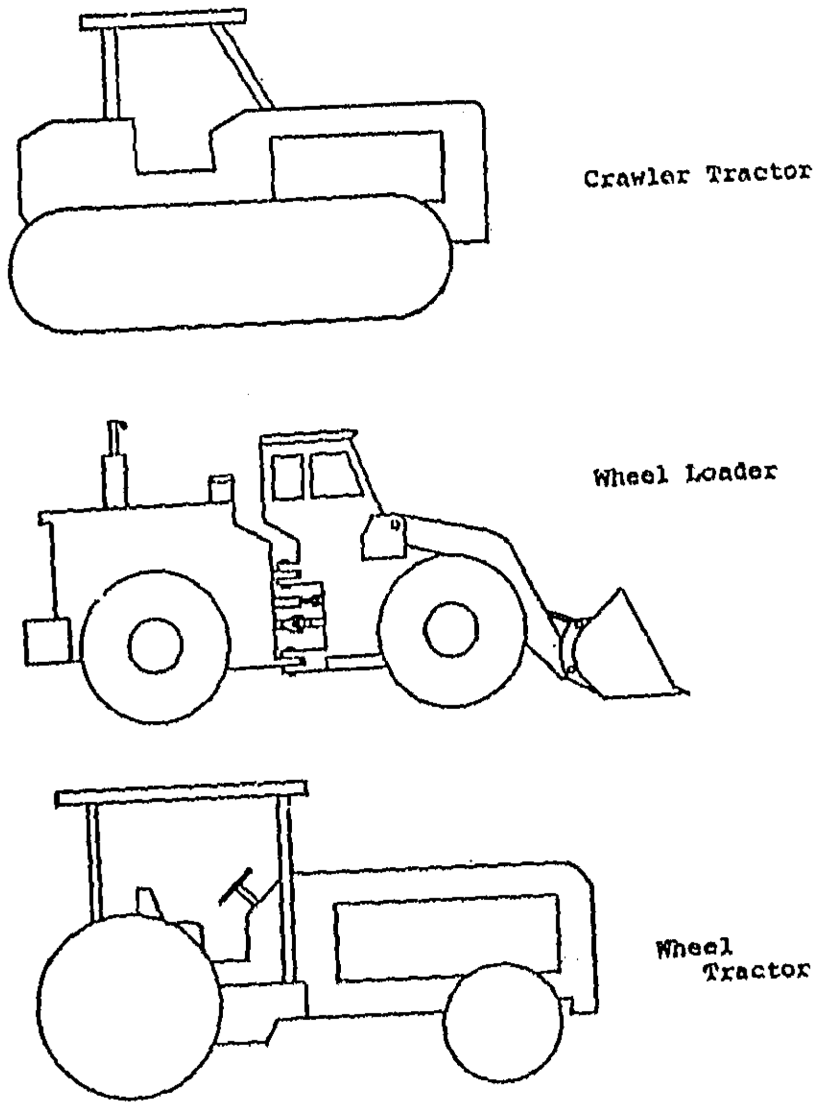


FIGURE 1

Illustration of Three Basic Machine Types

PROPOSED NOISE REGULATION

This proposed regulation is intended to reduce the level of noise emitted from wheel and crawler tractors used in construction activities for loading and dozing operations. It also establishes a uniform national standard for this equipment when it is distributed in commerce, thereby eliminating differing State and local time-of-sale noise emission regulations which may impose a burden on the wheel and crawler tractor manufacturing industry.

Statutory Basis

The proposed action establishes noise emission standards for newly manufactured wheel and crawler tractors 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 regulation are available to EPA: 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 regulation is not feasible.

Wheel and crawler tractors were identified, pursuant to section 5(b)1 of the Noise Control Act of 1972, as major noise sources on May 28, 1976 (40 FR 23069). Subsequent to this identifiecation, comprehensive studies were performed to evaluate wheel and crawler tractor 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 wheel and crawler tractor noise is feasible through available technology taking the 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.

The Agency selected identical effective dates for all regulated equipment in order to minimize market impacts resulting from possible substitution of unregulated machines and to discourage the shifting of horsepower ratings at the breakpoints of 200 and 250 horsepower. An incremental, rather than a single step reduction in noise levels for this equipment was selected because it yields substantial near term benefits with a minimum of industry dislocations.

Table 1
Proposed Noise Emission Standards

		Not-to-Exceed A-Weighted Sound Level (dBA @ 15 Meters)	
		Effective Dates	
Machine Type	Horsepower	March 1, 1981	March 1, 1984
Crawler Tractor	20-199	77	74
Crawler Tractor	200-450	83	80
Wheel Loader	20-249	79	76
Wheel Loader	250-500	84	80
Wheel Tractor	20+	74	74

The estimated health and welfare benefits from this proposed noise emission regulation can only be attained if wheel and crawler tractors meet their not-to-exceed levels for a reasonable period of time. Therefore the Agency has developed the concept of an Acoustical Assurance Period (AAP) to be defined as that period during which the product must meet the standard when the product is properly used and maintained. In the case of wheel and crawler tractors, the AAP will be 5 years or 9000 operating hours, which ever comes first, after sale of the product to the ultimate purchaser.

To ensure compliance with the AAP, the Agency requires manufacturers to develope a Sound Level Degradation Factor (SLDF) for each machine configuration. the SLDF is the degradation (sound level increase) which the manufacturer expects to occur on a given configuration during the specified AAP. This SLDF will be factored into the results of production verification and selective enforcement audit tests of compliance. Compliance will be determined by the ability of the newly manufactured product to emit a sound level equal to or less than the applicable standard.

Enforcement. The EPA will use the following two methods to determine whether wheel and crawler tractors comply with the acceptable noise emission standard:

> Production verification - Prior to distribution into commerce of any wheel and crawler tractor, as defined in this regulation, a manufacturer must submit information to EPA which demonstrates that his product conforms to the standard.

- Selective enforcement auditing - Pursuant to an administrative request, a statistical sample of wheel and crawler 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 affect several other government regulatory effortsz. It will also require supplementary actions by State and local government.

Federal Government Agencies. General Services Administration (GAS) regulations seet maximum sound emission levels for equipment operating on Government property. These will remain in effect.

State and Local Government. Although the Noise Control Act prohibits an State or political subdivision there of 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 identical to the stnadard prescribed by the Federal regulation, primary resoponsibility for control of noise rests with State and local govewrnments.

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 construction site noise. The EPA has developed a model ordinance to indicate the form and content of an instrument whereby State and local governments may control construction site noise in the absense 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.

An EPA sponsored survey of existing regulations applicable to construction equipment revealed few laws, regulations or ordinances which mention wheel and crawler tractors specifically, although some legislation setting limits on construction equipment includes wheel and crawler tractors as examples of such equipment. Most regulation of wheel and crawler tractor noise is presently accomplished indirectly by limiting construction site noise or construction equipment noise.

ENVIRONMENTAL IMPACT

The environmental impacts of the proposed regulation include the primary impact which is reduced annoyance from construction noise resulting from lower wheel and crawler tractor noise and the secondary impacts on other environmental considerations.

Impact on the Population of the United States

Compliance with the most stringent proposed standards will, on the average, reduce noise emissions from wheel and crawler tractors by 5 dBA. In terms of reduced impact on the nation's population, the 5 dBA reduction, when considered in combination with existing Federal standards for new portable air compressors and medium and heavy trucks, should result in a reduction of approximately 37 percent in the severity and extensiveness of construction site noise impact by the year 1991. This represents an increase of approximately 10 percent in additional benefits over those anticipated to accrue from current Federal noise regulations of construction equipments (air compressors and 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. Although wildlife may possibly benefit from reduced noise levels of construction equipment, not enough is known to conclude that the extent of noise reduction achieved by the proposed regulation will actually result in such a benefit.

ECONOMIC IMPACT STATEMENT

SUMMARY

The establishment of noise standards for newly manufactured wheel and crawler tractors gives rise to expenditures which would otherwise not be directly incurred by the private and public sectors. However, it should be understood that we really do not have the option of not paying for noise pollution costs. 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 machine 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 wheel and crawler tractors may increase by 4.6 percent.
2. The demand for wheel and crawler tractors could decrease by 3 to 5 percent, but total manufacture revenue in such a case should remain unchanged due to increased prices.
3. The increase in annualized costs to users (including increased capital cost, operation and maintenance) through the year 2000 is estimated to be about $228 million or an increase of approximately 3.4 percent.

ECONOMIC IMPACT ESTIMATES

Cost of Complinace.

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

Table 2

Estimates of Manufacturer Incurred
Capital and Annual Costs of Abatement
($ Millions 1976)

	Year									
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Capital Cost	4.3	3.7	3.7	2.8	1.0	1.0	0.8	0.0	0.0	0.0
Cumulative	4.3	8.0	11.7	14.5	15.5	16.5	17.3	17.3	17.3	17.3
Annual Cost	3.7	3.7	3.7	50.0	50.0	50.0	97.0	97.0	97.0	97.0

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. Profits are expected to decline only slightly, possibly 0.3 to 0.4 percent over the 22 year period.

Competitive Effects. Nineteen wheel and crawler tractor manufacturers comprise the industry affected by the proposed action in 1977: Eight may be classified as small to medium firms and eleven classified as large. Six of the eight small and medium firms may be placed under capital availability pressures; however three of these firms are already encountering capital availability problems. Five of the eleven large firms would have capital cost of abatement/sales ratios greater than five percent and, because of this, may encounter higher capital borrowing rates than the other firms in the industry in seeking to comply with the regulations.

Direct Effect on Prices

Effect on List Prices. The average estimated increase in list price for each of the five machine classes is displayed in Table 3. The potential cost increases on a per model basis may vary from the average since abatement costs are relatively insensitive to variations between machines. Lower priced vehicles (wheel tractors and small wheel loaders produced by small firms) may have significantly higher cost increase/price ratios.

Table 3
Estimated Average Cost Increase as a Percentage of List Price for Five Machine Classes

Machine Class		Percent Increase
Crawler tractors	20-249	5.4
Crawler tractors	250-500	2.6
Wheel loaders	20-199	5.7
Wheel loaders	200-450	2.3
Wheel tractors-Industrial/Utility	20+	7.2
All Machines		4.6

Effect on Operation & Maintenance Costs. The estimated average annual dollar and percentage O&M cost increases to be faced by users, primarily in the construction, mining and forestry industries, are displayed in Table 4 for each machine class, using a 22-year time frame.

Table 4

Estimated Average Annualized Dollar and Percentage User O&M Cost Increase by Machine Class (1978-2000)

		Dollars (Millions)	Percentage
Crawler tractors	20-199 hp	44.5	3.0
Crawler tractors	200-450 hp	10.0	2.3
Wheel loaders	20-249 hp	25.0	2.5
Wheel loaders	250-500 hp	7.7	2.4
Wheel tractors	20+	26.5	1.2
All Machines		113.7	2.1

Productivity Effects

Regulation of the noise emissions from wheel and crawler tractors is expected to have a negligible overall effect on employment. There may be a modest increase in manufacturing labor required to design, build, and install the necessary noise abatement materials which in turn may be offset by a decline in regular production personel due to a possible decrease in demand for regulated equipment.

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 absorbent materials and other products required for abatement would be expected to experience increased sales.

Impact on Exports. Products manufactured for export only are not required under the Act to comply with the regulation. Accordingly, because the technology studied is essentially modular, machines for export can generally be produced without noise abatement equipment: Therefore, the impact on U.S. exports should be minimal.

Impact on Imports. The proposed regulations will apply to all imported machines. However, the percentage (approximately 2 percent of wheel and crawler tractor sales) is very small. There is no reason to believe that imports will be unable to comply competitively with the standards and thus the proposed regulation should have little or no effect on foreign trade.

Impact on Energy Use. Noise abatement treatments may cause some increased weight for regulated machines resulting in potentially reduced fuel economy, although this is not expected to be significant. The 6-year lead time provided to implement the more stringent noise standards should enable manufacturers to minimize this problem. Some techniques not being generally applied to these machines at this time, such as the use of turbocharging, will both decrease engine noise levels and improve fuel economy.

EPA 550/9-77-250

NOISE EMISSION STANDARDS FOR
CONSTRUCTION EQUIPMENT

PROPOSED WHEEL AND CRAWLER TRACTOR NOISE EMISSION REGULATION

PART 2

BACKGROUND DOCUMENT

JUNE 1977

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

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

FIGURES

FIGURES (Continued)

TABLES

TABLES (Continued)

TABLES (Continued)

TABLES (Continued)

Section 1

INTRODUCTION

CONSTRUCTION SITE NOISE

In recent years, the noise associated with construction projects has been increasingly responsible for the degradation of the urban environment. Equipment associated with construction has grown more numerous. At the same time, the trend towards urban renewal and high-rise structures has resulted in an increase in the amount and duration of construction site activity in densely populated areas. Consequently, many people are now residing or working near construction sites where they may be exposed to unacceptable noise levels for long periods of time.

The most prevalent noise source in construction equipment is the internal combustion engine (usually of the diesel type) used to provide motive and operational power. Engine-powered equipment may be categorized according to its mobility and operating characteristics as:

1) earthmoving equipment (highly mobile),
2) handling equipment (partly mobile),
3) stationary equipment.

Wheel and crawler tractors belong to the first category.

Construction is carried out in several reasonably discrete steps each of which has its own mix of equipment and its own noise characteristics. The phases are: ground clearing, excavation, foundation, erection and finishing. Typical average noise levels [1] at construction site boundaries for each phase of construction activity are shown in Table 1-1.

Table 1-1

TYPICAL ENERGY AVERAGE NOISE LEVEL, Leq (dBA)
AT CONSTRUCTION SITE BOUNDARIES

	Domestic Housing	Office Building Hotel, Hospital School, Public Works	Industrial Recreation, Store, Service Station	Highways Roads, Sewers Trenches
Ground Clearing	83	84	84	84
Excavation	88	89	89	88
Foundation	81	78	77	88
Erections	81	87	84	88
Finishing	88	89	89	84

Regulating the noise emissions of individual pieces of equipment is one method of alleviating construction site noise. Other methods include:

- o Replacing individual operations and techniques by less noisy ones.
- o Selecting the quietest of alternate operations to keep average levels low.
- o Locating noisy equipment away from site boundaries, particularly near noise sensitive land use areas.
- o Providing enclosures for stationary items of equipment and barriers around particularly noisy areas on the site.

These alternate methods may be used, by themselves or in combination, in noise sensitive areas or to meet local environmental noise ordinances. However, noise emission levels for individual products must be regulated on nation-wide basis to avoid the confusion of conflicting local requirements.

If no costs were attendant to the reduction of noise emissions, the construction equipment industry would undoubtedly take voluntary steps to quiet their products. Since noise reduction techniques may increase prices without improving marketability, regulations are needed to ensure that the basic steps are taken uniformly by all components of the industry.

Regulations promulgated earlier by EPA for new medium and heavy trucks and portable air compressors require that a product manufacturer be responsible to the ultimate purchaser for assuring :

1. that the product meets the specified standard(s) when introduced into commerce;

2. that components or parts of the product are not patently defective at time of sale (if the product exceeds the standards as a result of a part which was essentially "defective" a manufacture, the purchaser has recourse to obtain redress from the manfacturer);
3. that the ultimate purchaser is provided with the maintenance requirements necessary for the product to continue to meet the levels required at introduction into commerce, and
4. that parts or components which, if tampered with, will result in the product exceeding the noise standards, are identified.

These is, however, no assurance to the purchaser that the product has been designed and built so that the 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 manfacturer 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 standards 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 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 estimated 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 Acoustic 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 whould specify an SLDF of zero.

STATURORY 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 jeopordizes 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 appropriate Federal agencies, publish a report or series of reports "identifying products (or a classes of products) which in his judgement 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.

Pursuant to subsection 5(b)(1), the Administrator has published in the Federal Register (40FR 23105, May 28, 1975) a report identifying wheel and track loaders and wheel and track dozers as major sources of noise. As required by section 6, EPA shall prescribe regulations on the noise emissions from new wheel and crawler tractors[1] which are requisite to protect the public health and welfare, taking into account the magnitude and conditions of use, the degree of noise reduction achievable through the application of the best available technology and the cost of compliance.

After the effective date of a regulation on noise emissions from a new product, section 6 of the Noise Control Act requires that no State or political subdivision thereof may adopt or enforce any law or regulation which sets a limit on noise emissions from such new products, or components of such new products, which is not identical to the standard prescribed by the Federal Regulation. Subsection 6(e)(2), however, provides that nothing in section 6 precludes or denies that right of any State or political subdivision thereof to establish and enforce 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 by subsection 6(e)(2) include, but are not limited to the following:

1. Controls on the manner in which products may be operated.
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.

[1] The designation has since been changed to wheel and crawler tractors to comply with standard industry nomenclature.

To assist EPA in enforcing regulations on noise emissions from new products, State and local authorities are encouraged to enact regulations on new products offered for sale which are identical to Federal regulations.

Compliance Labeling

The enforcement procedures outlined in section 9 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. The label will also make the buyer and user aware that wheel and crawler tractors possess 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 imported 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 which they handle 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 or absence of a label in the engine compartment. A similar mechanism (labeling) appears viable for use to assess compliance of wheel and crawler tractors with the proposed regulations.

OUTLINE AND SUMMARY OF BACKGROUND DOCUMENT

Background information used by EPA in developing regulations limiting the noise emissions from new wheel and crawler tractors is presented in the following Sections of this document:

Section 2 - The Industry and the Product: contains general information on the manufacturers of wheel and crawler tractors and descriptions of the product, and a discussion of the data used in the development of an Acoustical Assurance Period.

Section 3 - 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 4 - Baseline Noise Levels for New Wheel and Crawler Tractors: presents current noise levels for existing new wheel and crawler tractors.

Section 5 - Health and Welfare: discusses the benefits to be derived from regulating noise emissions from wheel and crawler tractors.

Section 6 - Technology: provides information on available noise control technology and the criteria for determining the levels to which wheel and crawler tractors can be quieted.

Section 7 - Economic Analysis: examines the economic impact of noise emission standards on the wheel and crawler tractor 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 wheel and crawler tractors.

Appendix A - The Docket Analysis (Reserved).

Appendix B - Discusses development of regulatory study levels.

Appendix C - Presents details of individual options.

Appendix D - Lists sources of information consulted in completing this document.

Section 2

THE INDUSTRY AND THE PRODUCT

THE INDUSTRY

The wheel and crawler tractor (loader and dozer) industry is a mature and highly competitive industry. Manufacturers vary significantly in size, financial strength, manufacturing capability, applied technology, marketing ability, and extent of product diversification. Firms in the industry include automobile manufacturers, farm equipment manufacturers, industrial materials handling equipment manufacturers and forestry equipment manufacturers.

Nineteen firms produce tractors domestically. In 1974 these firms had over $1.87 billion in sales and shipped more than 50,000 units worldwide. Domestic sales were $1.195 billion and more than 38,000 units were shipped. These figures exclude utility tractors which had 1974 total sales of $165 million and shipments of 34,000 units.

Firms

Firms in the industry were identified from information provided by industry trade associations, trade publications, other firms, and equipment dealers. Specifications for individual models were obtained from the identified manufacturers and their dealers. Available financial reports, including Value Line, Moody's, and Dun and Bradstreet, as well as information provided by individual firms, was used to assess the financial strength of each firm.

The wheel and crawler tractor industry is comprised of eleven very large and eight small firms. The large firms are: Allis-Chalmers, J. I. Case, Caterpillar Tractor Company, Clark Equipment Company, Deere and Company, Eaton Corporation, Fiat-Allis, Ford Motor Company, General

Motors Corporation, International Harvester, and Massey Ferguson Limited. Each of these firms had 1974 assets of over $250 million with eight having assets in excess of $1 billion. Ten of the firms had 1974 sales of over $1 billion. All of these firms manufacture lines of products other than construction equipment, with the exception of Fiat-Allis, which was formed by two large diversified firms, Fiat and Allis-Chalmers, exclusively to manufacture construction equipment.

The smaller firms are ATP, Digmor Equipment & Engineering Company, Dynamic Industries Incorporated, Hy-Matic Corporation, Owatonna Manufacturing Company Incorporated, Taylor Machine Works Incorporated, TCI Power Products Incorporated, and Waldon Incorporated. Assets of these firms in 1974 ranged from $0.1 million to $15 million, and 1974 sales ranged from $0.2 million to $30 million. Taylor is the only firm that does not market tractors for construction use. However, the equipment it does manufacture is quite comparable to construction equipment.

Figure 2-1 illustrates the range of sales volume for these firms. On the whole, the 11 large firms dominate the market accounting for nearly 98 percent of unit sales volume, and over 99 percent of dollar sales volume.

All but two of these are American firms; Massey-Ferguson is a Canadian firm, Fiat-Allis is a joint venture of Allis-Chalmers and Italy's Fiat S.P.A.

<u>Products</u>

Approximately 175 models of the wheel and crawler tractors produced by domestic manufacturers may be subject to regulations. Wheel loaders dominate the list with 81 models, followed by 70 models of crawler tractors, and 24 wheel tractor models.

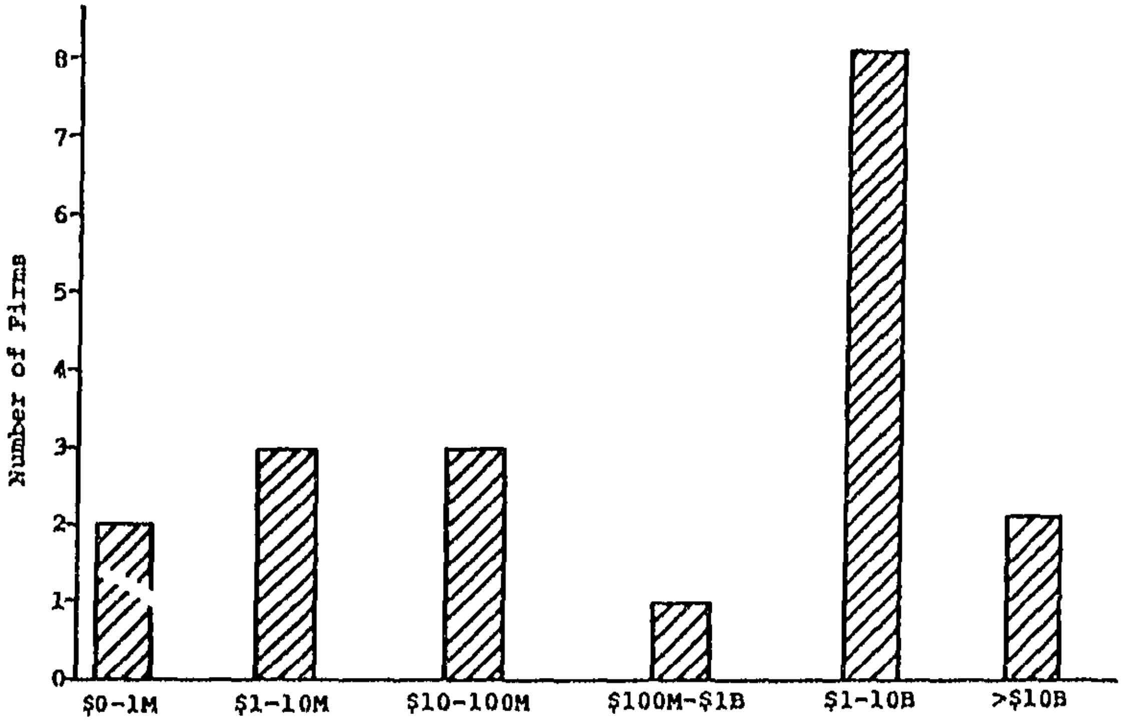


FIGURE 2-1 . Sales Volume of Impacted Firms

Figure 2-2 shows estimated 1976 market shares for these categories, together with estimated unit sales. Historical sales data, divided into 14 product classes, are reported by the Bureau of Census in Current Industrial Reports (CIR), Series MA 35D and MA 35S. Additional inventories on individual model sales were obtained for 12 of the 19 manufacturers. These submissions, together with the CIR data, were used to make model-by-model estimates for the entire industry which are the basis for Figure 2-2. However, estimated sales of each model are not shown in this document to avoid release of any company-proprietary information supplied voluntarily to EPA by individual manufacturers [2,5].

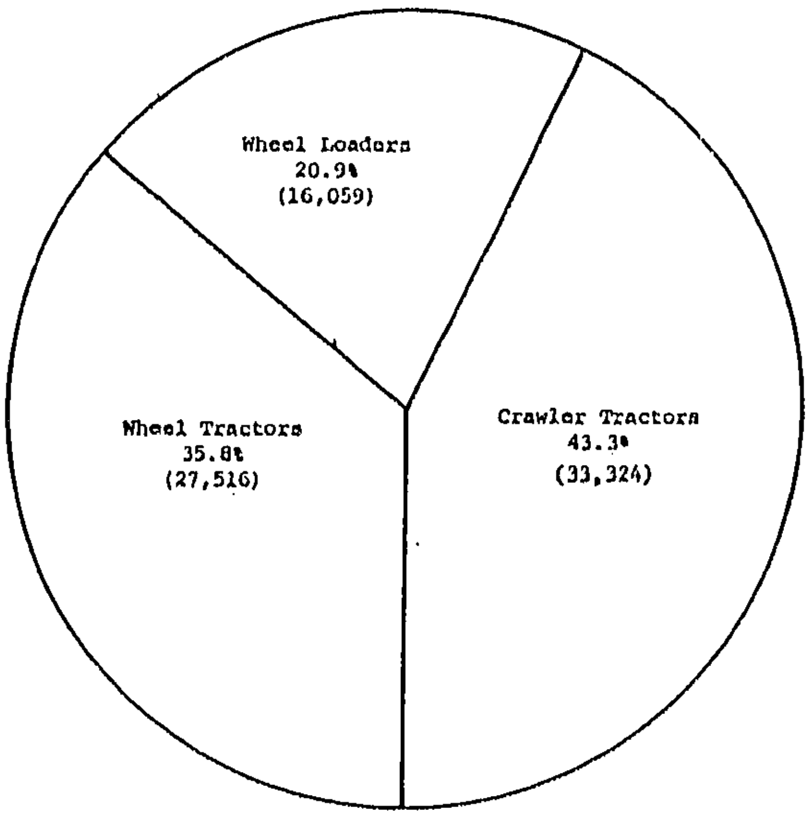
All of the firms produce a wheel loader line. The eight smaller firms and four of the larger firms - Allis-Chalmers, Clark, Eaton and Ford - build only wheel loaders. Six firms - Case, Caterpillar, Deere, Fiat-Allis, International Harvester, and Massey Ferguson - produce crawler tractors. Five of the firms - Deere, Case, Ford, International Harvester, and Massey Ferguson - produce wheel tractors. Table 2-1 shows distribution of impacted equipment produced by these firms. Table 2-2 shows market shares for product classes by size of firms.

Plants

The 19 firms maintain 28 plants within the United States and 6 plants abroad which perform final assembly of impacted equipment for the domestic market. Most of the domestic plants are located in the

---

[2]In 1976, unit sales of impacted equipment totaled approximately 76,899.



Source: EPA Estimates

FIGURE 2-2
Market Share Estimates for Wheel and Crawler Tractors
(1976 Unit Sales)

Table 2-1
DISTRIBUTION OF IMPACTED EQUIPMENT PRODUCT CLASSES
MANUFACTURED BY FIRMS

FIRMS	WHEEL LOADERS	CRAWLER TRACTORS	WHEEL TRACTORS	NUMBER OF IMPACTED PRODUCTS
Allis-Chalmers	3			3
ATT	1		(1)	1[a]
Case	6	10	3	19
Caterpillar	7	13		20
Clark	7			7
Deere	2	5	5	12
Digmor	1			1
Dynamic	3			3
Eaton	8			8
Fiat-Allis	7	15		22
Ford	3			3
General Motors	7	3	7	17
Hy-Matic	1			1
International Harvester	12	13	4	29
Massey Ferguson	6	11	5	22
Owatonna	2			2
Taylor	2			2
TCI	1			1
Waldon	2			2
NUMBER OF MACHINES	81	70	24	175
NUMBER OF FIRMS	19	7	5	19

[a]ATP makes only one machine but it is a cross between a wheel loader and utility tractor.

TABLE 2-2

ESTIMATED U.S. SALES OF CONSTRUCTION LOADERS AND TRACTORS, BY FIRM SIZE
(Units)
Year - 1976

	WHEEL LOADERS	CRAWLER TRACTORS	WHEEL TRACTORS	TOTAL
SMALL FIRMS (Sales <$10 million)	973	_[a]	_[a]	973
MEDIUM FIRMS (Sales $10 to $100 million)	699	_[a]	_[a]	699
LARGE FIRMS	14,378	33,324	27,516	75,218
TOTAL	16,050	33,324	27,516	76,890

[a]Wheel loaders are the only impacted equipment manufactured by small and meduim size firms.

Midwest, particularly in Illinois, Ohio, and Michigan; Figure 2-3 shows the geographical distribution of these plants. Eleven of the firms, including all of the small firms, maintain only one final assembly plant for impacted equipment. While several of the firms producing two or more classes of tractor equipment have only one plant, most have multiple plants. Most of these firms do not segregate equipment classes by plant; Segregation is more likely to occur by vehicle size. Table 2-3 lists distribution of plants by firm.

Competitive Factors of Machine Selection

Competition among producers takes on many forms, including price, equipment durability, service and optional equipment features. Small firms generally use price and equipment innovations to compete in the market for smaller machines.

The buyers of the larger equipment generally are more sophisticated and are concerned with total operation costs over the life of the machine, including purchase price, operation and maintenance, expected machine life, and quality and reliability of manufacturer's service.

A large number of financial, climatic and job-specific factors influence a customer's selection of a specific wheel or crawler tractor and the subsequent decision to purchase or to lease. Generally, a prospective buyer will first determine the type and size of equipment needed and then decide which brand he wants. It is not uncommon for an equipment user to buy one firm's equipment exclusively, allowing his dealer to help him choose the equipment he may need.

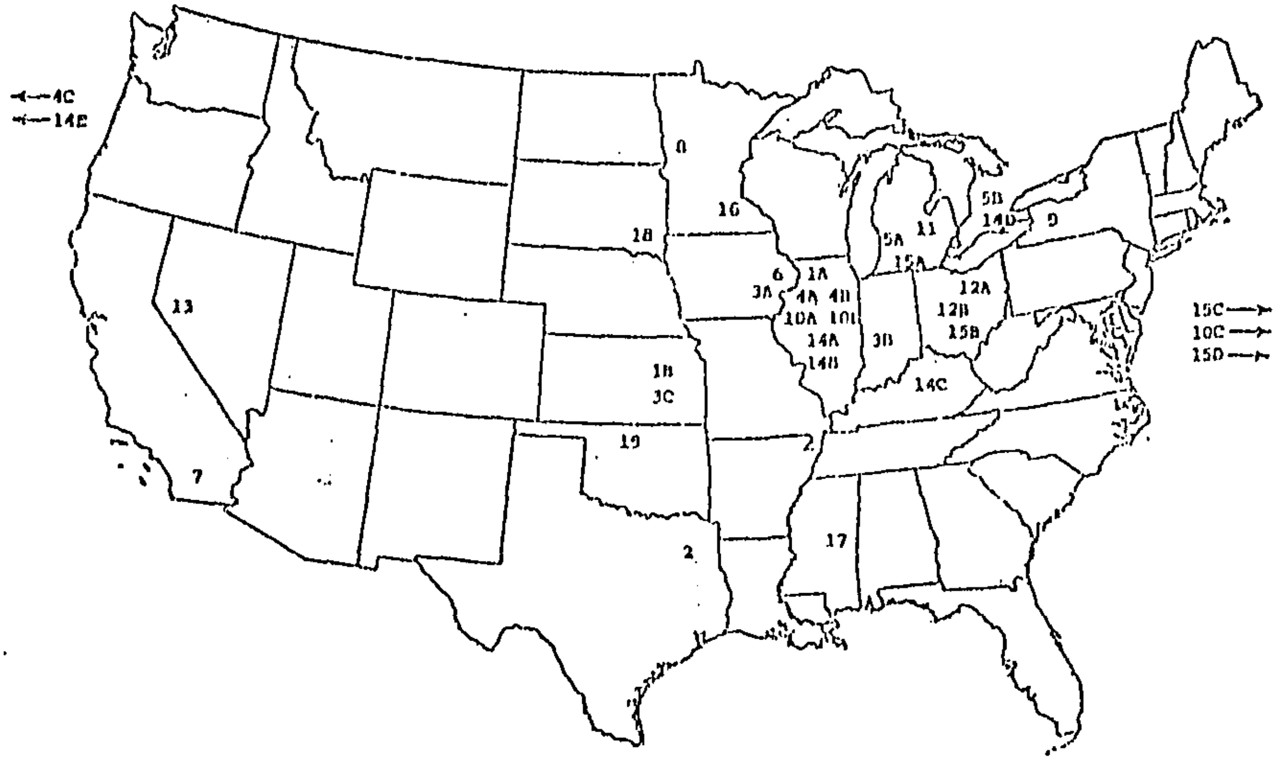


Figure 2-3 GEOGRAPHICAL DISTRIBUTION OF DOMESTIC WHEEL AND CRAWLER TRACTOR MANUFACTURING PLANTS

FIGURE 2-3
(Continued)

KEY:

Code	Firm	Location
1A	Allis-Chalmers	Deerfield, IL
1B	Allis-Chalmers	Topeka, KS
2	ATP	Longview, TX
3A	Case	Bettendorf, IA
3B	Case	Terre Haute, IN
3C	Case	Wichita, KS
4A	Caterpillar	Aurora, IL
4B	Caterpillar	E. Peoria, IL
4C	Caterpillar	Sigami, Japan*
5A	Clark	Benton Harbor, MI
5B	Clark	St. Thomas, Ontario*
6	Deere	Dubuque, IA
7	Digmor	Redlands, CA
8	Dynamic	Barnesville, MN
9	Eaton	Batavia, NY
10A	Fiat-Allis	Springfield, IL
10B	Fiat-Allis	Deerfield, IL
10C	Fiat-Allis	Lecce, Italy*
11	Ford	Romeo, MI
12A	General Motors	Hudson, OH
12B	General Motors	Cleveland, OH
13	Hy-Matic	Sparks, NV
14A	International Harvester	Melrose Park, IL
14B	International Harvester	Libertyville, IL
14C	International Harvester	Louisville, KY
14D	International Harvester	Hamilton, Ontario*
14E	International Harvester**	Tokyo, Japan*
15A	Massey Ferguson	Detroit, MI
15B	Massey Ferguson	Akron, OH
15C	Massey Ferguson	Hanover, Germany*
15D	Massey Ferguson	Aprilia, Italy*
16	Owatonna	Owatonna, MN
17	Taylor	Louisville, MS
18	TCI	Yankton, SD
19	Waldon	Fairview, OK

*Plants outside the United States.

**Two International Harvester wheel loaders are made at the Komatsu plant in Tokyo, Japan.

Table 2-3

DISTRIBUTION OF FIRMS
BY DOMESTIC AND FOREIGN PLANTS
PRODUCING MACHINES FOR DOMESTIC SALES

Name of Firm	Number of Firms Domestic	Foreign
Allis-Chalmers	2	
ATP	1	
Case	3	
Caterpillar	2	1
Clark	1	1
Deere	1	
Dynamic	1	
Eaton	1	
Fiat-Allis	2	1
Ford	1	
General Motors	2	
Hy-Matic	1	
International Harvester	3	
Massey Ferguson	2	3
Owatonna	1	
Taylor	1	
TCI	1	
Waldon	1	

The type of equipment selected depends upon the kind of material to be moved, as well as the climate, terrain, and other site-specific factors. Among loaders, crawler loaders are generally designed for digging and moving applications, while wheel loaders, with larger buckets, often without a cutting edge or teeth, are usually used for loading loose materials. Crawler tractors are designed primarily for bulldozing, while wheel tractors can be put to a variety of uses, depending upon their attachments. Three of the most common attachments for wheel tractors are loaders, backhoes, and trenching equipment.

The size of equipment chosen would optimally depend upon the most efficient application for a particular job; i.e., the earthmoving capacity of the machine would be commensurate with the volume to be moved. Thus equipment size is generally dependent upon the type of service provided, financial strength and work backlog of the customer's company and sometimes on the availability of machines. The cost of a given loader or tractor depends, to a great extent, upon its size. The cost of operation, maintenance, and repair, as well as purchase price, generally are commensurate with machine size.

An important competitive edge can be gained through technical innovation. Most firms maintain research and development programs in order to develop machines with improved performance and durability. New models are continuously entering the market and existing models are constantly being updated with new features. Increases in machine productivity have kept the cost of moving dirt constant from 1930 to 1972 even though machine and labor costs have risen continuously [2].

Research and development expenditures usually run at 2 to 3 percent of sales. Given a $2 billion domestic market and healthy exports, this allows for a conservative estimate of $50-60 million annual expenditures for R&D for affected equipment alone.

All the large firms maintain large ongoing R&D programs to constantly improve products. While smaller firms do not have the resources for major R&D programs, they often come into existence because they offer a radically new concept. These firms are generally formed by former engineers of larger corporations who set out on their own to develop their new techniques. ATP, Dynamic, Hy-Matic, and Waldon exemplify this type of firm. While their equipment is in the same horsepower range with machines produced by the larger firms, these small manufacturers compete more with each other for their specialized markets.

Four of the major improvements in tractors and loaders are:

1. tractor shovel loader (combined operations of power shovel and front end loader)
2. articulated wheel loader (reduced cycle times by facilitating positioning and turning)
3. hydraulic systems (improved bucket loading capability, brake systems and steering)
4. power shift transmission (increased efficiency of load handling and power and speed changes).

While construction and forestry firms are continuously updating equipment, most industrial and mining firms expect to keep their equipment indefinitely. They purchase machines expecting full amortization of their equipment. Large contractors and municipalities have historically purchased new equipment. As more advanced equipment becomes available, these firms will trade in their present equipment, often after only a year of use.

Noise regulations will probably cause a short-term increase in used equipment sales because the price of new quieted machines may rise and make unabated machines more economical for more buyers.

Vertical Integration and Suppliers

All construction equipment contains components purchased from other manufacturers. The degree of supplier involvement varies widely throughout the industry. Suppliers make such important components as engines, drive trains, axles, tires, and attachments that are often sold as standard equipment.

Among the manufacturers of impacted equipment, the degree of vertical integration of component manufacture correlates directly with firm size. The larger producers manufacture most of their component parts, while smaller producers rely heavily on outside suppliers. In some cases these suppliers are the larger firms; in other cases they are independent manufacturers of engines, parts, or attachments. The engine is an important component in the cost of a wheel or crawler tractor. It is also a major noise source. The engine contains the most moving parts and requires considerable service and maintenance.

There are three categories of engine users among the impacted firms:

1. Those which use their own engines exclusively;
2. Those which use their own engines and also purchase those of other manufacturers; and

3. Those which purchase all of their engines.

The distribution of firms by this categorization is displayed in Table 2-4. The nine companies which manufacture their own engines all have sales and assets in excess of $100 million.

TABLE 2-4

ENGINE USE IN IMPACTED PRODUCTS

USE OWN ENGINES EXCLUSIVELY	USE OWN AND OTHERS'	USE OTHERS' EXCLUSIVELY
Caterpillar	Allis-Chalmers	ATP
Deere	Case	Clark
Ford	Fiat-Allis	Digmor
General Motors	Massey Ferguson	Dynamic
International Harvester		Eaton
		Hy-Matic
		Owatonna
		TCI
		Taylor
		Waldon

Of the ten manufacturers using engines supplied by other manufacturers, those producing large machines rely on the engines of Cummins, GM, and Perkins, while the smaller manufacturers, who usually produce smaller machines, are primarily dependent upon Wisconsin, Deutz, and Ford. Of the eleven largest firms, only Clark and Eaton do not manufacture their own engines.

Because of the significant contribution of fan and engine noise to vehicle noise, engine manufacturers are likely to be significantly impacted by noise regulations.

In addition to engines, major components obtained from outside suppliers include:

- o drive train components (transmissions, torque converters, etc.);
- o hydraulic components;
- o undercarriage parts;
- o accessories (blades, buckets).

Certain of the manufacturers specialize in manufacturing components for their own use and/or outside sale, while others buy most of their components and parts. Among the large firms, Caterpillar, Ford and GM make most of their own components, while Eaton and Clark specialize in axles, axle housings, transmissions, and torque converters for use in their own products and for sale to the heavy earthmoving equipment industry. The smaller companies purchase most of their parts and components and engage almost exclusively in final assembly.

Although these components and accessories are only marginally important for noise abatement, a number of independent suppliers could be impacted by noise regulations. If the regulations result in a decrease in demand for new machines, there is likely also to be some decrease in demand for parts and accessories.

Conversely, suppliers of mufflers and other noise abatement equipment may benefit from the promulgation of noise standards.

Product Distribution

Most construction equipment is sold through independently-owned dealerships that practice varying degrees of specialization. Dealers may handle the product line of one major manufacturer or several, and they may limit themselves exclusively to construction equipment or may market everything from lawnmowers to mining equipment.

Company stores include outlets that are either wholly or partially owned by the equipment manufacturer. Their sales in both cases are limited to the owning company's product line and supporting equipment accessories which may be complementary but not competitive. Case is the only one of the impacted firms which sells exclusively through company stores.

Most of the firms in the industry occasionally sell equipment directly to large customers, such as the Federal government. Taylor, among others, has a regular practice of selling directly to commercial or industrial consumers. In most other cases, sales may be directly negotiated with the company, but are actually transacted through a company store.

Dealers (and company stores) have gone to great lengths in order to maintain a solid relationship with customers for their service backup. Dealer service often includes regular weekday shop service, off-hour service, as well as field service. In addition, dealers or manufacturers will often instruct end-users in the proper periodic maintenance of their equipment. Such instructions usually make the contractor independent of the dealer between major breakdowns or overhauls and lowers the cost to the contractor of excessive dependence upon dealer service. Many dealers maintain fleets or radio dispatched service trucks able to perform all but major repair work, on the job site. Dealers also develop large in-house service facilities to provide rapid repair of machines.

Foreign Trade

Exports. The producers of wheel and crawler tractors in the United States currently enjoy an export market approximately 30 percent of total sales. For larger size machines, the export market is greater than its U.S. counterpart. Not surprisingly, the larger firms dominate the export market. They specialize in the larger machines, and they have well-developed service networks, an essential factor in export marketing. Foreign competition is most intense in smaller size machines, which often are assembled by U.S. firms with overseas facilities.

The smaller manufacturers generally concentrate their sales efforts on the domestic market and export only a small percentage of their production. The foreign sales of the smaller companies range from zero to 11 percent of gross sales, and all are direct exports rather than sales by subsidiaries overseas.

Barriers to Trade. Barriers to trade may influence exporting patterns as well as total exports. In particular, tariffs imposed by consuming nations frequently protect domestic industries from competition from abroad.

Another group of trade barriers, used primarily in developing countries, involves "local content" requirements. Foreign nations require that a minimum percentage of the value of a product be contributed by national manufacturers. This trade barrier has caused several domestic manufacturers to open factories in other nations in order to gain entry into the local equipment market. Because of this practice, exports are reduced, even though foreign sales of domestic firms continue to increase. Under this arrangement intra-company transfers and parts shipments still occur, but most sales are generated from locally produced equipment.

Several nations require that local branches of multinational firms be owned in part (generally over 50 percent) by domestic firms. This restriction has caused the formation of numerous joint ventures between domestic manufacturers and foreign firms. Some examples of this are Massey-Ferguson's tractor and engine venture with the government of Iran, International Harvester's venture with Komatsu in Japan, Caterpillar's involvement with Mitsubishi in Japan, and Massey-Ferguson's industrial cooperation agreements with Poland and the Polish tractor industry.

Imports. Imports of impacted equipment are minuscule relative to total sales. Unlike exports, imports are concentrated in smaller machines. In 1974 recorded imports accounted for 2.7 percent of the total apparent unit consumption and 1.9 percent of total dollar consumption. Compared to total domestic shipments including exports, imports accounted for 1.8 percent of the total units and 1.2 percent of total dollars.

The above figures may be somewhat understated since manufacturers often misclassify construction equipment as agricultural. Under the current tariff structure agricultural tractors are allowed free passage

---

[3]Apparent consumption equals total sales from U.S. plants, plus imports, less exports, plus or minus estimated changes in inventory.

into the United States, while construction equipment is subject to a 5 to 5.5 percent duty. Any equipment that can be classified as agricultural (particularly smaller machines) is so listed on its bill of lading and counted as such by the Bureau of Census.

Table 2-5 shows that over 50 percent of all imports, measured in either units or dollars, originate in Japan, with Italy next (22 percent of dollars and 24 percent of units), followed by Canada (14 percent of dollars, 6 percent of units). Wheel loaders represent 56 percent of unit imports and 48 percent of dollar imports of the three types of equipment. Crawler tractors represent 28 percent of unit imports and 37 percent of import value.

Two basic types of firms import equipment into the United States:

1. Larger domestic manufacturers who build certain models outside of the United States;
2. Large foreign manufacturers, who provide parts and service backup.

Some domestic manufacturers who have opened foreign manufacturing facilities import these foreign-produced models for sale in the United States, with sales and backup provided by the distribution organization of the domestic manufacturers. Importing is often preferable to producing the line domestically because lower labor costs as well as production economies of scale often outweigh shipping and tariff costs. These plants account for some of the equipment from Japan, Canada, Italy and West Germany.

TABLE 2-5

TRACTOR AND LOADER IMPORT SHIPMENTS 1974

ORIGIN	WHEEL LOADERS UNITS	WHEEL LOADERS $	CRAWLER TRACTORS UNITS	CRAWLER TRACTORS $	WHEEL TRACTORS UNITS	WHEEL TRACTORS $	TOTAL UNITS	TOTAL $
Japan	360	5,347,046	361	6,987,487	NA	NA	721	12,345,533
Italy	170	3,040,563	169	2,209,503	NA	NA	339	5,250,066
Canada	28	715,464	62	2,590,180	NA	NA	90	3,305,644
U.K.	201	1,894,614	19	344,160	NA	NA	220	2,228,774
Sweden	13	159,186	2	9,637	NA	NA	15	168,823
W. Germany	3	142,244	-	-	NA	NA	3	142,244
TOTAL	775	11,299,117	389	8,623,747			1,388	23,430,084

Data are not maintained for industrial wheel tractors.

Source: Bureau of the Census Report IM 146.

Foreign manufacturers whose equipment is sold in North America include:

- o Aveling Barford
- o Bray Construction Machinery
- o JCB Excavators
- o Karl Schaeff
- o Komatsu Limited
- o Kubota Tractor Limited
- o Matbro
- o Volvo

Only Komatsu, a Japanese firm, is expected by domestic manufacturers to become a serious competitor. Though still only a minor force in the U.S. market, Komatsu appears willing to maintain the large investment necessary to make significant inroads into the American market.

Sales Patterns - 1974

Table 2-6 shows 1974 sales of impacted equipment, by machine type, and compares these sales to the estimated stock as of January 1, 1974. Due to expansion and retiring of old equipment, new shipments amount to nearly 20 percent of existing equipment. Wheel tractors are the largest category of impacted equipment considered here. Almost 33,000 of these machines were produced in 1974, representing 46 percent of the total production of impacted equipment. Crawler tractors contributed 33 percent of the total, while wheel loaders comprised 21 percent of the total production of impacted equipment.

TABLE 2-6

SHIPMENTS OF IMPACTED EQUIPMENT, BY TYPE
1974 Estimates

IMPACTED EQUIPMENT TYPE	NUMBER OF MACHINES SHIPPED (1974)	PERCENTAGE OF TOTAL EQUIPMENT SHIPPED (1974)	PERCENTAGE OF MACHINE IN PRESENT USE
Wheel Loaders	15,416	21	19
Crawler Tractors	22,923	33	19
Wheel Tractors	32,014	46	16.9
TOTAL	71,353	100	17.4

<u>Prices</u>

The prices suggested by manufacturers are known as list prices. Manufacturers set them as an early guide to the relative cost of their machines. List prices vary substantially for machines of similar horsepower. This is due to the lack of comparability among machines of different manufacturers. While two machines of identical horsepower may be able to perform the same work initially, product durability and operating maintenance expenditures may vary significantly.

Equipment users are concerned with the total life cycle cost (amortized initial equipment cost, labor, maintenance downtime, and repair) of getting a job done. Accordingly, manufacturers' prices are comparable only when considering total costs.

While list prices are set competitively, dealers seldom sell a machine at its list price. Rather, they generally have a margin of 23 to 24 percent above their purchase cost out of which they must pay their overhead, take their profit and bargain with customers. As with automobiles, the amount of discount a dealer is willing to give (which is inversely related to his profit) to make a sale will vary slightly from dealer to dealer and can be important in determining whether the dealer makes a sale. However, the 23 to 24 percent margin is relatively constant and no dealers gain particular advantage through discounting.

Price Trends

The 1955-1975 wholesale price indices for tractors and parts for all commodities since 1955 are displayed in Figure 2-4. This figure shows that the wholesale prices of impacted equipment have been rising more rapidly than the overall wholesale prices. The one exception of this pattern occurred in 1973, when strict price controls were placed on construction equipment. When the controls were lifted, the prices resumed their previous pattern. The more rapid rise of impacted equipment prices is due to the increase in size and sophistication of the machines. A price index controlling for increased machine size and productivity would have remained relatively consistent over this period.

THE PRODUCT

Crawler and wheel tractors employed in the construction industry are used primarily in road building and excavating for building foundations. The major activities for which they are employed are loading, leveling, and some shallow excavating. Table 2-7 displays the uses of various equipment in the different industries.

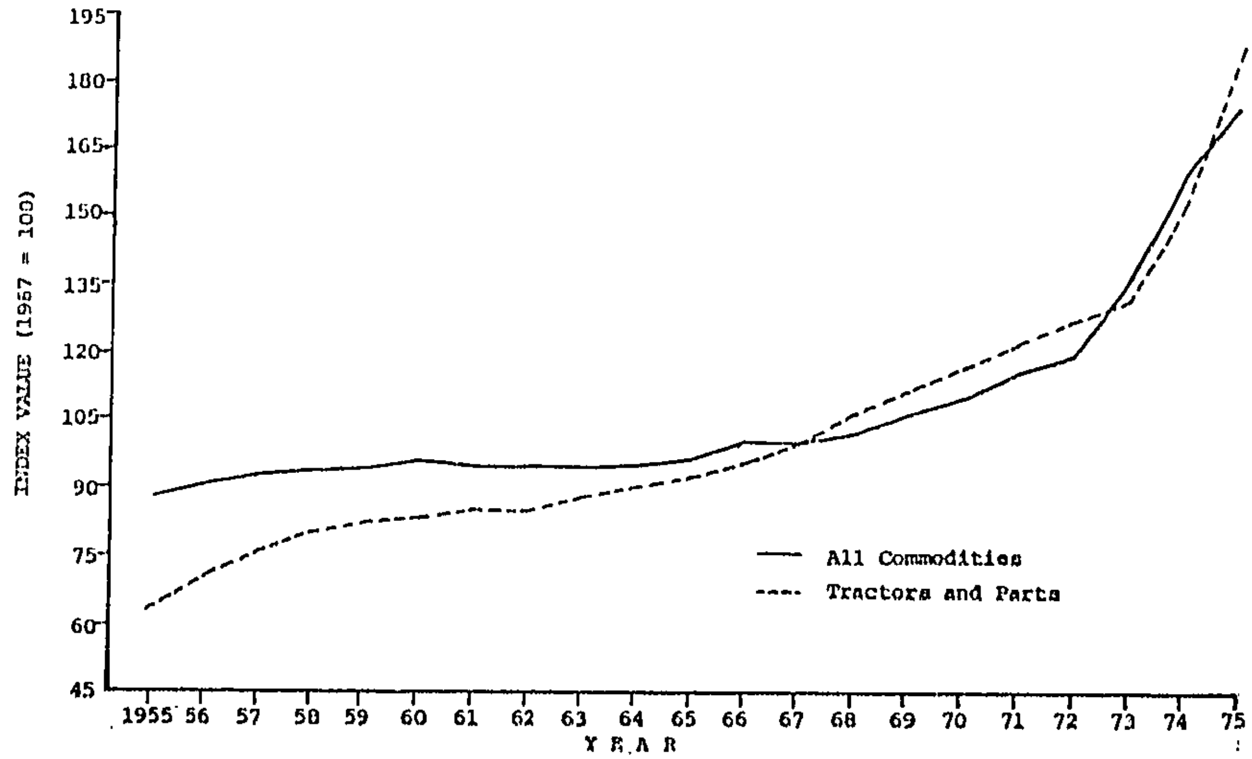


Figure 2-4 COMPARATIVE WHOLESALE PRICE TRENDS OF IMPACTED EQUIPMENT AND OTHER COMMODITIES

SOURCE: U.S. Dept. of Labor, Bureau of Labor Statistics, Wholesale Price Indexes for Tractors and Parts and for All Commodities; personal communication with Mr. G. Howell, Bureau of Labor Statistics, Branch of Wholesale Price Indexes

Table 2-7
Impacted Equipment Applications

Basic Industry	Equipment — Generic Kind: Wheel Loader 4-Wheel Drive	Wheel Loader 2-Wheel Drive	Crawler Loader	Crawler Tractor (Dozer, etc.)	Utility Tractor 2-Wheel Drive	Loader/Backhoe
EARTHMOVING, ETC. (Roadbuilding, Construction, Industrial and Utility)						
Digging - Excavations	X	X	X	X		X
Digging - Trench and Ditch	X	X	X	X		X
Backfilling	X	X	X	X	X	X
Landclearing, Raking	X		X	X	X	
Ripping	X		X	X		X
Dozing/Landscaping	X		X	X	X	X
Pavement Breaking	X		X	X	X	X
Scarifying	X		X	X		
Materials Loading	X	X	X			X
Materials Hauling	X	X	X			X
Materials Mixing						
Materials Pumping						
Materials Hoisting						X
Materials Lifting	X	X	X			X
Road Grading				X		
Soil Compaction, Tamping				X	X	X
Cable Laying			X	X		X
Pipe Laying			X	X		X
Drilling and Boring	X		X			X
Pile Driving						X
Pile Extracting	X		X			
Paving						
Rolling					X	
Snow Removal	X	X	X	X	X	X
Street Sweeping	X	X			X	X
Mowing		X			X	X
Trash Compaction	X		X	X		
MINING AND MILLING						
Digging—Excavations	X	X	X	X		X
Land Clearing	X		X	X		X
Ripping	X		X	X		X

Table 2-7
(Continued)

Basic Industry	Equipment — Generic Kind					
	Wheel Loader 4-Wheel Drive	Wheel Loader 2-Wheel Drive	Crawler Loader	Crawler Tractor (Dozer, etc.)	Utility Tractor 2-Wheel Drive	Loader/Backhoe
MINING AND MILLING (Continued)						
Dozing	X		X	X		X
Scarifying	X		X	X		
Materials Loading	X	X	X			X
Materials Hauling	X	X	X			X
Materials Mixing						
Materials Pumping						
Materials Hoisting						X
Materials Lifting	X	X	X			X
Road Grading				X		
Drilling and Boring						X
Rock Crushing	X		X			
FORESTRY						
Land Clearing	X		X	X		
Tree Harvesting	X	X	X	X	X	
Log Hauling	X	X	X	X		X
Log Loading	X	X	X			X
Log Hoisting						X
Road Grading				X		
AGRICULTURE						
Planting — Spraying						
Digging — Trench and Ditch	X	X	X	X		X
Backfilling	X	X	X	X		X
Land Clearing	X		X	X		
Materials Loading	X	X	X			X
Materials Hauling	X	X	X			X
Materials Lifting	X	X	X			X
Mowing and Chopping		X			X	X
Plowing				X	X	
Cultivating					X	
Power Take-Off Drives		X		X	X	X
Dozing/Land Leveling			X	X	X	
Snow Removal	X	X				X
Terracing	X	X			X	X

Estimates of impacted machines in existence are shown in Table 2-8. Approximately two-thirds are used in construction, with the remaining one-third used in a variety of applications. The estimated 286,790 machines used in construction are distributed by type of construction site as shown in Table 2-9.

Machine Types

Six broad classes of tractors - (1) wheel loaders, (2) crawler tractors, (3) wheel tractors, (4) wheel dozers, (5) skid-steer loaders and (6) integral backhoe-loaders - comprise the wheel and crawler tractor industry for which the major activities of loading, leveling and shallow excavating are product design objectives. Figure 2-5 shows line drawings of these broad classes of tractors.

Wheel Loaders. Wheel loaders are characterized by a loader bucket linkage which is an integral part of the machine. They are normally four-wheel drive with articulated steer. An articulated steer loader is hinged midway between the front and rear axles. The front end axle can swing either side of the straight forward position. Wheel loaders usually have diesel engines. Transmissions are designed for forward and reverse cycling and usually have three or four gears in both forward and reverse. Bucket sizes range from less than 1 cu. yard to about 25 cu. yards. The bucket is used to dig, load, lift, carry, and dump earth and material. At construction sites, loaders are used to load material for hauling, for excavating foundations, for clean up and for other similar tasks.

Table 2-8

ESTIMATED NUMBER OF MACHINES IN EXISTENCE AND NUMBER USED IN CONSTRUCTION BY TYPE

January 1, 1974

Machine Type and Horsepower Class	Total in Construction	Total in Existence	Percent in Construction
Crawler Tractor	91,746	132,183	69.4
Wheel Loaders	48,341	80,586	60.0
Wheel Tractors	128,700	195,000	66.0
Total Above	268,790	407,769	65.9

Table 2-9
Estimated Number of Machines in Construction by Site Type

Machine Type and Horsepower Class	Site Type				Total in Construction	Total in Existence
	Residential	Nonresi-dential	Industrial/ Commercial	Public Works		
Crawler Dozers						
20-89	13,660	9,478	1,951	2,788	27,880	36,680
90-199	8,764	10,050	1,069	1,496	21,380	33,929
200-259	1,056	3,486	370	370	5,282	11,004
260-450	426	2,132	142	142	2,843	9,170
Crawler Loaders						
20-89	11,240	7,642	1,349	2,248	22,480	25,254
90-199	5,355	5,239	233	815	11,640	15,732
200-275+	108	108	5	24	244	414
Wheel Loaders						
20-134	7,092	5,910	4,491	6,146	23,640	35,816
135-241	8,174	5,686	1,955	1,955	17,770	30,118
242-348	3,020	1,937	627	114	5,698	11,396
349-500	668	433	124	12	1,237	3,256
Utility Tractors						
20-90+	46,330	21,880	41,180	19,310	128,700	195,000

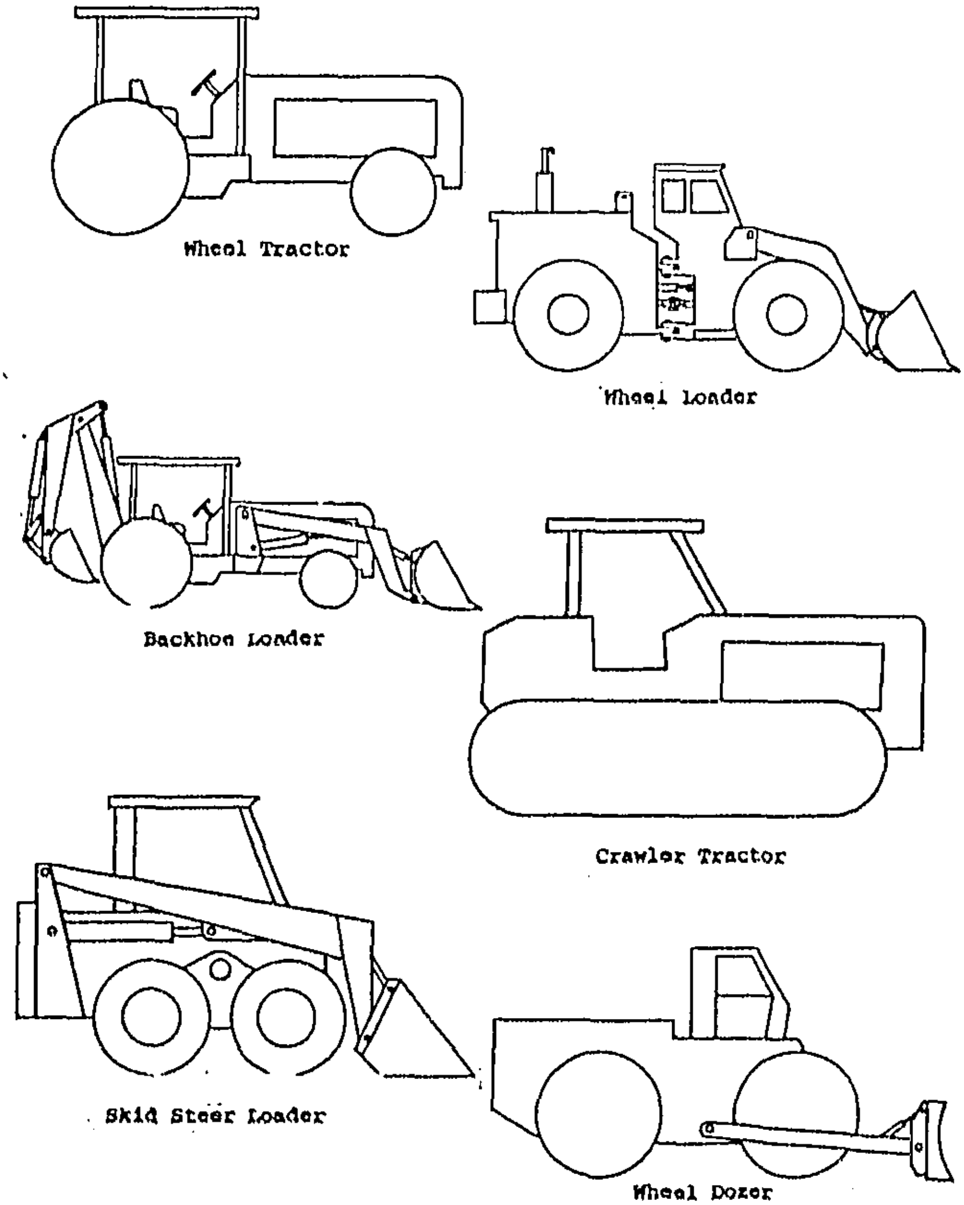


Figure 2-5 LINE DRAWING OF TRACTOR TYPES

Crawler Tractors. Crawler tractors can be equipped with or without integral linkage for dozer blades or loader buckets. In construction, dozers are used for land clearing, loosening and moving earth, filling, backfilling, compacting, and clean up. Horsepower ranges from under 50 to over 500 hp. Engines are usually diesel, with from three to six cylinders. Machines are offered with the option of power shift or direct drive transmissions and typically provide three to four forward and reverse operating speeds. Crawler tractors with loader buckets are used when the site terrain is too rough or muddy for wheel loaders to operate. They are usually less than 300 horsepower and their loader buckets are on the lower end of the range of bucket sizes.

Wheel Tractors. These machines may also be called industrial tractors or utility tractors. They are general purpose machines usually designed for use with bucket, blade, and/or backhoe attachments for light construction work, and other attachments for operations such as mowing, snow-blowing, street cleaning, and landscaping. The design features are rigid frame, front engine, rear cab, two wheel drive, large tires in the rear and small front tires for steering. Most models are offered with gasoline and diesel engine options. Engines are typically four cylinder, with horsepower ranging betwen 20 and 100 hp. The transmission is often direct drive and provides up to eight operating speeds.

Wheel tractors commonly used in construction are very similar in design to agricultural tractors and one may be confused for the other. No specific engineering distinctions have currently been established which have consensus acceptance by industry, to clearly define the agricultural tractor. There are, however, some general characteristics which distinguish the agricultural type tractor from the utility/industrial wheel tractor. Agricultural tractors are characterized by a rear power takeoff, draw bar, and design features for the towing of farm implements in the cultivation of crop fields. Frequently there are as many as eight to twelve forward gear speeds with one to four reverse speeds. The transmission of the agricultural tractor is designed for constant speed rather than the forward and reverse cycling required of tractors used in construction. The machine is not manufactured with the heavy casting around the radiator and engine component necessary to protect construction equipment from debris and vandalism.

The agricultural tractor is more likely to have a direct drive transmission. The tractor is likely to ride higher for crop clearance and wheel separation is typically adjustable.

Because the agricultural tractor need not be designed for large overload and the ranges of operating conditions necessitated by construction work, the tractors are lower in weight and cost when compared with wheel tractors of similar horsepower. The agricultural tractor is excluded from this regulation.

Skid Steer Loaders. These machines are small loaders that are maneuvered by varying the speed and/or direction of rotation of the right or left set of wheels independently of each other. The frame of the machine is rigid and the wheel base is shorter than that of other loader types. Engines are small--40 hp or less--and are usually air-cooled and gasoline powered. Loader linkages are integral to the frame. Skid steer loaders find limited use in construction. Their lightweight design is optimized for materials handling applications. They are not usually able to compete economically with the larger machines in loading operations. Skid steer loaders are excluded from this regulation.

Loader/Backhoe. This refers to a wheel tractor with both an integral loader bucket apparatus and an integral excavating bucket (backhoe apparatus. The loader bucket is generally placed on the front and the excavating bucket (backhoe) generally located on the rear of the machine. The machine can perform loading operations but its primary use is for excavating. Manufacture and construction contractor estimates indicate that the loader/backhoe is used 60 to 80 percent of operating time for excavating purposes. The integral loader/backhoe is excluded from this regulation.

A family tree which illustates the relationship for the various equipment is presented in Figure 2-6.

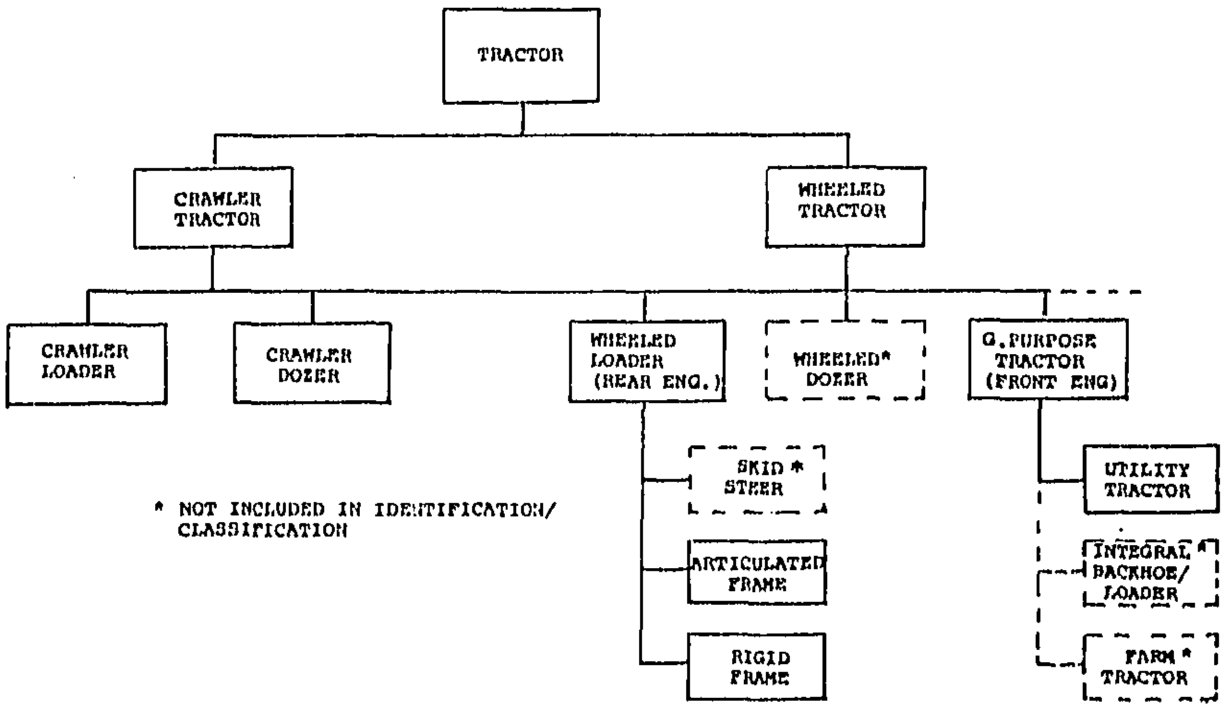


FIGURE 2-6

Identification of Tractor Types/Classifications
by Design Features

Table 2-9
Estimated Number of Machines in Construction
by Site Type

Machine Type and Horsepower Class	Site Type				Total in Construction	Total in Existence
	Residential	Nonresi-dential	Industrial/ Commercial	Public Works		
Crawler Dozers						
20-89	13,660	9,478	1,951	2,780	27,880	36,680
90-199	8,764	10,050	1,069	1,496	21,380	33,929
200-259	1,056	3,486	370	370	5,282	11,004
260-450	426	2,132	142	142	2,843	9,170
Crawler Loaders						
20-89	11,240	7,642	1,349	2,248	22,480	25,254
90-199	5,355	5,239	233	815	11,640	15,732
200-275+	108	108	5	24	244	414
Wheel Loaders						
20-134	7,092	5,910	4,491	6,146	23,640	35,816
135-241	8,174	5,686	1,955	1,955	17,770	30,118
242-348	3,020	1,937	627	114	5,698	11,396
349-500	668	433	124	12	1,237	3,256
Utility Tractors						
20-90+	46,330	21,880	41,180	19,310	128,700	195,000

SECTION 3

MEASUREMENT METHODOLOGY

OVERVIEW

The proposed measurement methodology involves the arithmetic averaging of noise levels measured at four orthogonal positions, 15 meters from the machine, with the wheel and crawler tractor operated at high idle in a stationary mode with all controls in neutral.

In deriving this procedure, EPA has endeavored to arrive at a simple, low cost, test method that will provide the accurate data requisite to product verification at a manufacturer's plant and compliance testing in the field. The Agency believes the proposed measurement methodology will accomplish these desired objectives.

Measurement Requirements

In developing a noise emission test procedure, EPA recognized the need for a relatively simple method of accurately determining wheel and crawler tractor noise emissions which would be suitable for production verification by manufacturers, selective enforcement auditing by EPA and compliance determination by local enforcement officials. A methodology was chosen consistent with the objective that it should:

- o ensure that noise emissions characteristic of major noise sources are being represented.
- o correlate well with the known effects of environmental noise upon public health and welfare.
- o be uniformly applicable to the wheel and crawler tractor industry.
- o provide repeatable sound level data in the simplest manner.
- o be economically effective.

Wheel and Crawler Tractor Noise Sources

The measurement methodology must monitor the contribution of all major noise sources resulting from equipment operation that significantly affect public health and welfare. The major engine-related noise sources for wheel and crawler tractors have been identified as the:

- cooling fan
- engine casing
- exhaust
- air intake
- transmission or power conversion unit.

Peculiar to noise emissions from wheel and crawler tractors is the consideration of track noise for crawler tractors and the operation of either installed or attached loader buckets and dozer blades related to machine motion or attachment cycling. The development of the noise emission test methodology required that each of these noise sources be evaluated in tests of the individual effect upon public health and welfare. It was determined that engine related noise sources provided the dominant contribution.

Relationship of Sound Levels, Health/Welfare and Measurement Methodology

The current test procedures used by industry to measure sound levels generated by construction equipment are engineering development type tests aimed at acquiring data representative of the higher range of sound levels generated by equipment operation under actual conditions [3]. Due to the wide range of conditions under which construction equipment operates, industry sources have not been able to define a typical work cycle for machinery in order to assess spectator noise impact Meaningful, if not typical, work cycles are currently being considered [4].

The usage cycle or typical work cycle is needed in relationship to the measurement methodology, because operating conditions, as encountered in the field, determine the extent of noise impact. To base a noise emission test methodology only on the acquisition of higher sound levels as reported by the SAE/J88a procedure would weight the noise impact unrealistically towards higher values.

In order to assess quantitatively the effect upon values of work cycle L_{eq} resulting from noise source control and its implications for a test methodology, a conceptual work cycle was formulated. This work cycle model was then used to determine the change in the equivalent A-weighted sound levels, L_{eq}, resulting from either implementation of noise control or alteration in the operational mode of the machine. Using both manufacturer-supplied sound level data and additional independent field measurement data, calculations were made to determine whether a stationary or moving test procedure - or both - would be required in order to insure that health and welfare benefits were achieved.

The conceptual work cycle considers two time segments or operational modes and the associated sound levels at a spectator location, as well as accumulated times for each of the two operational modes. The A-weighted sound level pressure associated with static machine operation

---

[4] L_{eq} is defined in Section 5, Equation 5-1.

[5] A-weighted sound level, generally denoted by L_a with units in dBA, is defined in the detailed description of the measurement methodology.

is denoted by L_s and is assumed to be the time-average mean sound level for the time span T_s. The A-weighted sound pressure level associated with moving machine operation is denoted by L_m and is assumed to be the time-averaged mean sound level for the time span t_m .

During static machine operation, the sound level at the receiver will vary with time primarily as a result of component operation, engine speed, and (static) distance between source and receiver. During moving machine operation, the sound level at the receiver will vary primarily as a result of engine speed, traction noise, and changing distance between the source and receiver. The effect of these variations in sound level and the effect of noise control techiques as related to work cycle L_{eq} values was assessed using noise emission test data. The results of this investigation indicate that trends estimated and indicate the benefits accrued from implementing noise control [23].

The conceptual work cycle which is depicted in Figure 3-1 presents a relationship between accumulated time and A-weighted sound pressure level. The moving sound level L_m, is assumed to be ΔdBA above the static sound level L_s. It has been further assumed that two types of noise control are applied to quiet the machine. First, it has been assumed that the noise sources prominent during static operation are decreased L_s which also results in a decrease in moving noise of Δ_{ms}. Next, it has been assumed that noise sources prominent during moving operations are decreased L_m.

$$\Delta L_{eq} = \Delta L_m + 10\ \log\left\{\frac{\tau_2+\tau_1\cdot 10^{-\Delta/10}}{\tau_2+\tau_1\cdot 10^{-(\Delta-\Delta L)/10}}\right\} = \Delta L_m + 10\ \log\left\{\frac{1+(10^{-\Delta/10}-1)\,\tau_1}{1+(10^{-(\Delta-\Delta L)/10}-1)\,\tau_1}\right\} \text{ where } \tau_2 = 1-\tau_1$$

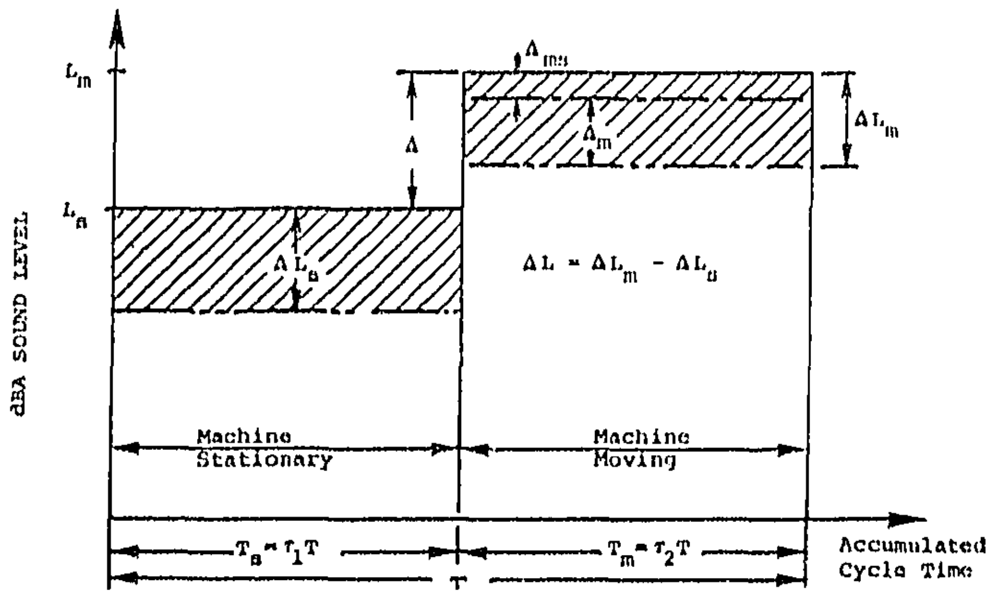


Figure 3-1 EFFECT OF NOISE CONTROL ON WORK CYCLE ΔL_{eq}

also results in a decrease in moving noise of Δ_{ms}. Next, it has been assumed that noise sources prominent during moving operations are decreased L_m.

Using a simplified form of construction site model described in section 5 and the health/welfare relationships discussed in EPA "Levels Document" [6], a mathematical relation for the equivalent A-weighted sound pressure level, L_{eq}, has been obtained for the original machine configuration and the "quiet" machine for the work cycle presented in Figure 3-1. The positive decrease in L_{eq} resulting from implementing noise control is obtained as:

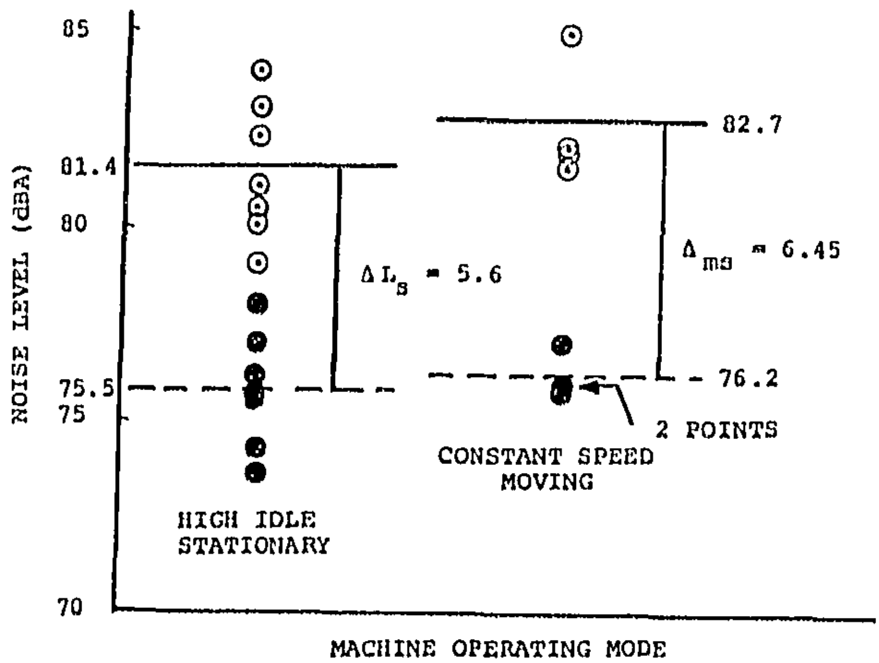
The quantities expressed in Equation 3-1 are defined in Figure 3-1. The utility of this result is that the equivalent A-weighted sound level change for the work cycle L_{eq} can be directly related to both the degree of static source and moving source noise control achieved in each operational mode.

In order to evaluate quantitatively the significance of the moving and static noise sources and the effects of their control on the value of L_{eq} for the conceptual work cycle, estimates were obtained using the sound level descriptors indicated in Figure 3-1. Values of L_{eq} were then calculated by varying the parameters T_m and T_s corresponding to L_{eq} for the conceptual work cycle, estimates were obtained using the sound level descriptors indicated in Figure 3-1. Values of L_{eq}

were then calculated by varying the parameters T_m and T_s corresponding to moving and stationary accumulated time (work cycle variation). In particular, estimates were obtained for the magnitudes of the parameters ΔL_s , ΔL, and Δ_{ms} .

Data were collected using SAE J88a procedures for identical wheel and crawler tractor machine types both before and after implementing noise control treatments. The available data pertained to machines featuring noise control treatments designed to meet either OSHA requirements or the French Construction Equipment Noise Regulation [7].

Next, the high-idle static sound levels of standard machine types and for identical machines with OSHA kits or French Regulation Noise Control Treatment were averaged to establish mean sound levels for both machine configurations. This effort resulted in an estimated value of L_s = 5.6 dBA. Sound levels from moving-mode conditions for standard machines and for machines with noise kits were averaged to establish mean sound levels for both machine configurations. Assuming that Δ_m = 0 (i.e., no noise control for moving sources was implemented since the French Regulation or OSHA requirements are the applicable criteria), the estimated value of Δ_{ms} is 6.4 dBA. The data are based upon averages of manufacturer supplied test data and cover both wheeled and crawler tractors. The data developed is presented in Figure 3-2. As shown, the decrease in moving-mode sound levels is significantly related to the level of static noise control. This implies that a measurement



NOTES: DATA INCLUDES BOTH WHEELED & CRAWLER MACHINE TYPES

HP RANGE 39 - 170

WT. RANGE 5900 - 32400 LBS.

FIGURE 3-2 NOISE LEVEL REDUCTION IN STATIONARY AND MOVING MODES methodology which monitors stationary (engine-related) noise sources will correlate well with L_{eq} which, in turn is related to health/welfare impacts. The following values of sound level parameters, defined in Figure 3-1, have been determined from the data in Figure 3-2.

$$\Delta = 82.7 - 81.4 = 1.3$$

$$\Delta L_s = 81.4 - 75.8 = 5.6$$

$$\Delta_{ms} = 82.7 - 76.2 = 6.5 = L_m \; (\Delta_m = 0)$$

$$\Delta L = 6.5 - 5.6 = 0.9$$

Using these value in Equation 3-1, the resulting expression is:

$$\Delta L_{eq} = 6.5 + 10 \log \frac{1 - 0.2587\tau_1}{1 - 0.0880\tau_1} \qquad (3\text{-}2)$$

where the relation $\tau_2 = 1 - \tau_1$, has been used.

The parameter τ_1 is the fraction of the total work cycle time that the machine operates in a stationary mode)i.e., not productive). The variation in L_{eq}) with τ_1 and τ_2 is presented in Figure 3-3. It is seen that ΔL_{eq} increases as the machine spends more time moving than stationart. This result stems from the fact that Δ_{ms} is shown to be greater than ΔL_s (i.e., stationary source noise control apparently has decreased moving mode sound levels more than the decrease in stationary mode sound levels).

This analysis indicates that a noise emission test procedure monitoring

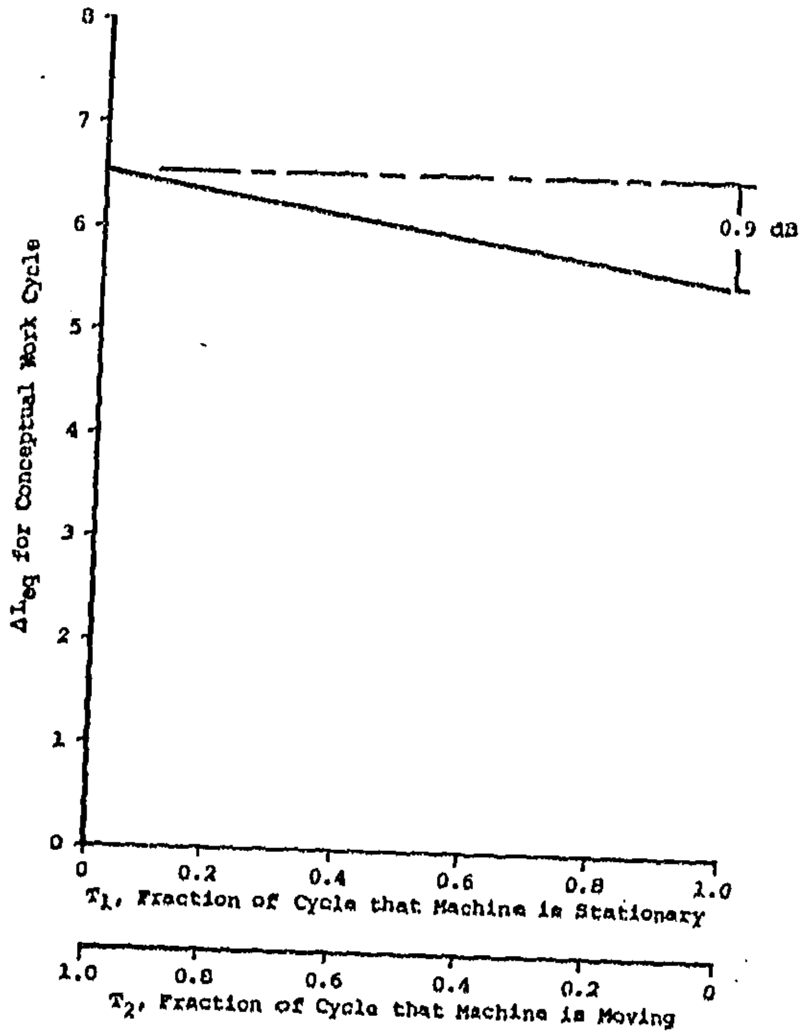


FIGURE B-3

ΔL_{eq} vs. Fraction of Work Cycle Time in Stationary Mode or Moving Mode the reduction of engine-related noise sources correlates well with health/welfare benefits via the L_{eq} descriptor for noise emissions above 75 dBA.

CURRENT TEST PROCEDURES AND STANDARDS

Numerous test procedures and standards for noise measurement have been proposed by organizations such as the Society of Automotive Engineers (SAE), the International Organization of Standardization (ISO), the American National Standards Institute (ANSI) and the Diesel Engine Manufacturers Association (DEMA) to standardize the measurement methodology used by industry, consumers and government regulatory bodies. A comparison of existing and proposed standards is shown in Table 3-1.

The basic nature of these test procedures is to provide standardized methods to be used by industry to evaluate noise emissions from equipment. As such, these procedures are essentially engineering tools for manufacturers and are not well suited for regulatory methods. These test procedures have established an extensive data base and provide an indication of the potential measurement difficulties associated with translating these engineering tools into a meaningful regulatory procedure. Due to the extensive industry wide data bank that is based on the SAE test procedure, that procedure was given high priority in the development of the proposed noise emission measurement methodology.

Table 3-1
Spectator Noise Measurement Procedures for Loaders and Dozers

Procedure	SAE J88	SAE J88a	ISO TC43 SC1/[illegible]	FRENCH DECREE [illegible]	GERMAN REGULATIONS: TRACK-TYPE TRACTORS	GERMAN REGULATIONS: WHEEL LOADERS	GERMAN REGULATIONS: TRACK-TYPE LOADERS
Measurement Pad Surface	Concrete or asphalt, or hard packed earth	Concrete or asphalt, or hard packed earth	Concrete or asphalt, or hard packed earth	Concrete or asphalt	Concrete or asphalt, or hard-packed earth*; compacted earth†	Concrete or asphalt, or hard packed earth	Concrete or asphalt, or hard packed earth†
Cleared Area Radius (m)	20.0	30	30	25	30	30	30
Test Machine Operation	stationary forward	stationary forward	stationary forward reverse	stationary	stationary forward reverse	stationary forward reverse	stationary forward reverse
Number of Microphone Positions	4* / 2†	4 / 2	6 / 2	4 / 0	8 / 2	8 / 2	8 / 2
Location of Microphone Positions (m)	15.2[a] / 15.2[b]	15[a] / 15[b]	7[c] / 7[b]	7[d] / –	7[c] / 10[e]	7[c] / 10-20[e]	7[c] / 10-20[e]
Number of Measurements Per Position	≥2 / ≥2	1 (HI) ≥2 (cycling) / ≥3	1 / ≥3	1 / –	1 / 1	1 / 1	1 / 1
Modes of Machine Operation[f]	1,2,3 / 6,7,8,9	1,4,5 / 6	1,4,5 / 7,10	1 / –	1 / 10,11	1 / 7,11	1 / 11
Datum[g]	slow, maximum	slow, maximum	slow, average of maxima	slow, maximum	fast avg of* locations / avg of maxima†	fast avg of locations / avg of maxima	fast, avg of locations / avg of maxima

NOTES: *STATIONARY TEST; †MOVING TEST

[a] FROM SIDE OF BOX ENCLOSING MACHINE EXCLUDING BLADE OR BUCKET

[b] FROM MAJOR SIDE SURFACE PARALLEL TO MACHINE PATH

[c] FROM SIDES AND CORNERS OF BOX INCLUDING BLADE OR BUCKET

[d] FROM SIDES OF ENGINE ENCLOSURE

[e] FROM BOTH SIDES OF MACHINE PATH CENTERLINE

[f] OPERATING MODES:

1 - HIGH IDLE (MAXIMUM GOVERNED ENGINE SPEED)
2 - MAXIMUM ATTAINABLE ENGINE SPEED - TORQUE CONVERTER STALL
3 - ENGINE CONDITION OF MAXIMUM SOUND LEVEL
4 - IDLE - MAXIMUM GOVERNED SPEED - IDLE (HMI)
5 - APPARATUS CYCLING
6 - MAXIMUM FORWARD SPEED - INTERMEDIATE GEAR
7 - MAXIMUM FORWARD SPEED
8 - HALF MAXIMUM FORWARD SPEED
9 - ACCELERATION
10 - MAXIMUM REVERSE SPEED
11 - SIMULATED WORK CYCLE

[g] A WEIGHTED SOUND PRESSURE LEVEL, SLM RESPONSE AS INDICATED

TECHNICAL AND OPERATIONAL CONSIDERATIONS

The majority of the data used as a basis for the development of an EPA test methodology has been compiled from SAE J88 and SAE J88a test procedures. These procedures, however, require both stationary and moving operating modes and are time consuming and costly. The SAE/J88a procedure includes a stationary mode test comprising the low idle-maximum governed speed-low idle operation sequences (IMI).

One problem which is associated with either wide open throttle tests or low idle-maximum governed egine speed - low idle tests is that these modes can result in governor "overshoots" at high engine and fan speed conditions. Since almost all significant stationary-mode noise sources are highly dependent upon engine speed, higher than normal noise emissions would be measured with these test modes than would be measured if the steady maximum governed engine speed was utilized as in actual field conditions.

Machine Operation

Moving Mode vs. Stationary Testing. Except for the French Regulation, all procedures studied call for moving-mode tests for equipment. However, moving-mode tests result in increased land area for test facilities, machine refurbishing efforts, and altered production sequence for the machine configuration.

For rubber tire vehicles, moving-mode tests represent potential damage or wear for tires so it would be necessary to install production/test tires prior to noise emission testing and after testing install original equipment tires for vehicle delivery. (It is common production practice to use dummy tires for vehicles produced for inventory rather than immediate sale. This practice results from the fact that deterioration of rubber tires would occur if the machine was so equipped during storage.) A stationary mode noise emission test, of course, avoids this problem.

For tracked (or crawler) vehicles, moving-mode tests for regulation noise emission testing represent a singular impact upon the production sequence. Each test vehicle must be refurnished subsequent to testing and prior to delivery because moving-mode testing must be conducted along an earthen test track and the track, track driver and support rollers, and track guides become clogged with compacted dirt. To restore the vehicle to a new condition, the vehicle must be washed and perhaps painted.

Fortunately, the analyses detailed earlier in this section indicated that stationary noise sources, e.g., engine and cooling fan, predominate for both crawler and wheel vehicles in most construction environments and that stationary noise control will correspondingly lower the noise levels measured under moving modes. As discussed earlier, work cycle and component noise source evaluation have been conducted for crawler tractors by U.S. Army MERADCOM personnel at Fort Belvoir, Virginia to establish limits below which moving-mode sound levels would have to be monitored.

Tests conducted at Fort Belvoir (Section 4) are in general agreement with the data in Figure 3-2 and indicate that the monitoring of noise source reduction to approximately 75 dBA during a stationary maximum governed engine speed test results in a corresponding decrease in moving-mode machine sound levels.

Below this range it is possible that noise generated by tracks, transmissions under load, etc., will become the predominant noise sources. In this instance, the noise sources monitored by a stationary test may not be accurate descriptors of the machine noise emission characteristics for the machines in field use.

Attachment Cycles. Another machine operating mode required as part of the SAE J88a procedure is the attachment cycle mode used to simulate the field operation of loader buckets and dozer blades. This test mode requires that the engine be at a stabilized maximum governed engine speed and the appropriate controls be activated to cycle the attachments. The typical variation between the stabilized stationary maximum governed engine speed mode and the attachment cycle mode is 2 dBA or less with the attachment cycle levels being higher. These higher levels generally result from highly transient noise related to attachments striking stops rather than component operational noise. Since hydraulic systems are employed for attachment actuation and since the hydraulic pumps are usually driven directly from the engine, high idle engine speeds are typical for this mode of operation for machines in field use. Thus, attachment cycle modes yield sound level data representative of the stationary maximum governed engine speed mode with transient peak levels superimposed that result from attachment cycling.

Any test methodology requires that the machine being tested should be operable and at least simulate the configuration in which the machine will appear in field use. The operation of wheel and crawler tractors for conditions specified by a noise emission regulatory test procedure implies that the machine is assembled to the extent that the predominant noise sources being monitored are installed and operable. Effects of machine configuration that may influence noise regulatory testing are components and/or attachments that may not represent significant noise sources in themselves but may influence the noise emission characteristics of the vehicle. These components are, specifically, loader buckets and dozer blades that may not be supplied by the manufacturer but will only be installed at a dealership or in the field.

The consideration of implementing a noise emission test on an operable machine or set of operable machines as may be dictated by the sampling plans for regulation testing implies that, in general, the emission tests will be performed at the manufacturer's assembly plant. However, in the case of very large machines and/or machines requiring extensive shipping - such as foreign imports - these units may be transported unassembled. (For imported machines that are shipped unassembled, the noise emission tests must be applied at the point of assembly if it is not economically feasible to assemble and test the machine at the manufacturing plant.)

The measurement of noise emissions from a machine on which the operable attachment will not be installed at the point of final assembly is not a significant problem if attachment cycling noise emission tests are not required. As described previously, the attachment cycle test in reality repeats the static mode maximum governed engine speed test for SAE J88a procedures with the higher sound levels reported resulting from short duration transient sounds which do not significantly increase the value for L_{eq} for the machine work cycle. If the configuration requirements for the machine being tested are relaxed, then it is feasible for a manufacturer to provide a mock simulation of either a loader bucket or dozer blade to provide the geometrical configuration of the end product and avoid problems with assembly and disassembly of a unit solely for noise emission testing.

Acoustical Considerations

Four-side Arithmetic Average. The previous analysis has indicated that moving mode measurements can be eliminated in favor of a stationary mode test in which the machine operates at a maximum governed engine speed (high-idle). Additionally, the four-side arithmetic, rather than energy average of high idle measurements, bears a good correlation [Section 4] to average in-the-field L_{eq} values; therefore, it has been selected as both the measurement procedure and the method for reducing the noise emission data base for use in the health/ welfare analysis (Section 5).

Overhead Measurement. The possible need for an overhead measurement position was also investigated. Machines tested by MERADCOM at Fort Belvoir, Virginia had lower levels at the overhead position of the machines than at the spectator (side) position. Due to the physical size of the facility, the sound levels recorded were adjusted to provide an equivalent 50-foot reading. The results indicate that, in almost all cases, the overhead levels are significantly less than the spectator levels (levels measured in the horizontal plane) and, on the average, the spectator levels were 3.7 dBA higher than overhead.

Another consideration for overhead measurements concerns the effort involved in purposely redirecting noise to defeat a regulation. Such an effort, at the minimum, would require well sealed engine compartments and rather large ducts directing the engine noise (including the exhaust noise) in a vertical direction. Engine cooling, operator visibility (field & vision) and cost considerations make it unlikely that manufacturers would purposely attempt to redirect noise in order to reduce levels at the spectator location at the expense of increased noise in the overhead position. In addition, since 15 meter measurements at the side positions are in the free field of sound propagation from these machines, intentional attempts to defeat a regulation by redirecting the noise could be difficult to achieve.

Another factor mitigating against a desire to include an overhead measurement is that measurement equipment for a vertical position will be extremely complex, especially for manufacturers that have a large variation in machine size throughout their line. Whenever there is a remote microphone calibration, connecting cable, etc. problems increase. If the various regulated equipment vary in size, the changeability of microphone height to correct machine-to-microphone distance would require a significant amount of personnel time. In use compliance tests performed by local enforcement officials will also become quite difficult to perform.

An unresolved issue concerning the possible need for an overhead measurement concerns the fact that data are not available to determine the extent, if any, of population impact from directional noise. The procedures for calculating health and welfare impacts resulting from construction site noise, as described in section 5, do not consider vertical directivity. Additionally, population density data above ground level are not available for various site types nor does a sound theoretical basis for determining transmission loss through exterior partitions resulting from grazing incidence sound wave exist.

Until more information is obtained ,it is difficult to justify an overhead microphone position using purposful direction of Wheel and Crawler Tractor noise upwards and attendant population impact as an argument. It is noted that the normal operation of wheel and crawler tractors involves movement within a construction site, so that a constant angle of incidence and distance from surrounding buildings is not maintained. This fact complicates the procedures for calculating vertical population impacts. Also the movement of wheel and crawler tractors is in contrast to the stationary mode of operation of portable air compressors where the compressors' close proximity to surrounding buildings provided a defensible basis for an overhead measurement.

In summary, EPA believes that an overhead measurement position does not seem to be required at this time because: (1) it will needlessly increase the cost and complexity of the test; and (2) existing machines have the sound energy directed along a horizontal direction. Should the need arise in the future, the additional overhead microphone location may be added.

Test Site Considerations

The basic requirement of any noise emission test is that the test procedure must define conditions that allow for accurate and repeatable measurement of the sound levels of the noise source being monitored. Two requirements associated with construction equipment noise emission testing are that testing must be conducted, in general, outdoors due to the physical size of the machines and that the ambient sound levels at the test site must be at least 10 dBA below the noise emission levels being monitored. These considerations require that the limiting environmental conditions at the test site be specified so that the noise emission test at different sites can be expected to determine the machine noise levels on an industry basis.

Test Pad. The review of current test methodologies indicates a general agreement that noise emission testing should be conducted in an acoustically free field condition with an acoustically hard (i.e., reflective) ground surface between the machine and monitoring positions. However, the Fort Belvoir test data [39] indicate no more than a 1 dBA difference between machines operated on hard-packed earth surfaces and concrete surfaces. Therefore, individual manufacturers may elect to verify such correlations and to test machines over hard-packed earth in order to minimize costs associated with test pad construction.

Fifteen-Meter Measurement. Since much of the noise emission test data used in this study is based upon a 50-foot (15.2-meter) distance between the source and the monitoring location and since this separation distance is accepted as a representative location for a nearby spectator location in field use, a 15-meter separation distance appears to be an appropriate location to ensure both acoustical free-field conditions and direct determination of repeatable sound levels at a spectator location.

Acoustical Environment. The impact of the acoustical environment upon the propagation of sound from the source to the microphone location must be considered. For typical microphone heights (1.2 meters), experience indicates that the sound levels measured are influenced by atmospheric pressure, by characteristics of the reflecting plane such as acoustic impedance and flatness, and temperature gradients above the reflecting plane. In addition, wind velocity and humidity conditions at the time of measurement represent factors which must be accounted for in the test procedure.

Outdoor Testing. Many domestic construction equipment manufacturers and, in particular, the production facilities for wheel and crawler tractors, are located in the mid-western portion of the United States. The requirement for out-of-door noise emission testing places a severe constraint upon both test scheduling and machine inventory in that environmental conditions suitable for noise emission testing may not exist for extended periods of time. Unless a simplified noise emission test procedure is adopted that can allow a large number of machine tests to be accomplished in a short period of time, there exists a distinct possibility that schedule delays for equipment delivery and possible accumulation of a large inventory of completed machines may result from delays associated with unsuitable weather conditions for noise emission testing.

Test Site Configuration. Test site configuration presents both a technical and a practical consideration with respect to methodology. Since the size of wheel and crawler tractors (and construction equipment in general) indicates out-of-door noise emission testing, a site must be provided that is convenient to manufacturing operations and that can be expected to retain its required acoustical environment for a sufficient time to allow for amortization of any capital expenditure to provide the site. Using the methodology recommended by SAE J88a, approximately 2 to 5 acres of cleared land plus isolated surroundings must be acquired or allocated from land near to the manufacturing facility to avoid additional costs for equipment transportation and inventory. One construction equipment manufacturer has estimated that - exclusive of land acquisition costs - from $100K to $200K of capital investment would be required to develop a test site complying with the SAE J88a procedures [8]. A stationary-mode noise emission test would reduce the land area required and the capital expenditures required for testing. Additionally, in anticipation of future noise regulations, the test site geometry could reflect the consideration of other machine types produced at a facility so as to ensure the future compatibility of the site in relation to machines produced at the plant. The availability of a suitable test site area at each manufacturing facility or assembly plant may not be realistic and can only be determined on an individual facility site review by each manufacturer.

Cost Considerations

Several manufacturers have provided data allowing a cost comparison of performing the full SAE J88a test versus a simplified test methodology. Table 3-2 provides one manufacturer's estimate of a comparison of the test costs involved for a typical wheel or crawler tractor. It is noted that this manufacturer was able to eliminate transportation costs, which may not be typical.

These costs are exclusive of the costs of a J88a approved test site which could cost more that $200,000 for and acquisition and capital investment. Elimination of a moving test will reduce land requirements by a factor of approximately 10 percent to 30 percent and therefore reduce land acquisition and preparation costs by a comparable amount.

EPA NOISE EMISSION TEST METHOD FOR WHEEL AND CRAWLER TRACTORS

This test procedure describes the test site, measurement equipment, machine operation, test conditions, microphone positions, required data, data reduction, and a suggested data reporting format for documenting sound levels for construction equipment classified as wheel and crawler tractors.

The A-weighted sound pressure level is the sole noise level measure in this test procedure. The A-weighted sound pressure level is widely used at present to describe noise and is often used in single-number descriptors of community noise. In addition, many state and local agencies and private concerns already have equipment that measures the A-weighted sound pressure level, are familiar with the descriptor and employ the descriptor in their communication of noise levels to their audiences.

The procedure specifies an exterior test site for measuring sound levels and is thus dependent upon local weather conditions. Machines under test are operated in a stationary mode only. For the test, the machine is operated with no load. All sound levels are reported as A-weighted sound pressure levels. Average sound levels are determined arithematically with all sound level data used in the caculation, tabulated and reported.

The test procedure is based upon current industry practices for measuring exterior sound levels at spectator locations resulting from the operation of mobile construction equipment [5]. The required data, obtained as a result of this test procedure, will provide an index of the higher sound levels generated by the machine under field conditions and is relatable to conceptual work cycle sound levels. With presently available data, it is believed that the procedure described herein is the minimum effort required to establish current noise emission characteristics of the machine under test such that the data obtained are repeatable within the bounds of acceptable experimental error.

TABLE 3-2

SAE/J88a VS. SIMPLIFIED TEST COST COMPARISON

(ONE MANUFACTURER'S ESTIMATE FOR CRAWLER TRACTORS)

Step	Item	Manhours (SAE/Recommended Test)	Estimated Item Cost SAE J88a	Estimated Item Cost 4-Side High-Idle Stationary Test
1	Disassemble to transport	10/0	$ 250	$---
2	Transportation	---	350	---
3	Reassemble	12/0	300	---
4	Testing	3/2	66	44
5	Disassemble to transport	10/0	250	---
6	Transport	---	350	---
7	Reassemble, clean-up, touch-up	16/0	400	---
	TOTALS		$1966	$ 44

Definitions

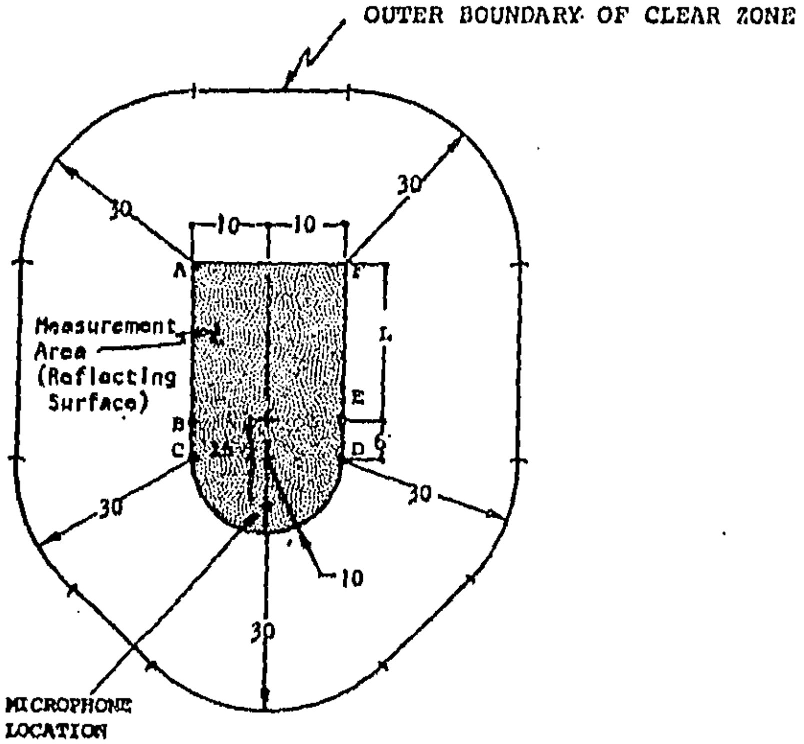
The following definitions are presented for reference:

- A-weighted Sound Level - The sound level measured using a sound level meter set to the electrical frequency weighting network designated as the A-weighting relative response in dB, defined in American National Standard Institute (ANSI) Specification 51.4-1971, "American National Standard Specification For Sound Level Meters".
- Clear Zone - The portion of the test site area between the measurement surface and the test site boundary that is free of any large reflecting surfaces such as buildings, signboards, hillsides, etc. See test site description.
- dB - Abbreviation for decibel. The decibel is defined as 10 times the logarithm to the base 10 of the square of the ratio of the rms value of the acoustic pressure to a reference pressure of 2×10^{-5} N/m^2 (pascals).
- High Idle - The maximum governed engine speed of the test machine.
- Machine - The piece of mobile construction equipment subject to noise emission testing including major machine components or simulated components.
- Major Machine Component - The primary device and/or other attachments to the machine for which the machine is designed or equipped to perform the construction operation for which it is sold.

- Simulated Major Machine Component - A mock version of the major machine component position statically about but not attached to the machine to simulate the major machine component in geometry and acoustical properties as if it were to be installed at the time of the test.
- Microphone Location(s) - The position of the microphone relative to the machine orientation determined at a distance from a major machine surface and at an elevation above the test site measurement surface.
- Noise Emission Test - The entire procedure comprising machine configuration, microphone locations, and acquisition of required data as described in this procedure.

<u>Test Site Description</u>

The location for measuring sound levels for noise compliance testing must comprise a large, flat open area generally exposed to ambient sound levels at least 10 dBA below the sound levels generated by the test machine under test conditions. A minimum area measurement surface for sound level measurements is described below. Use of this configuration requires reorientation of the test machine for each measurement point for stationary machine tests. This test site configuration is illustrated in Figure 3-4. Alternatively, the measurement surface can be greater in extent to allow microphone relocation or multiple microphone locations rather than machine reorientation using criteria described below and criteria presented in <u>Test Conditions</u> and <u>Microphone Locations</u>.



NOTES:

- All dimensions in meters
- L = Longer vehicle dimension: length or width
- No scale

Figure 3-4 TEST SITE CONFIGURATION FOR NOISE EMISSION TEST FOR WHEEL AND CRAWLER TRACTORS

Test Site Area. The test site area shall comprise a measurement surface and a clear zone. The clear zone comprises the surface area between the measurement surface and the test site boundary.

The minimum area measurement surface for noise compliance testing shall comprise a rectangular area formed by the points A, B, C, D, E and F and a circular area of radius 10 meters connecting points C and D as illustrated in Figure 3-4.

Test Site Surface. The test site surface shall comprise a hard reflecting plane of smooth concrete or smooth and sealed asphalt. The clear zone shall be free of any large reflecting surfaces such as buildings, signboards, hillsides, etc., within 30 meters of either a microphone location or the machine being tested.

Measurement Equipment

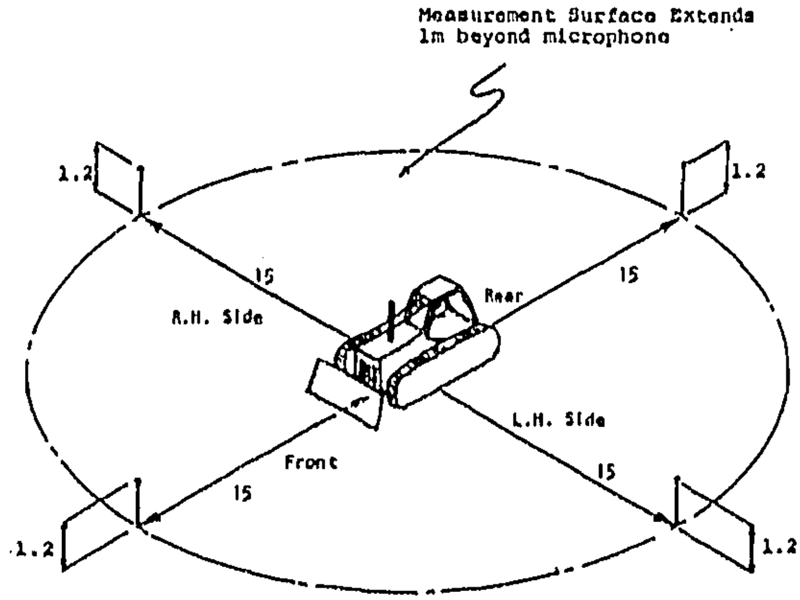
The measurement equipment required for noise standard compliance testing shall comprise the equivalent of the following items:

- Sound Level Meter - For all sound level measurements, a sound level meter and microphone system that conforms to the Type 1 requirements of the American National Standard Institute (ANSI) Specification S1.4-1971, "American National Standard Specification for Sound Level Meters," and to the requirements of the International Electrotechnical Commission (IEC) Publication 179, "Precision Sound Level Meters," shall be used.
- Microphone Windscreen - For all sound level measurements, a microphone windscreen shall be used that shall not change measured sound levels in excess of $\pm$ 0.5 dB to 5 kHz and $\pm$ 2.0 dB from 5kHz to 12 kHz.

- o Calibration - The entire acoustical instrumentation system shall be calibrated before and after each test series on a given machine. A sound level calibrator accurate within ± 0.5 dB shall be used. A complete frequency response calibration of the instrumentation over the entire range of 25 Hz to 12.5 kHz, shall be performed at least annually using a technique of sufficient precision and accuracy to determine compliance with ANSI S1.4-1971 and IEC 179 Standards. This calibration shall consist, as a minimum, of an overall frequency response calibration and an attenuator (gain control) calibration plus a measurement of dynamic range and instrument noise floor.
- o Anemometer - An anemometer or other device, accurate to within ± 10 percent, shall be used to measure ambient wind velocity.
- o Power Source Speed Indicator - An indicator accurate to within ± 2 percent shall be used to measure power source speed (rpm).
- o Barometer - A barometer accurate to within ± 1% shall be used to measure atmospheric pressure.
- o Thermometer - A thermometer accurate to within ± 1 percent shall be used to measure ambient temperature.

Machine Operation

During noise emission compliance testing, the machine shall operate in a stationary mode. The machine shall be centrally located within the rectangular measurement surface areas defined by the points A, B, E and F in Figure 3-4 and oriented to the microphone positions as shown in Figure 3-5.



NOTES:

- All dimensions in meters
- Not to scale
- Reorient machine for measurement surface indicated in Figure 5.3-1.

Figure 3-5 MICROPHONE LOCATIONS FOR TEST METHODOLOGY

High Idle and No Load. With the ground propulsion transmission shift selector in the neutral position and with all component drive systems in the neutral position, operate the engine at no load and maximum governed engine speed (throttle simply fully open) at a stabilized operational condition.

Test Conditions

Noise standard compliance testing must be carried out under the following conditions:

Test Environmental Conditions. Noise standard compliance testing shall not be conducted during rain or other precipitation. During the measurements, the ambient wind speed at the test site shall be below 19 km/hr. The ambient sound level at the test site shall be 10 dBA less than the sound levels generated by the test vehicle at each microphone location. The test site surface under and between the test vehicle and microphone shall be smooth and free of acoustically absorptive material such as snow or grass.

Test Operational Procedures. During the sound level measurements, no one other than the person reading the meter shall be located within 2 meters of the microphone and no person or object shall be positioned between any microphone and the machine.
The test machine shall be operating in a stable condition as for continuous service. All cooling air vents service doors and/or inspect on panels normally open during service operation shall be at their design maximum opening during all sound level measurements. Service doors and/or inspection panels, that should be closed during normal operation, at any and all ambient temperatures, shall be closed during all sound level measurements.

The test machine shall be configured with either the major machine component or a simulated major machine component located in the lowered position with the bottom edge of the component resting on the test pad surface. Pads of anti-vibration material may be installed between the major machine component and the test pad surface to prevent the major machine component from vibrating and radiating sound.

Machine Operational Conditions. For all stationary machine noise emission tests, the test machine shall be operated at the conditions described as Machine Operation.

Microphone Locations

Four microphone locations must be employed to acquire machine sound level data. If a single fixed microphone is used, it should be placed on the test pad as shown in Figure 3-4. The machine would then be reoriented in relation to the microphone as indicated in Figure 3-5.

Machine Major Surface Outlines. The four major surfaces of the machine refer to the front, rear, and sides of the imaginary rectangular box that will just fit over the vehicle but does not include components such as buckets or dozer blade. See Figure 3.6.

Stationary Machine Noise Emission Tests. Locate the microphone at a distance of 15 meters, measured normal to the centers of the four major surfaces of the test machine at a height of 1.2 meters above the measurement surface. All linear dimensions shall have a tolerance of $\pm$ 0.1 meter.

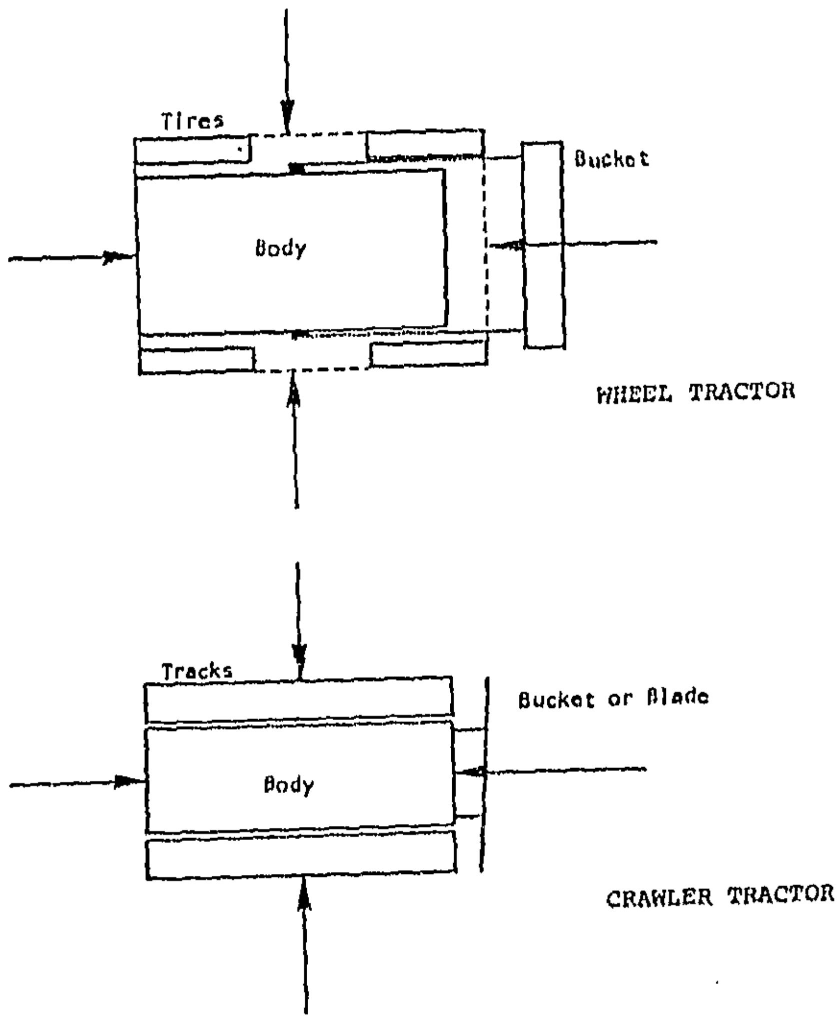


Figure 3-6 MAJOR REFERENCE SURFACES

Test Site Environmental Conditions. A-weighted ambient sound pressure level at one microphone location, wind speed, temperature, and barometric pressure shall be measured and reported at the beginning and at the end of the test.

Physical Characteristics of Test Machine. The machine model number, serial number, engine horsepower at rated speed, the stabilized maximum governed engine speed at no load and the major machine component shall be reported for each test.

Sound Level Data - General: The highest A-weighted sound pressure levels with the indicating meter set for slow response shall be measured at each microphone location as described in Microphone Location for the machine operating in the stationary condition described as Machine Operation.

Calculation of Average Stationary Machine Sound Level Data

The average dBA sound level from measurements at each of the microphone locations and the machine operational condition shall be calculated by the relationship:

$$\bar{L} = \frac{1}{N} \sum_{i=1}^{N} L_i$$

where $\bar{L}$ = average sound level in dBA for each test condition

L_i = measured sound level in dBA (See Figure 3-5)

i = 1, 2, ..., N an index denoting microphone location

N = number of measurement positions.

Data Reporting

All data acquired and the calculated averages shall be reported. A recommended format for reporting data required for noise emission compliance testing is presented in Table 3-4.

TABLE 3-3

WHEEL AND CRAWLER TRACTOR NOISE EMISSION TEST DATA SHEET

Test No. ____________

I. Machine Characteristics

Manufacturer: ____________ Model No. ______ Serial No. ______
Engine Manufacturer: ______ Model No. ______ Serial No. ______
Rated H.P. ________ RPM; Maximum Governed Engine Speed at No Load ____

Attached Simulated Major Component: Dozer Blade, Loader Bucket (Strike out inappropriate items)

Component Description: Dozer Blade; height ____ m, width ______ m; Loader Basket; Capacity ________ m^3

II. Test Conditions

Manufacturer's Test Site Identification and Location: ____________
Measurement Surface Composition: ____________
Ambient Sound Levels (a) Beginning of Test; ____________ dBA
(b) End of Test; ____________ dBA

III. Instrumentation

Microphone Manufacturer: ________ Model No. ____ Serial No. ____
Sound Level Meter Manufacturer: ______ Model No. ____ Serial No. ____
Acoustical Calibrator Manufacturer: ____ Model No. ____ Serial No. ____
Other: ____________ Model No. ____ Serial No. ____

IV. Sound Level Data (dB Reference 2×10^{-5} pascals)

A-Weighted Sound Levels (dBA)

Stationary Machine Test	Machine Front	Reference L.H. Side	Reference Rear	Surface R.H. Side	Calculated Average Level	Average Plus SLDF	Notes
High Idle No Load							
Test Engine Speed							
SLDF							

V. Test Personnel and Witnesses

Tested by: ____________ Date: ________
Reported by: ____________ Date: ________
Checked by: ____________ Date: ________

Section 4

NEW WHEEL AND CRAWLER TRACTOR NOISE LEVELS

A comprehensive survey of noise emissions from wheel and crawler tractor machines was undertaken by EPA to supply information needed for the following purposes:

(1) to establish the relationship of these measurements to selected machine engineering characteristics, e.g., net flywheel horsepower, as a basis for the development of classification categories;

(2) to establish a baseline for determining the benefits afforded to the health/welfare of the United States population by reducing noise emissions within each machine classification;

(3) to select a measurement methodology, which is consistent with the health/welfare analysis and the noise emission data base, for prescribing "not to exceed" noise emission level standards;

(4) to develop diagnostic data concerning the relative ranking of component noise sources as a basis for determining the technological potential for quieting wheel and crawler tractors; and

(5) to determine noise emission variability for samples of the same machine measured under different test conditions.

(6) to determine the change in the noise emission characteristics of machines with time as they are used in construction.

BASELINE NOISE EMISSION LEVELS

In order to establish baseline noise emission levels for current new wheel and crawler tractors, data were obtained from the following sources:

- o manufacturers (in response to EPA requests).
- o a limited field measurement program conducted by a contractor for EPA;
- o a test program conducted at Ft. Belvoir, Virginia, by EPA and U.S. Army MERADCOM personnel.

Noise Data Obtained from Manufacturers

The noise emission data obtained from manfacturers were based principally on a survey form and personal visits to nine manufacturers. All nine manufacturers responded with useful data. Briefly, nine manufacturers supplied acoustical measurements on over 225 machines, of which there were over 115 different models. Table 4-1 presents a summary of this data base.

A more detailed breakdown of the data supplied by manufacturers for various models is not shown here in response to manufacturers who requested that noise emission levels for their machines not be made public.

In general manufacturers tested their equipment for environmental (spectator) noise emission utilizing either of two standard procedures, SAE J88 [9] or SAE J88a [3]. These two standards prescribe noise measurement procedures in both the stationary and moving machine modes at a 50 foot distance from the machine. Manufacturers also submitted data as per the "French Regulation" [7] and other miscellaneous tests, including some data recorded at the operator's ear utilizing SAE 919a [10].

TABLE 4-1

Summary of Noise Data Received from Manufacturers

Machine Type & Horse Power Class	No. of Manufacturers	No. of Models	Range of Sound Level	Lowest Noise Kit Measurement
Crawler Dozers				
20 - 89	4	7	76 - 84	74
90 - 199	3	7	78 - 82	74
200 - 259	2	2	81 - 84	—
260 - 450 limit	4	8	82 - 86	—
Crawler Loaders				
20 - 89	3	6	78 - 85	75
90 - 275+	4	10	79 - 88	74
Wheel Loaders				
20 - 134	4	13	76 - 86	74
135 - 241	5	9	80 - 84	73
242 - 348	5	9	80 - 86	83
349 - 500 limit	2	2	84 - 85	—
Utility Tractors	4	8	74 - 81	—
Skid-Steer Loaders	2	8	66 - 77	—

[1]Sound level represents the Hi-Idle, four-position arithmetic average range at 50', i.e., the lowest machine average to the highest machine average of particular models.

The discussion in this subsection is limited to noise emission data provided by manufacturers that are in accordance with the SAE J88 or SAE J88a recommended procedures. In addition, some results obtained from the EPA/MERADCOM Test Program are also included here.

Figure 4-1 depicts for each machine type an estimate of the percentage of machines in existence currently emitting sound levels (dBA at 50') below specified levels. These curves are based upon the estimated number of machines in existence and the noise emission data base both supplied by the manufacturers and verified in the EPA/MERADCOM test program.

Relationship Between Noise Emissions and Machine Classification

Since the numbers of equipment and their associated sound levels both affect their impact on the population, it was desirable to classify machines into smaller groups based on some machine parameter which correlated well with emitted sound levels. This allowed for a more specific health/welfare analysis to be performed to indicate the relative contributions to the population impact of various groups of equipment.

To determine a machine parameter for classification of equipment two criteria were applied:

- o significant correlation with noise emissions levels.
- o availaibilty of relevant machine parameter data.

Various engineering parameters (e.g. net flywheel horsepower, weight, size, etc.) were examined and net flywheel horsepower was selected as a relevant parameter for classification and analysis

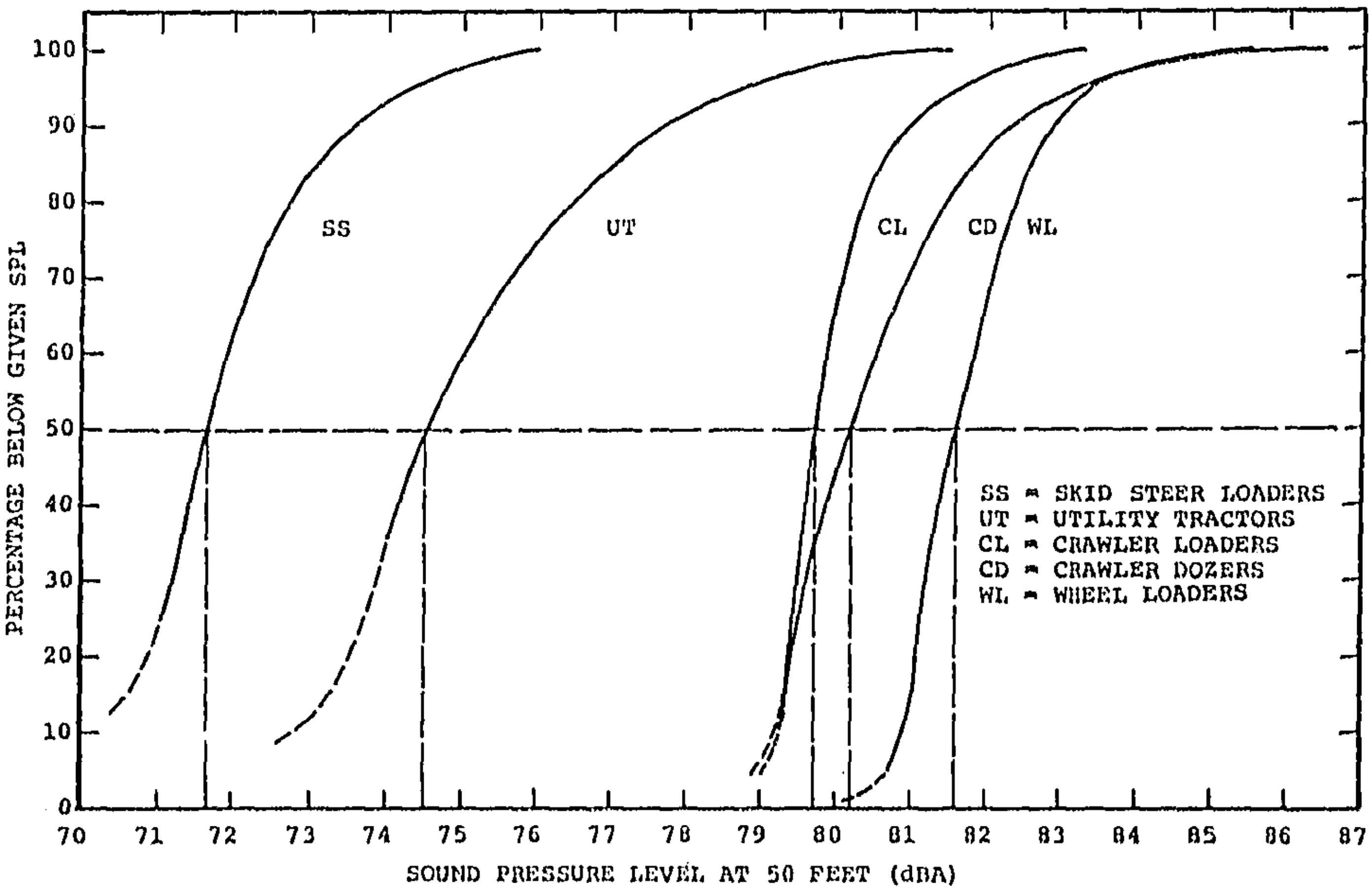


FIGURE 4-1

ESTIMATED PERCENTAGES OF MACHINES IN EXISTENCE WITH SOUND LEVELS BELOW A PARTICULAR HIGH-IDLE SOUND PRESSURE LEVEL purposes. As illustrated in Figures 4-2 through 4-6, horsepower, in general, was statistically correlated with measured sound levels (i.e. four sided High Idle arithmetic average at 50'). Furthermore, horsepower is the parameter used by the U.S. Census Bureau and the Farm and Industrial Equipment Institute (FIEI) for reporting shipment data. One exception to the reporting is that loaders are classified by bucket sizes; however, a linear regression analysis on bucket size (Figure 4-7) showed a high degree of correlation with horsepower. Thus, for consistency and simplicity, horsepower was considered suitable for classifying all equipment types including wheel loaders.

Average Sound Levels vs. Horsepower Used in Health/Welfare Analysis

Although the linear regression lines are useful in establishing the general trend in noise emissions as a function of horsepower, the sound levels used as baseline inputs to both the health/welfare calculations and the noise control technology analysis for each classification category have been based upon the use of average sound levels in each identified horsepower class. These average levels are based upon the manufacturer supplied data and EPA test data. Table 4-2 shows the comparison of the average levels, used in the health/welfare analysis, with the corresponding values obtained from the regression lines. Since the classifications cover rather large horsepower ranges, an average based on actual sample data within these classes is more representative of machines in that class than a regression line based on data over all horsepower categories. The results strongly indicated a significant difference

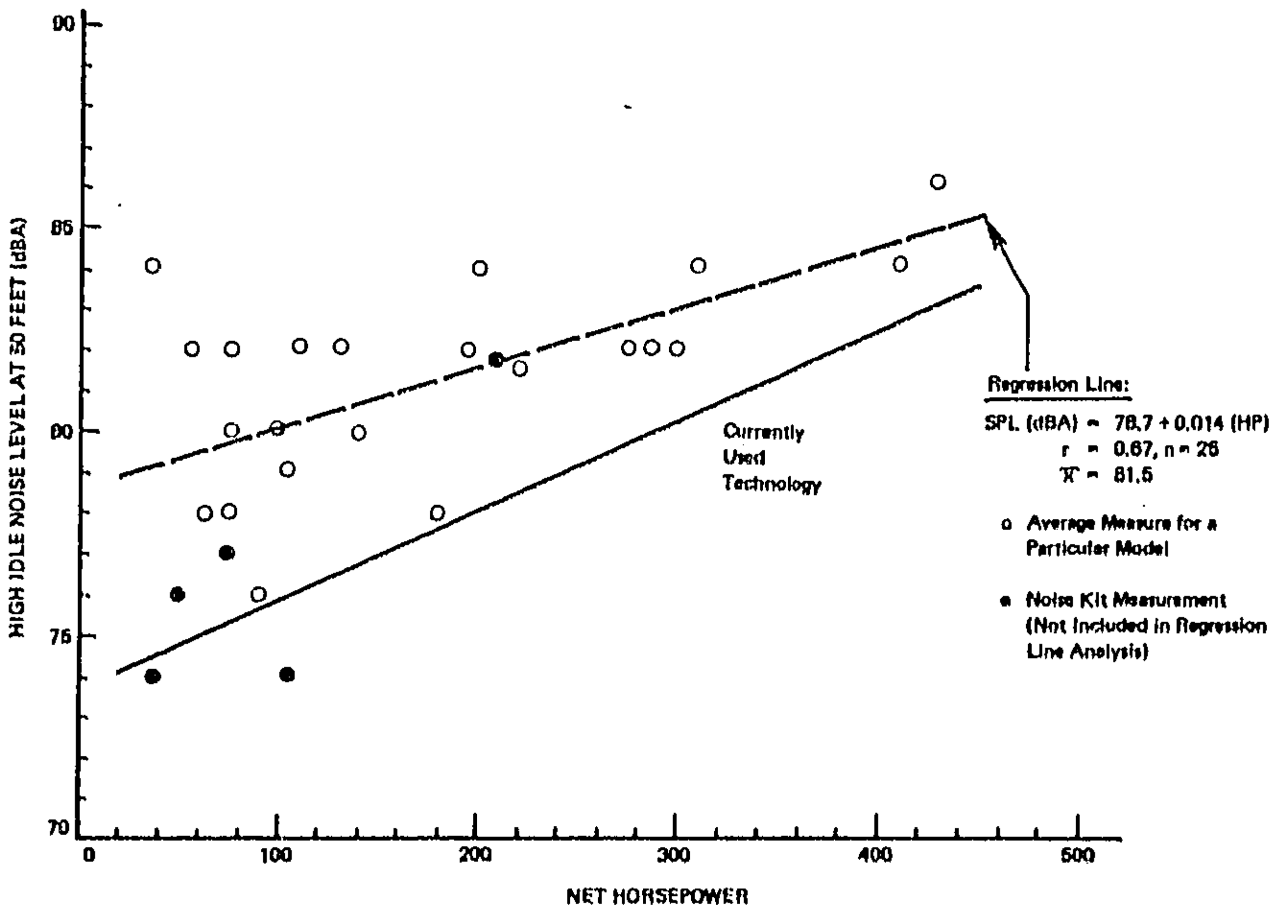


Figure 4-2 HIGH IDLE SOUND LEVEL VS. NET HORSEPOWER FOR CRAWLER DOZERS

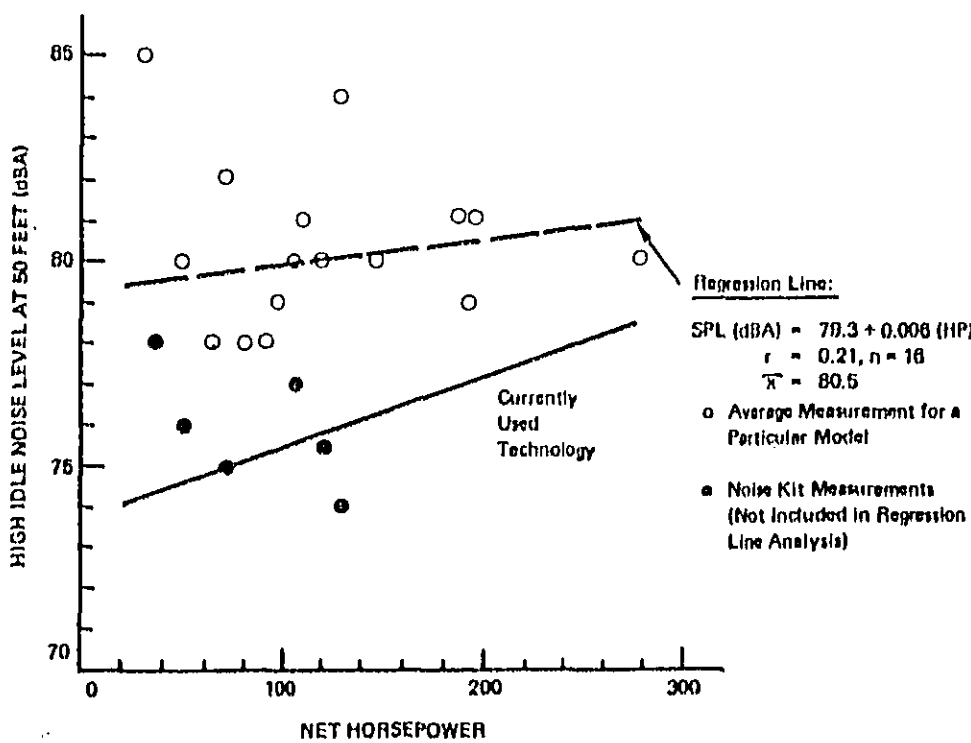


Figure 4-3 HIGH IDLE SOUND LEVEL VS. NET HORSEPOWER FOR CRAWLER LOADERS

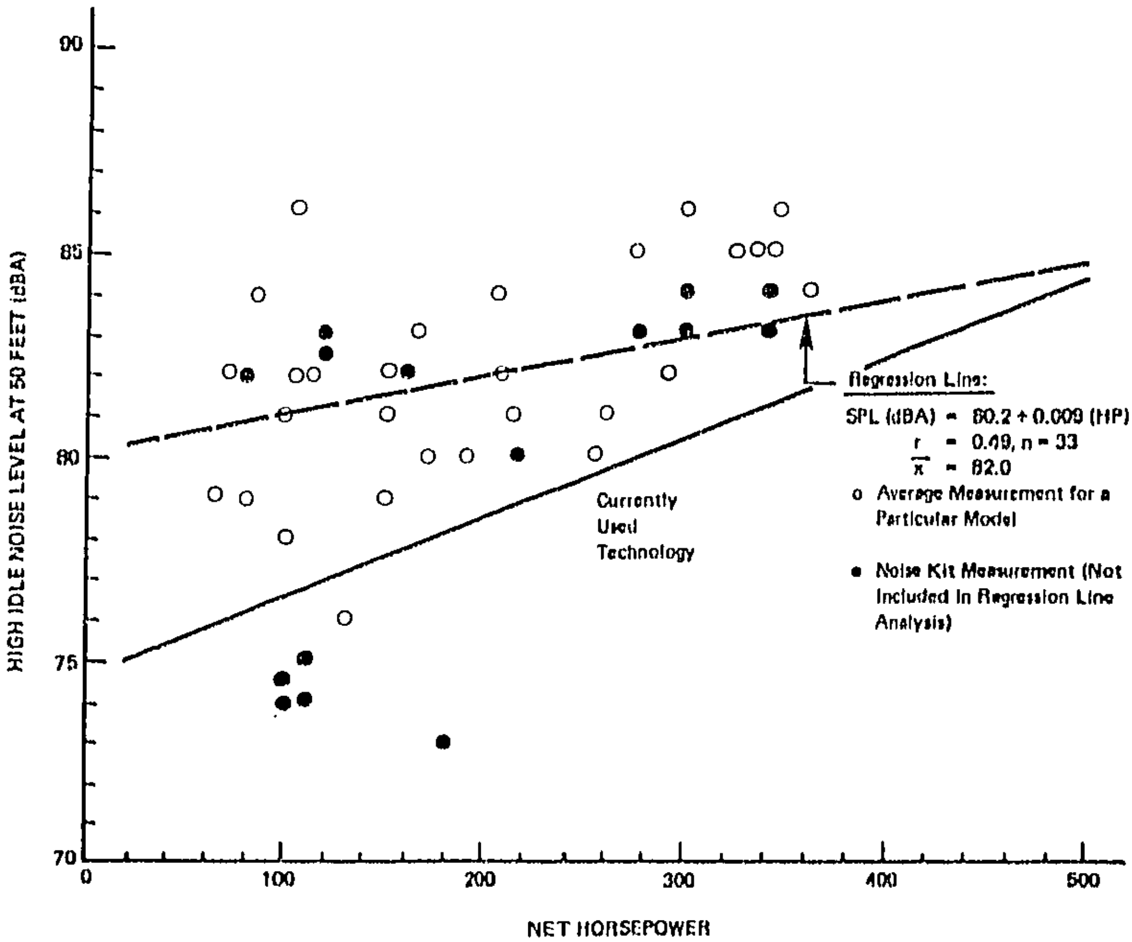


Figure 4-4 HIGH IDLE SOUND LEVEL VS. NET HORSEPOWER FOR WHEEL LOADERS

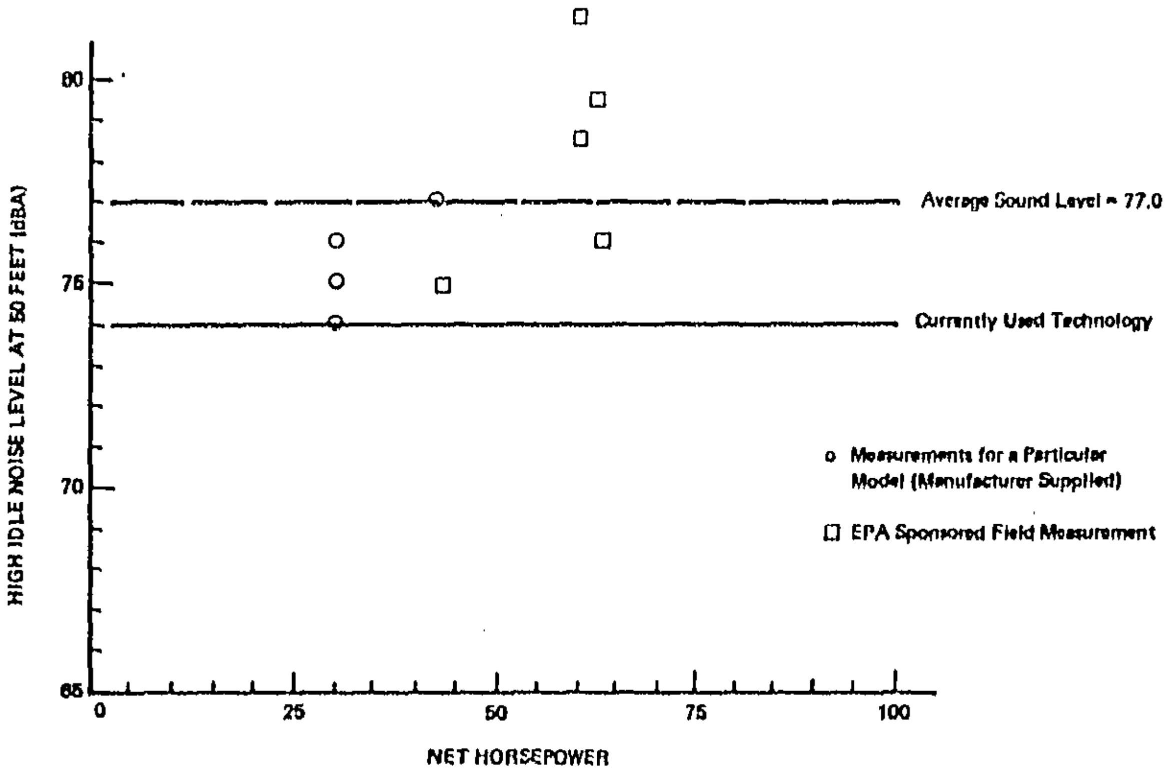


Figure 4-5 HIGH IDLE SOUND LEVEL VS. NET HORSEPOWER FOR WHEEL TRACTORS

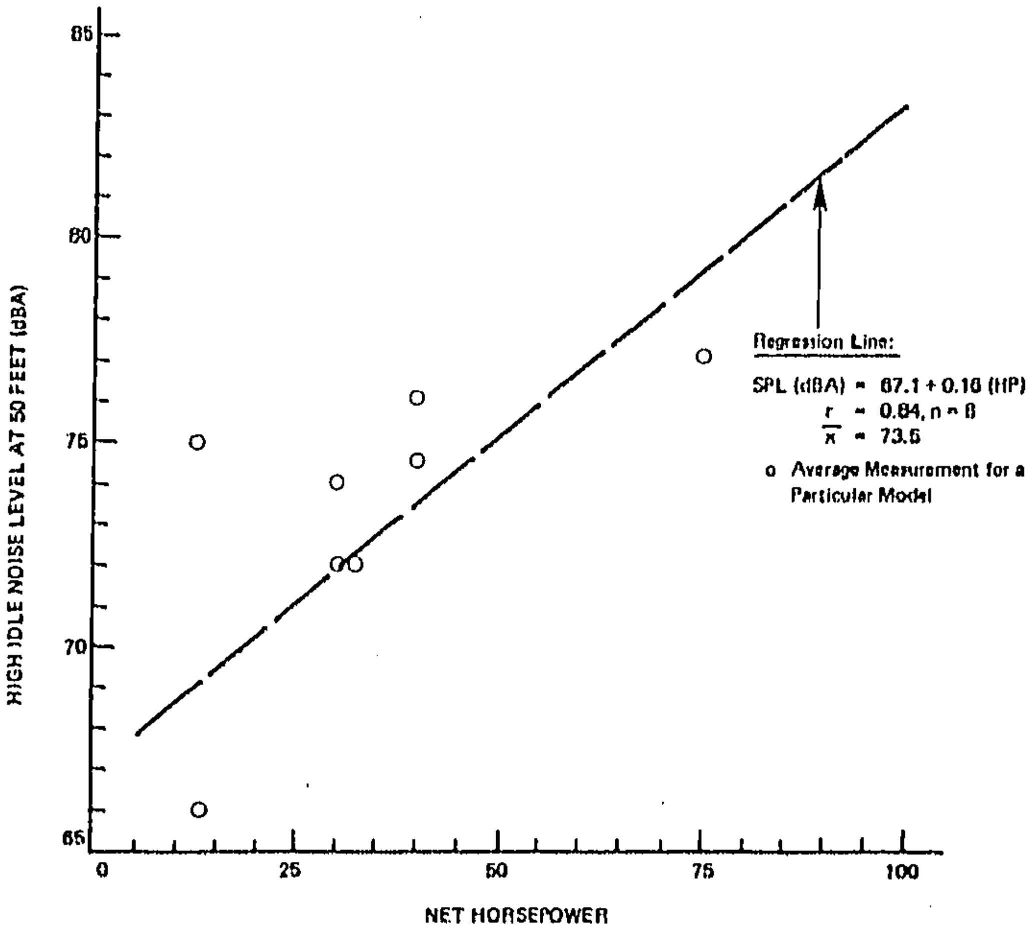


Figure 4-6 HIGH IDLE SOUND LEVEL VS. NET HORSEPOWER FOR SKID STEER LOADERS

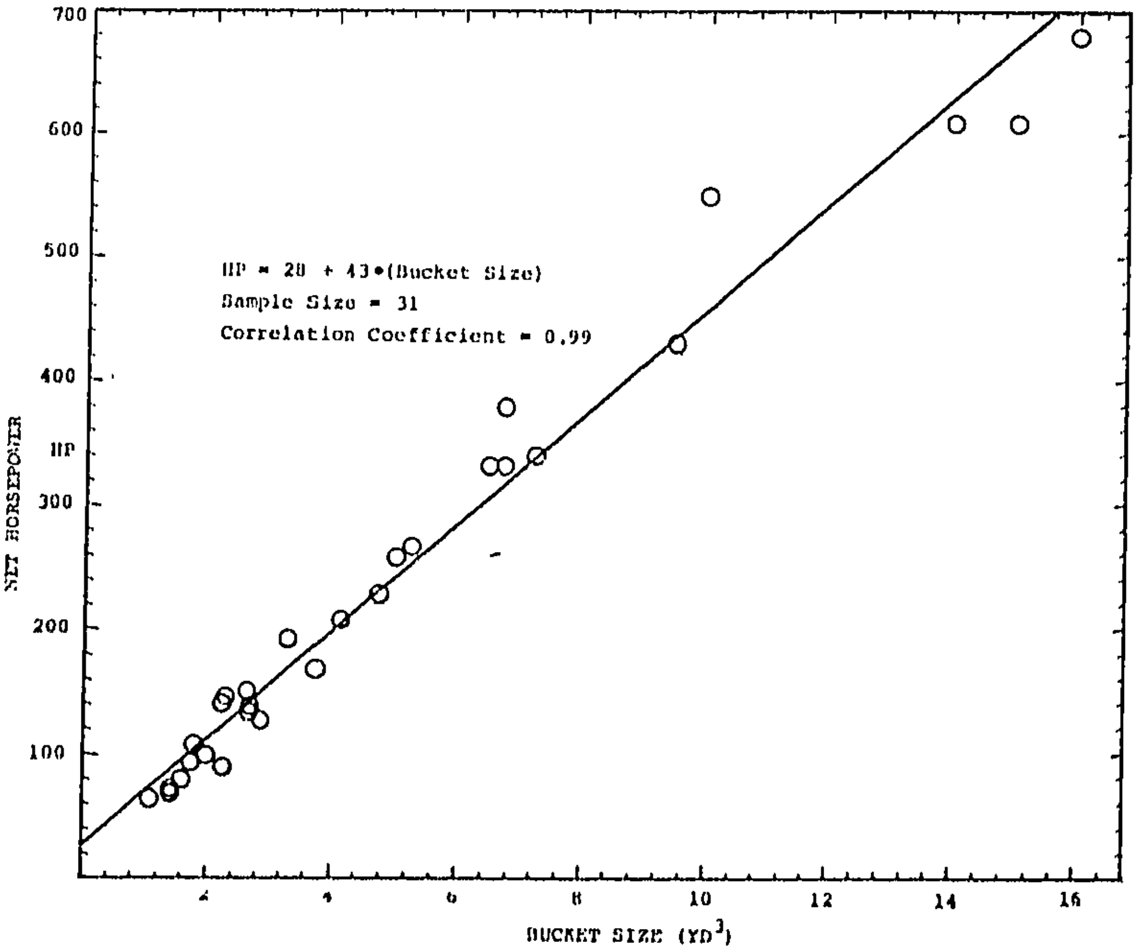


FIGURE 4-7 NET HORSEPOWER VS. BUCKET SIZE FOR WHEEL LOADERS

TABLE 4-2

COMPARISON OF AVERAGE
AND
REGRESSION LINE SOUND LEVELS IN EACH HORSEPOWER CLASS

Machine Type & Horsepower Class	Number of Models	Sound Pressure Levels (Hi-idle dBA @ 50') Average	Regression
Crawler Dozers			
20-89	7	79.5	80.0
90-199	7	80.0	81.0
200-259	2	84.0	82.0
260-450 limit	8	84.0	83.5
Crawler Loaders			
20-89	6	79.5	79.5
90-275	10	80.0	80.0
Wheel Loaders			
20-134	13	81.5	81.0
135-241	9	81.5	82.0
242-348	9	84.0	83.0
349-500 limit	2	84.0	84.0
Wheel Tractors	3	77.0	*
Skid Steer Loaders	8	73.5	73.5

NOTES: (1) All numbers are rounded off to the nearest .5 dBA.

(2) Average values are based on the arithmetic average of sound level measurements for each model (without a specific noise kit).

(3) Regression values are based on mid-point of the regession line for each class.

* Insufficient data to support regression analysis.

in sound levels for large horsepower machines (i.e., >200 hp) vs. small horsepower machines (i.e., <200 hp).

Noise Emitted with Noise Kits

Several manufacturers provided limited data for machines equipped with noise kits. Average measurements for each particular model for which noise kit data were provided are shown in Figure 4-2 through 4-6.

Conclusions concerning "noise kit" effects are based on a small sample. However, these data have been useful for estimation of currently used (i.e., off-the-shelf) technology levels and for use in conjunction with the health/welfare analysis and the noise control technology analysis to set the study levels for each equipment type.

Sound Levels Based on Currently Used Technology

Figures 4-2 through 4-6 also illustrate a lower bound on sound levels based on currently used techniques described in Section 6. These levels, as a function of horsepower and machine type, are assumed to be attainable using "retrofit" noise control techniques, i.e., not major equipment redesign. The levels shown were based on the data received from manufacturers for machines equipped with noise control kits coupled with an engineering analysis of component noise sources and quieting techniques currently in use. (Section 6 discusses quieting techniques.)

Model Noise Variability

An important aspect of the analysis for use in establishing "not to exceed" emission levels is a determination of the variability in noise measurements on different machines of the same model and also for the same machine measured under different test conditions. Several manufacturers provided sufficient information to allow an analysis of machine variability for different machines of a particular model.

The standard deviation of sound level measurements for different machines of the same model was typically less than 1.5 dB. However, it is noted that the results were not consistent among manufacturers. Variation in sound level measurements for the same model appear to be a function of manufacturer and equipment type. It may be anticipated that the larger manufacturers with better quality assurance and control programs will likely have less variability and can design with less tolerance than smaller manufacturers.

Assuming a conservative estimate of a 1.5 standard deviation to represent all machine types, a manufacturer "design to" difference of 2 dB from a "not to exceed" standard was calculated using the assumptions that noise emission variability is normally (gaussian) distributed and that an acceptable quality level (AQL) is 10 percent.

Degradation of Noise Emission Levels

In its study of the degradation of noise emission levels, the agency sought information and data to answer two basic questions addressing the noise signature and usage of wheel and crawler tractors.

(1) Is it expected that the noise emission levels of typical wheel and crawler tractors will change with time as they are used in construction?

(2) How long are wheel and crawler tractors typically used before the first major overhaul which would potentially affect the noise emission levels of these machines?

Increase in Noise Emissions with Time

Utilizing information contained in a publication of the American Building Associating (ARBA) [35] augmented by manufacturer and construction contractor data, the Agency has concluded that there is no clearly observable trend for noise levels of wheel and crawler tractors to either increase or decrease with age. Individual machine noise data compiled by ARBA, as typified in Figures 4-8 and 4-9, show reverse noise trends. For one machine, the noise may escalate with age, while for another model, the machine may become quieter. Furthermore, a statistical sample of several models within a product class, as shown in Figure 4-10 and 4-11, indicates a similar result. Some groups of machines become noisier while other groups become quieter with age. In the absence of detailed use and maintenance information no definitive conclusions can be drawn at this time concerning the magnitude of the change in noise emissions, as a function of age and use, expected for each machine.

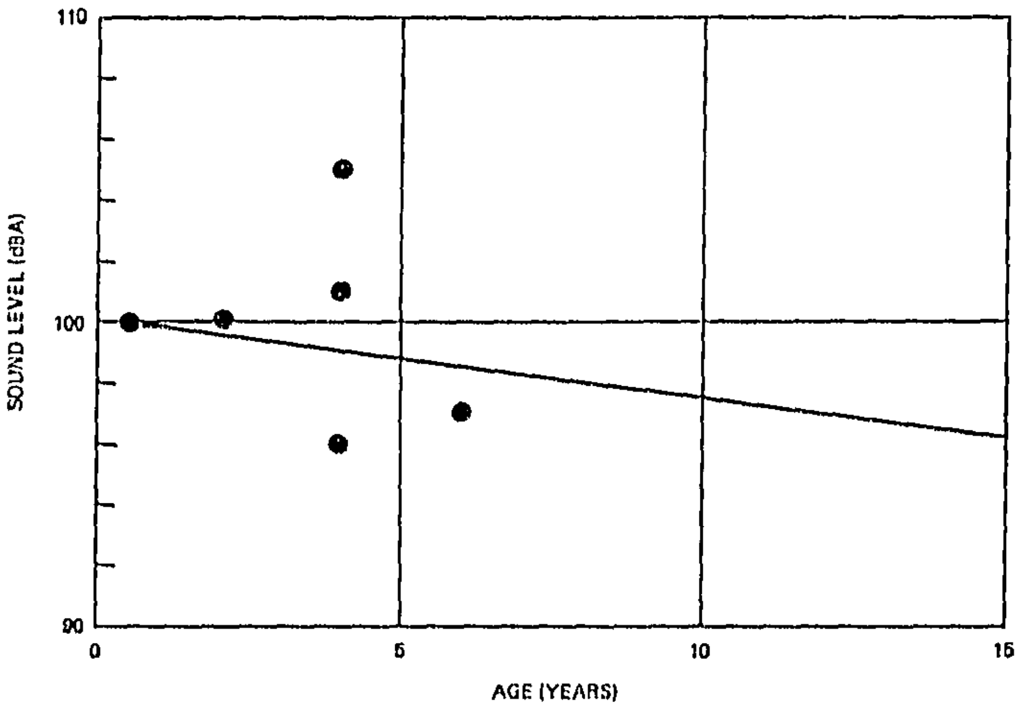


Figure 4-8 Sound Level vs Age for an Individual Crawler Tractor Model

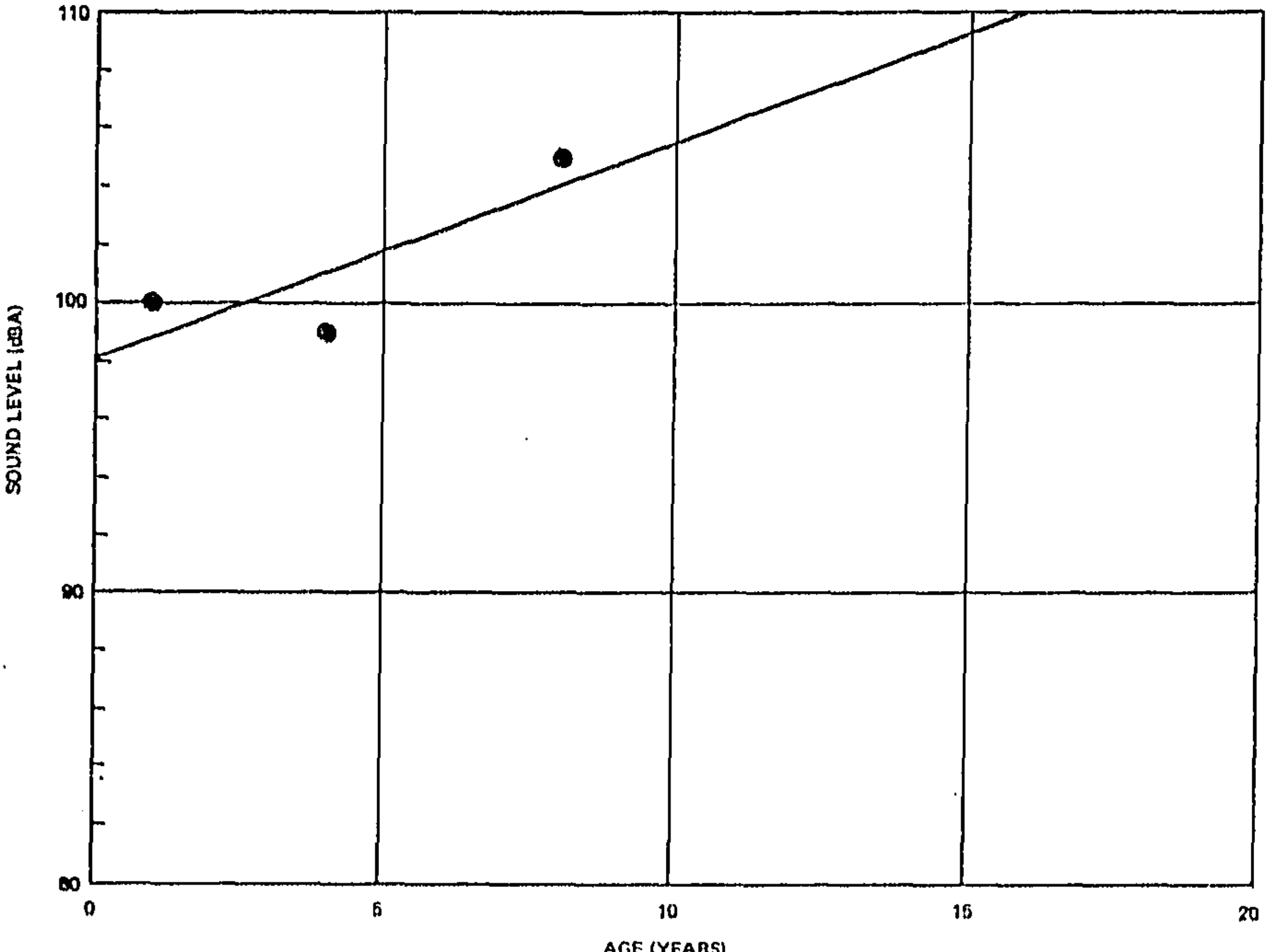


Figure 4-9 Sound Level vs Age for an Individual Wheel Loader

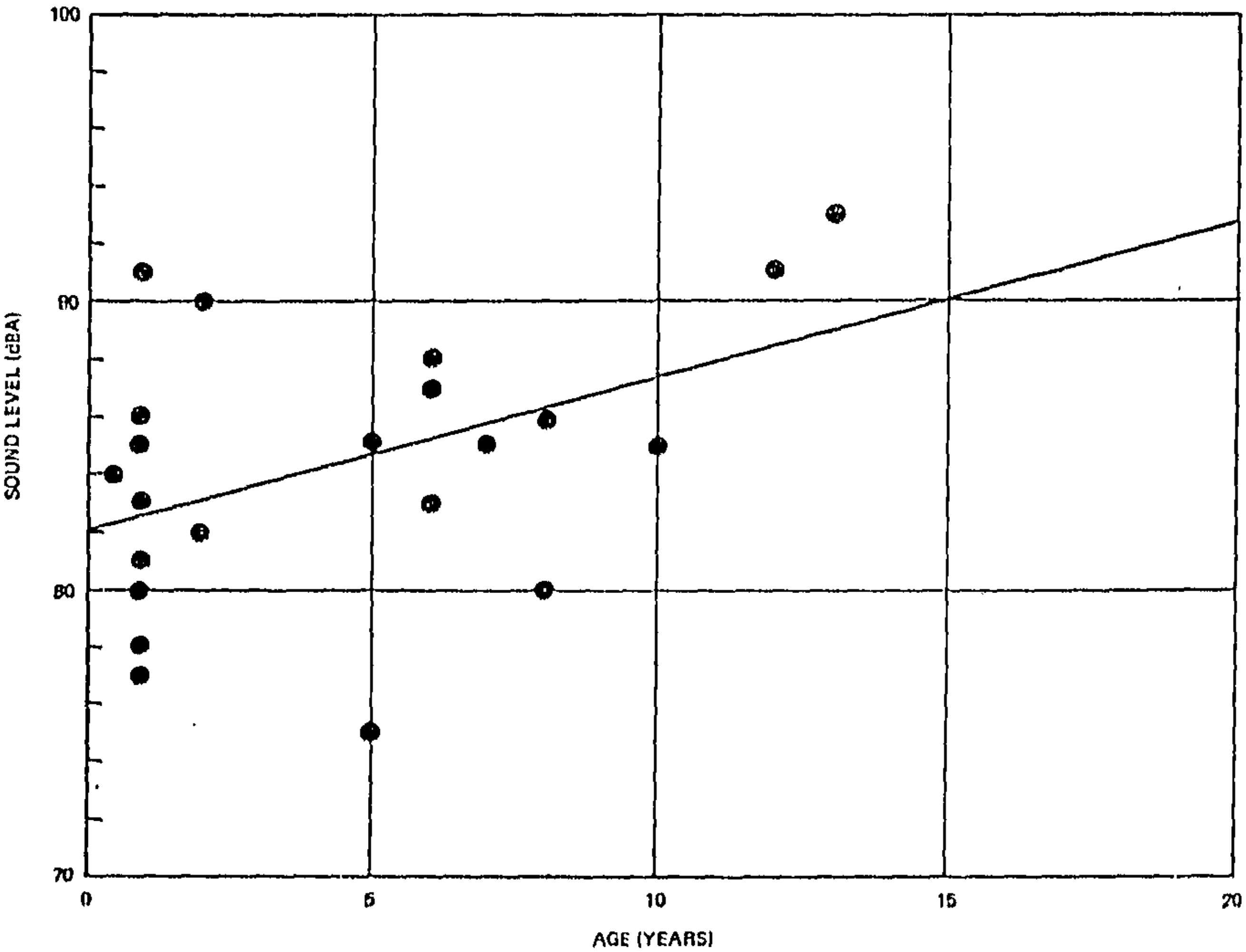
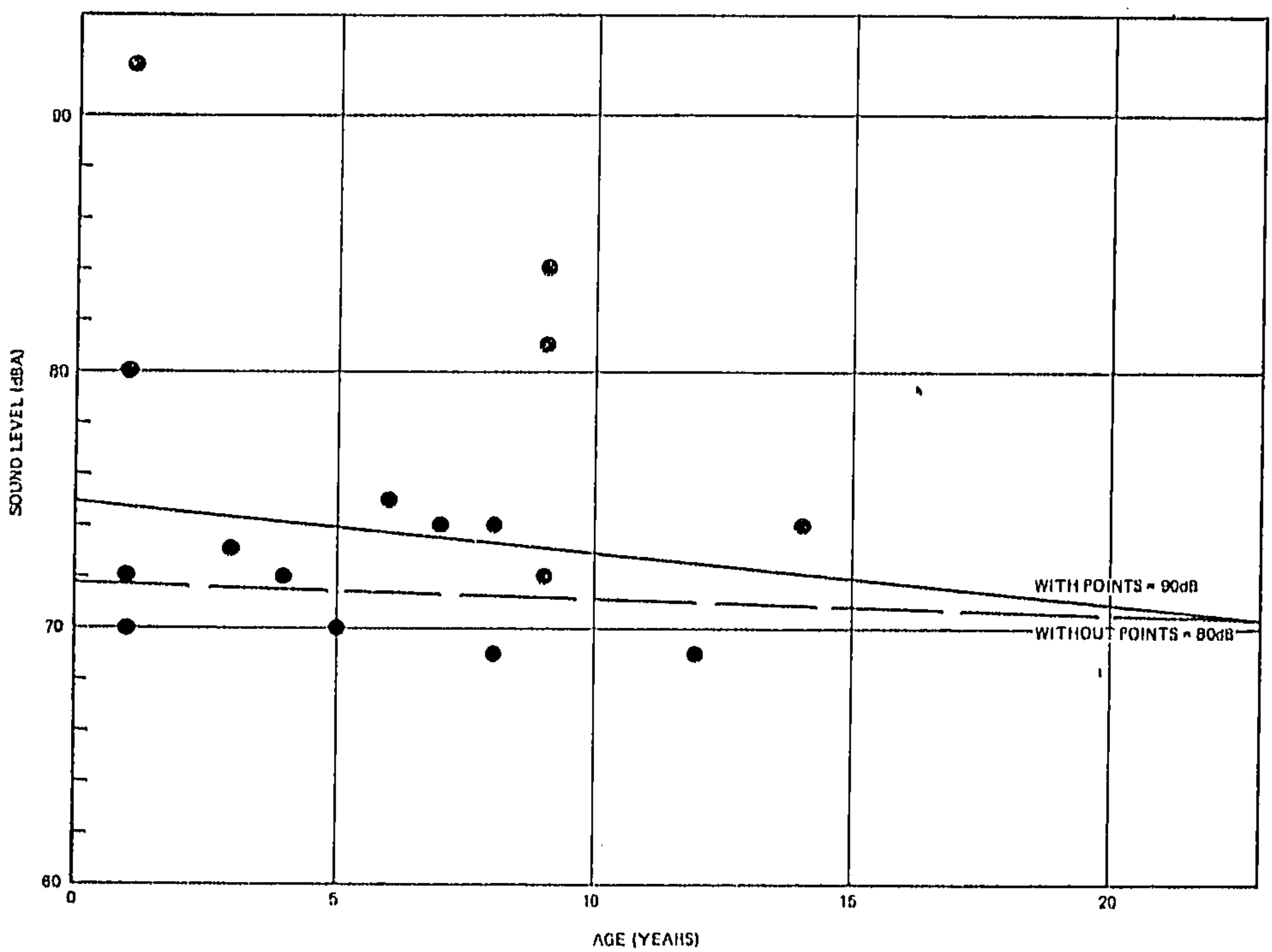


Figure 4-10 Sound Level vs Age for Several Wheel Loader Models (<250)


SOUND LEVEL (dBA)
90
80
70
60
0
5
10
15
20
AGE (YEARS)
WITH POINTS = 90dB
WITHOUT POINTS = 80dB

Additionally, one major manufacturer has stated that, if normal and periodic maintenance is performed, it is not expected that machine noise levels would increase during the economic life of his machines. In fact, a decreasing trend might occur since older machines are operated at lower RPM's resulting in reduced engine noise. This decrease in the primary source level may outweigh any increase in noise level resulting from a greater number of rattling parts. In general, engine noise would not increase until such time as internal clearances become excessive. Fan noise should not increase (in time) except in the cases of mechanical failure of parts which would prompt immediate repair, damaged. Exhaust noise is not expected to increase unless perforation of the exhaust pipes on muffler shells occurs as a result of internal corrosive effects or accidental external puncturing. With proper maintenance, those effects, that would tend to increase a product's overall noise signature, are not likely to occur before the time of the first major overhaul of the machine.

Average Time Before First Overhaul

Table 4-3 shows the average time in years, before first major overhaul for categories of wheel and crawler tractors. These times correlate with both increased repair costs as machines age and with possible increases in engine noise. The times also correspond closely with the period of first owner usage. In general, machines of the age of five to seven years are sold to a second owner and tend to be used at reduced frequency and in more rural applications where their noise emissions impacts are less pronounced.

Table 4-3

Average Time to First Major Overhaul of Wheel and Crawler Tractors

Product	Average Time to First Overhaul (yrs.)
Crawler Tractors	
20 - 199 HP	5
200 - 450 HP	7
Wheel Loaders	
20 - 249 HP	5
250 - 500 HP	7
Wheel Tractors	
20 + HP	5

Source: Contractors Equipment Manual, Associated General Contractors of America, Seventh Edition, 1974.

FIELD MEASUREMENT PROGRAM

EPA conducted a limited field measurement program to obtain noise measurements of machines for comparison with the manufacturer-supplied High-Idle noise data. Noise emission data were obtained for several crawler and wheel machine types during actual work conditions at construction sites at the request of EPA.

All on-site measurements were made during various operating modes at distances from the machine that varied depending on the machine task. Due to actual field operation constraints, it was not possible to obtain controlled experimental data for specified modes or distances.

Based on the measurements and the operating times in each mode, a work cycle was derived and work cycle L_{eq} was calculated. Comparisons of these data were made with the manufacturer supplied noise data base in order to assess whether L_{eq} correlated with noise emissions in a specific operating mode. As a result, it was determined that the four-side arithmetic average of high-idle measurements closely correlated with differences less than 1 dBA, with the calculated work cycle L_{eq}. In addition, as indicated in Figue 4-8, it was observed that sound levels of moving machines at construction sites are not significantly different from levels of a stationary machine measured, during high idle, at four positions around the machine. These data samples have provided a basis for using the four-side arithmetic average of the high-idle measurements as direct, uncorrected input into the health/welfare analysis.

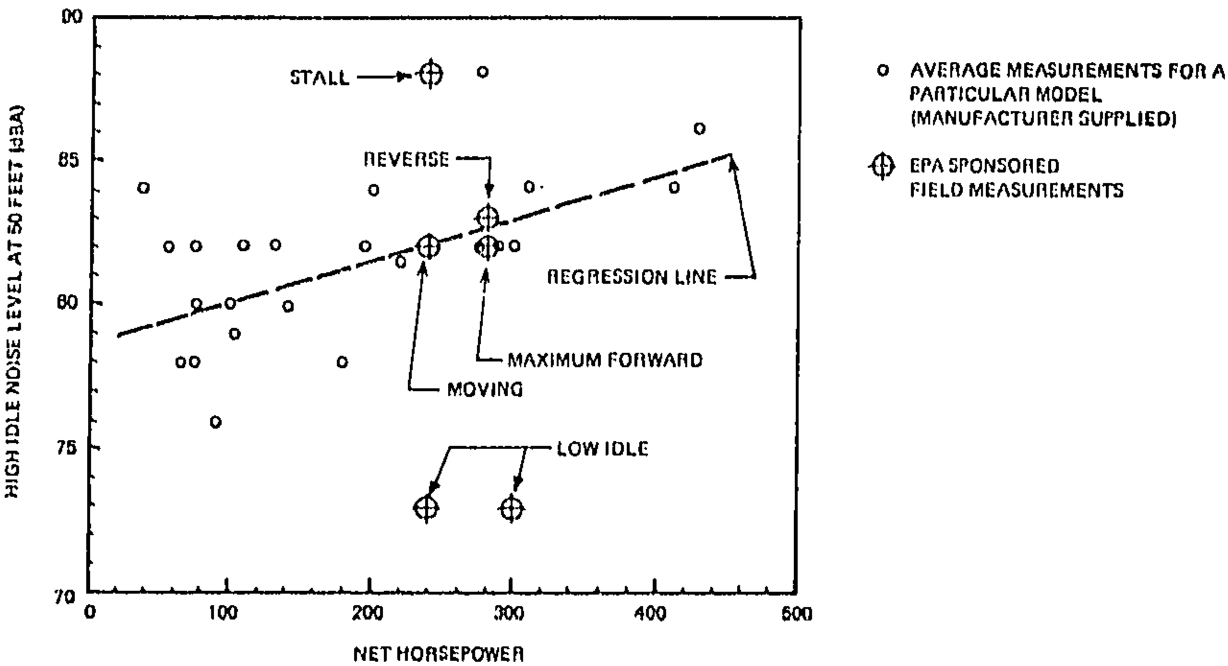


Figure 4-12 Observed Sound Levels at Construction Sites
(High Idle Sound Levels vs. Net Horsepower for Crawler Dozers)

EPA/MERADCOM TEST PROGRAM AT FORT BELVOIR, VA.

A field test program was implemented by EPA to provide additional noise emission data under controlled conditions for the following purposes:

- o To obtain data on certain models for which limited information was available (e.g., utility tractors).
- o To obtain additional noise data under various mode of operation, (e.g., reverse,) in order to develop a large data base for relating actual work cycles with the proposed measurement methodology as well as to provide an input to the component noise source analysis.
- o To obtain noise data on the directionality of the noise emissions as a function of distance (e.g., overhead, operator ear) to provide further validation of the four-position measurement procedure for estimating average noise levels emitted from a source. An additional objective was to determine whether measurements taken at the operator's ear would correlate well with hi-idle (4-position) average noise emissions. Overhead measurements were also to be obtained to assess their impact on overall noise emissions.

- To obtain further noise data regarding repeatability of measurement to assess the accuracy of measurements and the variability among the same (and similar) machines.
- To verify manufacturer supplied data to develop more confidence in the overall data base.
- To obtain data concerning site variation in order to show the effects of various types of sites (e.g., concrete vs. earth) on noise emission measurements.
- To determine the contribution of various components to overall machine noise.
- To assess the attenuation of noise as a function of distance for use in health and welfare analyses.

Test Procedures

Table 4-3 lists the machines tested. The machines were tested at three sites:

- the "concrete loop site" with compact earth between site and microphone,
- the "overhead measurement site", and
- a flat, hard compact site for tracked vehicles.

All sites essentially met requirements of SAE J88a tests. Table 4-4 summarizes the measurements taken. Stationary and moving modes, following SAE J88 and SAE J88a procedures were used to obtain the noise emission data. Also reverse mode, coast mode, etc., were examined.

Table 4-4
MACHINES TESTED AT FORT BELVOIR

MACHINE-TYPE	CATEGORY
CASE 1700	SKID STEER
IH 2500B	UTILITY TYPE LOADER/BACKHOE
FORD 4000	UTILITY TRACTOR
JD 301A	UTILITY TRACTOR
IH 3414 (2 MACHINES)	UTILITY TYPE LOADER/BACKHOE
AC 645	LOADER
IH 3200	SKID STEER
JD 401B	UTILITY TRACTOR
JD 401C	UTILITY TYPE LOADER
CLARK 175B	LOADER
CAT D8K	TRACKED DOZER
CASE MW24B	LOADER
CASE M450	TRACKED DOZER
CAT 966	TRACKED LOADER
CAT D7F	TRACKED DOZER
CAT D6	TRACKED DOZER
CASE 450 (Loader)	TRACKED LOADER
IH 125 (Loader)	TRACKED LOADER
JD 410D	LOADER/BACKHOE
CAT D7E	TRACKED DOZER
CAT 830MB	WHEELED DOZER

Table 4-5

Noise Level Measurements at Ft. Belvoir

Machine Code	High Idle Arithmetic Average Level (dBA)	Adjusted Overhead Level (1) (dBA)	High Idle Level Minus Overhead Level	SAE J88a Level	Mode of Operation (2)
1	75.5	74.9	0.6	81.5	D
2	78.7	73.8	4.9	82.5	C
3	77.2	74.1	3.1	83	B
4	76.1	70.4	5.7	77	B
5	83.2	83.3	-0.1	91	B
6	79.5	76.6	2.9	81.5	B
7	83.5	77.1	6.4	89.5	B
8	75.4	70.5	4.9	79	C
9	78.8 78.1*	74.3	4.5	79	B
10	78.3*			80.5	D
11	82.4*			89	C
12	82.1	78.4	3.7 $\bar{x} = 3.7$ $s = 2.1$	85	D
13	83.2*			89	B,C
14	74.2*			81	B
15	79.2*			88	B
16	76.3*			81	D
17	80.8*			89.5	B
18	72.1*				
19	76.7*			80.5	C

* Not measured at over head position

1) Levels are adjusted for 15m from exhaust pipe by subtracting 6 dB per doubling of distance. Original data was taken at 8.5m over ground. Exhaust pipes varied from 1.5m to 3.5m above the ground.

2) Mode of operation for SAE J88a level

   A Stationary - HI, highest of 4 sides
   B Stationary - IMI, highest of 4 sides
   C Stationary - Component Cycle, highest of 4 sides
   D Moving - Average of highest levels within 2 dB for highest side while traveling at full speed in intermediate gear (no load).

Results of Test Program

Significant findings and conclusions drawn from the results of the test program are presented below.

- Overhead noise levels averaged 3.7 dBA less than "spectator-height" levels. (Sample-10 machines; see Table 4-4.) These results indicate that the overhead measurement position is not required (unless a major redirection of noise is made) since the horizontal directivity is significantly greater than the vertical directivity in existing machines. The exhaust, usually directed vertically, is the major noise source in the vertical direction. The engine casing shields, at least partially, the noise radiating from the engine in the vertical direction. On the other hand, the horizontal directivity is increased by the grill/engine openings and partial barrier of the horizontal surfaces.
- The smooth concrete site produced, a relatively repeatable 1 dBA greater measured sound pressure level than a hard-packed earth site. Indications are that the repeatability of these results may offer manufacturers an opportunity to reduce the expenses involved in constructing a truly reflective test plane, if they can verify this correlation for their machines.
- Sound level data taken on separate days resulted in repeatability of sound level measurements with average differences of less than 1 dBA (see Table 4-5) for most modes.

Table 4-6
Repeatability of Test Results

Machine #3 Retest - Sound Levels (dBA) @ 50-feet
Concrete Loop Site

TEST DATE:	Tested 31 January 1976 High Idle Mode	Tested 20 May 1976 High Idle Mode	Difference
4 Position Arithmetic	76.0	76.6	+ .6
	Idle-Max-Idle Mode	Idle-Max-Idle Mode	
4 Position Arithmetic	82.3	80.6	-1.7
	Moving-Int. Gear	Moving-Int.Gear	
2 Side Arithmetic Average	76.0	77	+1
SAE J88a (highest side IMI Reading)	83 (83.5)*	82.5 (83.5)*	- .5(0)*
SAE J88 (72) (less side acceleration)	84.5 (85)*	84.5 (85.5)*	0 (.5)*

*Numbers in parenthesis are for the highest observation, while all others are the average to two observers.

- For a careful measuring procedure using handheld sound level meters, the range of readings at any given position exceeded 0.5 dBA between 50 percent to 60 percent of the time for the Constant Speed Moving Mode (CSM) and High Idle (HI) mode, respectively (see Figure 4-9).
- The standard deviation of sound levels among different machines of the same model is less than 1 dBA. (See Table 4-6.) The data shown in Table 4-5 and 4-6 are consistent with an overall 1.5 dBA standard deviation which was developed from the manufacturer's inputs.
- Directivity in the horizontal direction is dependent on machine type and manufacturer; but in general, the noise is non-directive as shown as in Figures 4-10 and 4-11.
- For propagation of sound levels, the attenuation rate of 6 dB per doubling of distance appears to be a reasonable approximation to the average rate obtained for the distances between 25' and 200'.
- Sound levels measured at the spectator level do not appear to be related, in a consistant manner, to sound levels measured at the operator position (see Table 4-7).
- Comparison of manufacturer supplied data with the EPA/MERADCOM results indicated that, in general, the test program measurements were lower. The exact reasons for this are not known, although, site type difference could be a factor. This points to

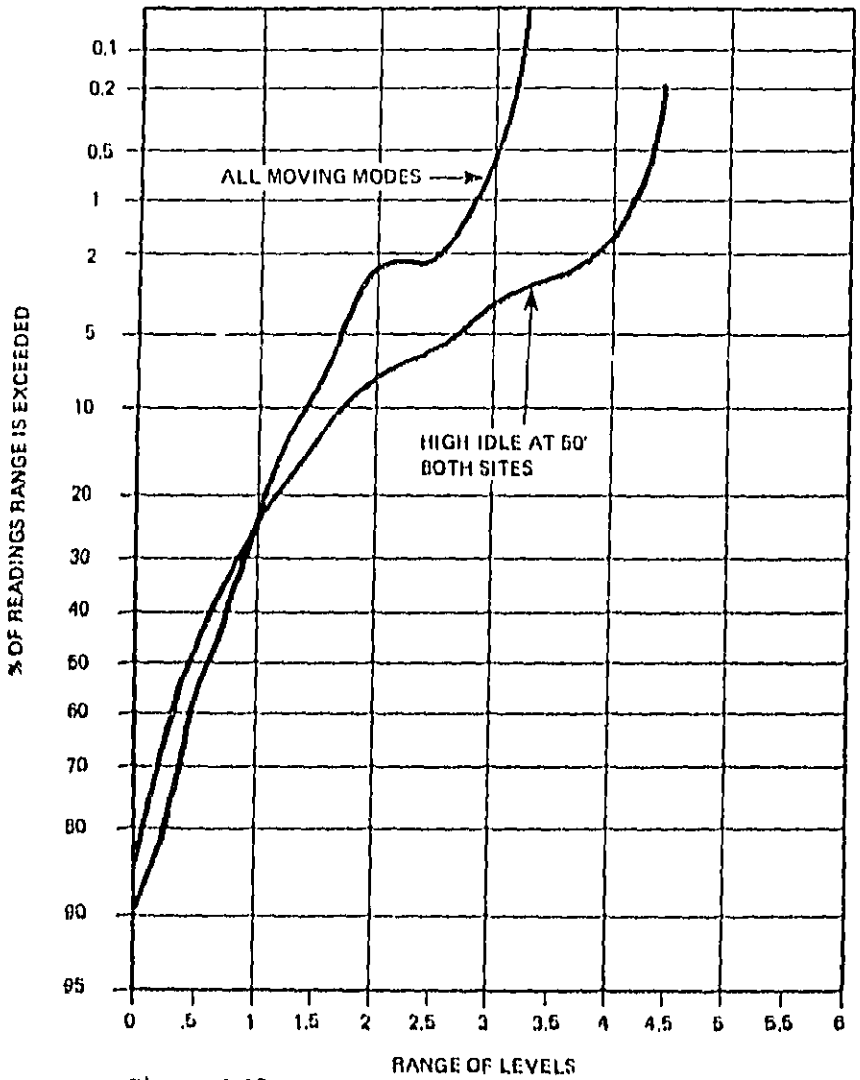


Figure 4-13 Percent of Readings a Range is Exceeded

Table 4-7
Variability of Operator Ear Sound Levels for Different Machines of the Same Mean

High Idle Mode - Sound Levles (dBA)

Machine		Test 1	Test 2	Test 3	Test to Test Range	Test to Test $\bar{x}$	Test to Test s
A		96.5	99.5	97.0	3.0	97.7	1.61
B		98.0	98.5	97.5	1.0	98.0	.50
C		97.0	98.5	97.5	1.5	97.7	.76
D		98.5	98.5	98.0	.5	98.3	.29
Machine to Machine	Range	2.0	1.0	1.0			
Machine to Machine	$\bar{x}$	97.5	98.8	97.5		97.9	.75**
Machine to Machine	s	.91	.50	.41		.29*	

*Overall machine-to-machine variation
**Overall test-to-test variation

$\bar{x}$ = sample mean
s = standard deviations

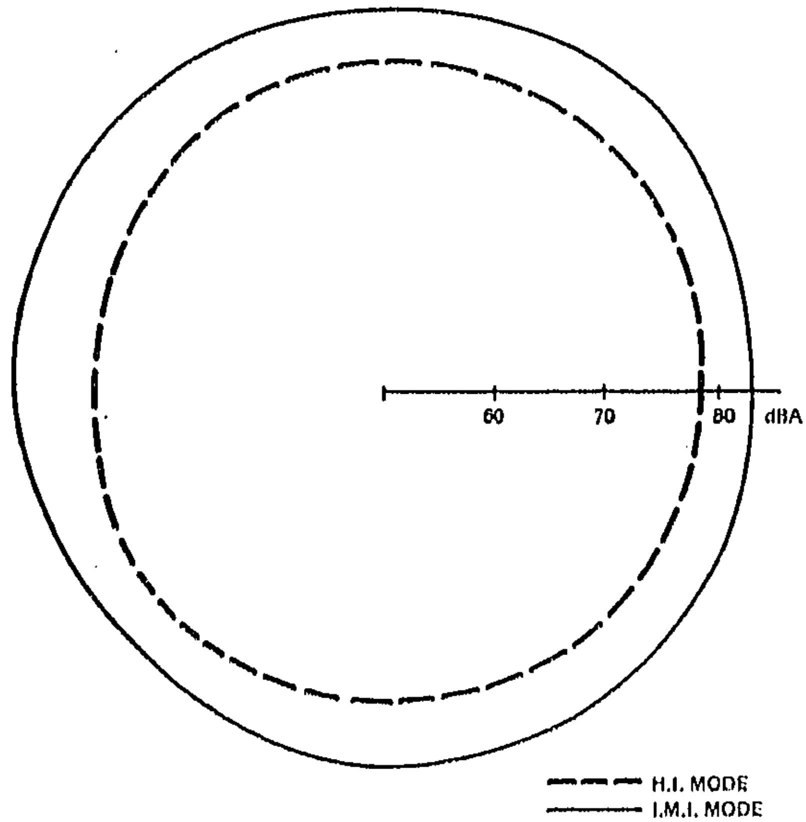


Figure 4-14 Directivity Pattern at 50 Feet for Machine #3 (Crawler Tractor)

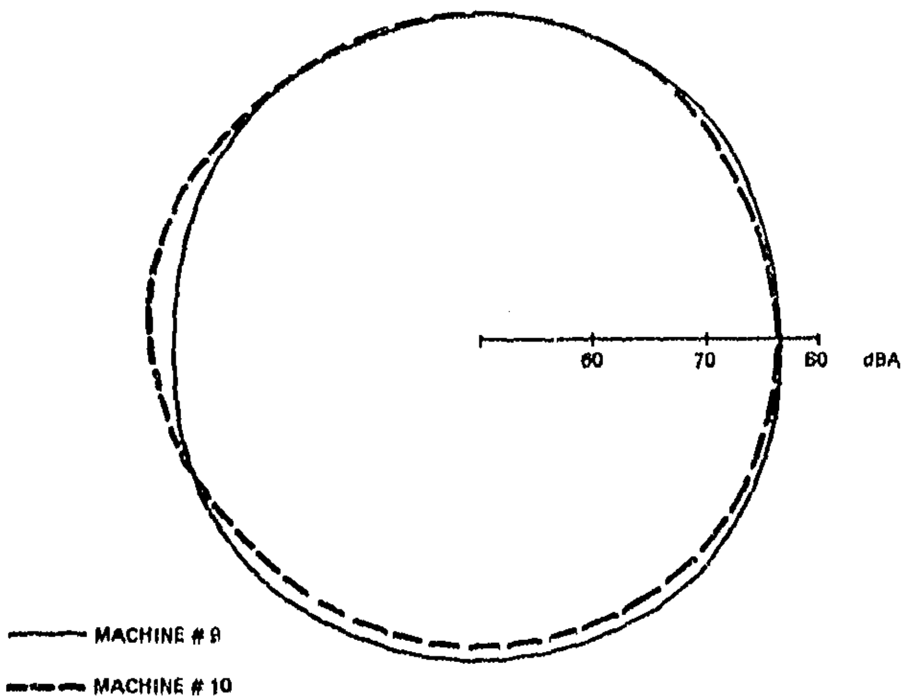


Figure 4-15 Directivity Pattern at 50 Feet for Machines #9 (Crawler Tractor) and #10 (Crawler Loader) in High Idle Mode

Table 4-8

Relationship Between Opeator and Spectator Position
Sound Levels at High Idle

Machine No.	Sound Levels at Operator Position dBA	Sound Levels at Spectator Position dBA	Difference dBA
1	89.5	74.3	15.2
2	96.8	78.6*	18.2
3	94.3	76.9	17.4
4	96	75.7	20.3
5	96	83	13.0
6	100.5	79.2	21.3
7	100	82.7	17.3
8	95.3	75.5	19.8
9	96.5	78.3	18.2
10	99.3	78.2*	21.1
11	87**	81.9*	5.1
12	100.5	81.5	19.0
13	96.5	81.9*	14.6
14	91.5	73.1*	18.4
15	93**	78.5*	14.5
16	93	75.6	17.4
17	98.5	80.6*	17.9
18	89	72.3*	16.7
19	97.5	76.0	21.5

*Loop Only
**Enclosed Cab
***4 Sided Arithmetic Average Over Both Sites

the need for a site calibration technique that will allow a method of adjustment of the readings (higher or lower) to assure the same results of acoustical measurements for the same machine and operating mode.

- Equipment tested with an improved muffler reduced High Idle sound levels by approximately 7 dBA and Idle-Max-Idle sound levels by approximately 10 dBA (see Table 4-8).
- Diagnostic tests on component noise contributions showed that the exhaust and fan components were dominant noise sources with the engine generally ranked next and all "other sources and paths" third (see Table 4-9). For wheeled tractors, noise produced in reverse motion was not significantly different than noise produced in forward motion. (See Table 4-10.) As a result, it has been concluded that transmission noise is not a predominant noise source relative to the engine casing. Since the transmission for crawler tractors is essentially the same as those for wheel tractors, the same conclusion holds. The exact ranking of components varied among the equipment types.

Table 4-9

Results of Improved Muffler

Concrete Loop

	Machine #6 (Good Muffler)	Machine #5 (Poor Muffler)	Machine #5R (Improved Muffler)	Noise Reduction
	High Idle Sound Levles @ 50' (dBA)			
4 Position Arithmetic Average	78.7	83.6	77.0	6.6
	Idle Max Idle Sound Levels @ 50' (dBA)			
SAE J88a	81.5	91	80.5	10.5

Table 4-10

Noise Source Levels at High Idle
for Four Typical Loaders and Dozers - dB(A)

Machine Code	22	7	16	12
Total Machine	77	82.5	75.5	81
Exhaust	72.5(1)	75.5(2)	66.5	77(1)
Fan	64.5	78.5(1)	74(1)	75(3)
Engine (Airborne)	71(2)	74	67(2)	76(2)
Other Sources & Paths	68.5(3)	74.5(3)	66.5	73.5

1. Dominant Source
2. Second Major Source
3. Third Major Source

Table 4-11

Comparison of Sound Levels in Moving Mode of Operation

Machine Code	Forward (1) Intermediate Gear(2) dBA	Forward (1) High Gear dBA	Reverse (1) High Gear dBA	Intermediate Gear Forward Minus 4 Position Arith. Average HI dBA
1	78.2	79.4	79.4	5.3
2	78.5	79.7	77.2	.4
3	76.2	78	76.3	0.0
4	76	77	76.2	1.0
5	85	87.7	84.5	1.4
6	80.2	79	79.5	1.5
7	84	85.5	84	1.6
8	—	76	76.2	—
9	77	77	77.7	.8
10	80	80.2	81	1.1
11	84.5	85	84.8	3.2
12*	84.8	87.5	88.5	4.0
13	85.5	85.2	84.8	3.6
14*	77.5	80	81	4.4
15	81.2	83	83.8	2.9
16*	80.8	84.8	86	5.2
17*	85	90.2	88.8	4.4
18*	—	—	—	—
19*	77.8	79.2	80.5	1.8

*Tracked Machines

(1) All levels given are average of both sides of the machine using the SAE J88a technique of obtaining the level for each side.

(2) Intermediate gear is defined in accordance with SAE J88a.

- A most important test phase was the comparison of "work cycle" L_{eq} with four-sided arithmetic average of high idle noise. Table 4-11 summarizes characteristics concerning the work cycle experiments. As indicated in Table 4-12, the overall (across all machines types) average difference between work cycle L_{eq} and the four-side arithmetic average of high idle noise was less than 0.5 dBA.

Table 4-12

Work Cycle Test Results

Mach#	Tape#	Machine/ Accessory		Operation	Distances m/angles	Speed	Side	Cycle Time Min: Sec	Time-Min # of cycles	L_{eq} dB(A)	Re-marks
2	4	IH2500	Backhoe	Stockpile	9-12/80°	-	Dump	:37.6	12.0/19	73.8	
"	"	"	"	"	"	-	Load	"	8.2/13	73.9	
	5	"	"	Backhoe	11	-	Right	-	19.6/-	75	
	6	"	"	"	8	-	Left	-	10.9/-	75.1	
10	10B	JD401C		Stockpile	11/80°	-	Dump	:57.3	12.6/13	74.9	
	11	"		"		4F,1R 1 Load	Load	:60	23.1/231	75	
19	15	IH125E	"	Stockpile	9/60°	2d,F&R	Dump	:46	21.0/27	76.5	
	16	"		"	"	"	Load	:43.2	21.3/30	77.3	
	17	"		"	"	"	Dump	:37	21.2/34	69.6	1
	18	"		"	"	"	Load	:39	-	70	1
20	20	JD410	Backhoe	Stockpile	14/60°	-	Load	1:00.5	23.5/23	75.6	
	21	"	"			-	Dump	0:47.3	23.5/28	77.1	
		"	"	"	5/60°	1,1	Dump	:30.1	10. /20	80.7	D*
		"	"	"	"	"	Load	"	"	79.2	D
16	23A	D7F	without Panels	Doze/ Spread	12/18	1,2,2	Left			74.3	2
24	B	D7E		"	"	"	Right	1:04	4.8/4.5	83.2	
16	27	D7F	without Panels	"	"	"	Left	1:09	15.0/6+7	77.6	C*
	28	"	"	"	"	"	Right	1:06	14.3/6+7	78.1	C&B
	29	"	"	"	"	"	"	1:17.5	15.5/6+6	77.9	C
	-	"	"	"	"	1,2,3	"	:49.7	5. /6	80.2	D
	-	D7F	without Panels	Doze/ Spread	12/18	1,2,2	Right	:58.5	5.9/6	75.8	D
18	30A	450L	-	Stockpile	11/80°	1,1	Left, Load	1:03	10.5/10	73.4	B,5
	B	"		"	"	"	"	1:00	8.9/9	73.3	"
	31A	"		"	"	"	"	1:05.4	10.9/10	73.5	A
	B			"	"	2,2	"	:43.6	8. /11	76.6	"
23	32	830MB	Muffler	Doze/ Spread	12/18	1,1,2	Left	0:53	11.5/6+7	75.5	
	-	"	"	"	"	"	Right	:55.6	13.9/6+7	77.8	
	-	"	"	"	9/15	1,1,1	Right	:41.6	9.7/6+8	76.2	
12	-	D8K	-	"	18/27	1,2,2	Left	1:19.6	14.6/11	79.2	D
	-	"		"	"	"	Right	1:13.2	7.3/6	80.5	C
	-	"		"	"	"	"	1:08	13.6/6+6	84.3	A

Table 4-12 (continued)

Work Cycle Test Results

Mach#	Tape#	Machine/ Accessory	Operation	Distances m/angles	Speed	Side	Cycle Time Min: Sec	Time-Min # of cycles	L_{eq} dB(A)	Re-marks
12	–	D8K	Doze/ Spread	15/23	1,2,2	Right	:56	11.1/6+6	84.7	A
	–	D8K	"	"	1,2,3	"	:55.8	5.6/6	81	D
	35	D8K	"	12/18	"	"	:44.1	5.1/7	81.7	D
11	33A	175B –	Backfill	30/90°	–	Right, Back	:52.5	10/11+	82	3
	B	"	Stockpile	30/180°	–	Front	:42	4.9/7	79.2	4
	–	"	"	"	–	Back	:44	11/15	86	4
	–	175B	Stockpile	30/180°	–	Front	:39.4	13.1/20	80.5	3
	–	"	Truck Loading	8/60°	1,1	Dump	:45	15 /20	80.6	3,E
	–	"	"	"	"	Load	"	"	84.5	3,E
	–	"	"	"	"	Dump	:46.2	15.4/20	80.5	F
	–	"	"	"	"	Load	"	"	83	F
			Excavation	22/90°	–	Right	:53.4	48.9/55	82.4	3
13	34	MW24 –	Stockpile	30/180°	–	Back	:39.6	13.2/20	78.4	
	–	"	"	"	–	Front	:41.4	13.8/20	80.4	4
	–	"	"	"	–	Back	"	"	84.5	4
7	–	AC645 –	Truck Loading	8/60°	–	Dump	:32.8	10.9/20	82.2	
	–	"	"	"	–	Load	"	"	84.1	

*Letters refer to Operators

1. Measurement position 33 m from work path.
2. Doze blad malfunctioned, not a productive work cycle.
3. Back up alarm operating.
4. Operatyor gradually worked closer to back mic. and further from front mic.
5. Soil moisture content and compaction did not allow grouser penetration.

Table 4-13

Comparison of High Idle to Work Cycle Noise Level

Type of Mach	Operation	Mach#	4 side Avg HI dB(A)	Leq(1) dB(A)	Leq Minus 4 side Avg HI - dB(A)
Utility					
	Stockpiling, 60° to 80° turn, 9 to 14m Travel Legs				
		2	78.6	73.8	-4.8
		10[2]	78.3	75.	-3.2
		20	78	76.8	-1.2
	Stockpiling, 60° to 80° turn, 5m Travel Legs				
		20	78	80	2.0
	Trenching				
		2	78.6	75	-3.6
Wheeled Loader					
	Simulated Truck, Loading, 60° turn, 8m Travel Legs				
		7	82.4	83.1	.7
		11	81.9	81.8	-.1
	Stockpiling, 180° turn, 30m Travel				
		11	81.9	82.6,81,5	.7,-.4
		13	81.9	82.5	.6
	Excavating				
		11	81.9	82.4[3]	.5
	Backfill				
		11	81.9	82[3]	.1
Tracked Loader					
	Stockpiling, 11m Travel, Low Gear				
		18	72.2	73.4[3]	1.2
		19	76	76.9	.9
	Stockpiling, 11m Travel, High Gear				
		18	72.2	76.6[3]	4.4
Tracked Dozer					
	Doze/Spread 1,2,2				
	18/27	12	80.8	79.9	-.9
	18/27	12	80.8	83.6[4]	2.8[6]
	15/23	12	80.8	84.[4]	3.2[6]
	12/18	16[5]	77.2	77.9	.7
	12/18	16	75.6	75.6[4]	0
	12/18	21[7]	81.5	83.2[3]	1.7

Table 4-13 (continued)

Comparison of High Idle to Work Cycle Noise Level

Type of Mach	Operation	Mach#	4 side Avg HI dB(A)	Leq(1) dB(A)	Leq Minus 4 Side Avg HI - dB(A)
Tracked Dozer					
	Doze/Spread 1,2,3 12/18	16[5]	77.2	80[4]	2.8
		12	80.8	81.1[4]	.3
		12	80.0	80.4[4]	-.4
Wheeled Dozer					
	Doze/Spread 12/18	23	84[7]	76.7	-7.3

1. Arithmetic average of both sides.
2. Only Gasoline Utility Tractor.
3. One side only.
4. Estimated, assuming difference in sides is constant.
5. Machine with part of noise suppression kit removed.
6. This data is questionable but no specific error could be found to justify excluding it.
7. Estimated from data for 2 sides and the directivity of similar machines.
8. Distance in meters.

SECTION 5

EVALUATION OF EFFECTS OF WHEEL AND CRAWLER TRACTOR NOISE ON PUBLIC HEALTH AND WELFARE

INTRODUCTION

The proposed noise emission regulations for newly manufactured wheel and crawler tractors specify levels not to be exceeded as measured according to the measurement method presented in section 3. Potential public benefits are necessary inputs to the assessment of trade-offs between the multiplicity of possible regulatory levels and effective dates. The analysis presented in this section is based on predictions of the potential health and welfare benefits for selected noise emission levels and effective dates considered achievable for new wheel and crawler tractors.

Because of the inherent differences in individual responses to noise, the multiplicity of types and phases of construction activity, the wide range of environments surrounding each construction site, and the complexity of the associated noise fields, it is not possible to examine all construction site situations precisely. Thus, in this predictive analysis, certain stated assumptions have been made to approximate typical or average situations. A statistical approach has been taken to determine the benefits associated with wheel and crawler tractor noise emission reduction in estimating 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 construction site noise, of which wheel and crawler tractors are integral components, in a variety of situations. Some examples are:

1. Inside a home or office
2. Around the home
3. As a pedestrian
4. As a construction site worker.

Reducing noise emitted by wheel and crawler tractors is expected to produce the following benefits:

1. Reduction in overall construction site noise levels and associated cumulative long-term impact upon the exposed population.
2. Fewer activities disrupted by individual, intense noise events.
3. Reduction in interference with speech communication and warning signals at construction sites, thereby lessening safety hazards, as well as reducing the risk of hearing damage to tractor operators and other site workers.

The approach taken for the analysis was to evaluate the effects, in terms of the percent change in the impact of construction site noise, on the U. S. population resulting from reduction of wheel and crawler tractor noise alone and then in combination with the reduction of truck and portable air compressor noise. These two products are major contributors to construction site noise and are currently subject to Federal noise emission regulations [11, 12].

Regulatory Schedules. The analysis predicts the population impacted by construction noise based upon the 24 wheel and crawler tractor regulatory options shown in Table 5-1. Each regulatory option listed takes into account each of the five major tractor types, lead times, and regulatory levels.

DESCRIPTION OF THE HEALTH AND WELFARE CONSTRUCTION SITE NOISE IMPACT MODEL

The assessment of potential reductions in construction site noise through regulation of wheel and crawler tractor noise emissions, requires that the average noise level produced by other types of construction equipment also be determined. The derivation of noise emission levels for wheel and crawler tractors is described in section 4 while the noise emissions of other construction equipment are summarized in this section. These average noise levels are adjusted to account for typical use cycles during each type of construction activity. The adjusted noise levels for each equipment are then summed on an energy basis and adjusted for their proportion of annualized activity. This process yields a measure which statistically describes the annualized energy average construction site noise levels for each type of construction.

TABLE 5-1

SUMMARY OF REGULATORY SCHEDULES*

Regulatory Schedules	Machine Types	Level Effective Dates				
		1980	1981	1982	1983	1984
1	CT_S	-	77	77	77	74
	CT_L	-	83	83	83	80
	WL_S	-	79	79	79	76
	WL_L	-	84	84	84	80
	WT	-	74	74	74	70
2	CT_S	-	-	-	-	74
	CT_L	-	-	-	-	80
	WL_S	-	-	-	-	76
	WL_L	-	-	-	-	80
	WT	-	-	-	-	70
3	CT_S	-	77	77	77	74
	CT_L	-	83	83	83	80
	WL_S	-	79	79	79	76
	WL_L	-	84	84	84	80
	WT	77	77	77	77	74
4	CT_S	-	77	77	77	74
	CT_L	-	-	83	83	83
	WL_S	-	79	79	79	76
	WL_L	-	-	84	84	84
	WT	-	74	74	74	70
5	CT_S	-	-	-	-	74
	CT_L	-	-	-	-	83
	WL_S	-	-	-	-	76
	WL_L	-	-	-	-	84
	WT	-	-	-	-	70
6	CT_S	-	77	77	77	74
	CT_L	-	-	83	83	83
	WL_S	-	79	79	79	76
	WL_L	-	-	84	84	84
	WT	77	77	77	77	74
7	CT_S	-	-	-	-	74
	CT_L	-	-	83	83	83
	WL_S	-	-	-	-	76
	WL_L	-	-	84	84	84
	WT	-	-	-	-	74

TABLE 5-1
SUMMARY OF REGULATORY SCHEDULES
(continued)

Regulatory Schedules	Machine Types	Level Effective Dates 1980	1981	1982	1983	1984
8	CT_S	-	-	-	-	74
	CT_L	-	-	-	-	83
	WL_S	-	-	-	-	76
	WL_L	-	-	-	-	84
	WT	-	-	-	-	74
9	CT_S	80	80	80	80	77
	CT_L	-	-	83	83	83
	WL_S	82	82	82	82	79
	WL_L	-	-	84	84	84
	WT	-	74	74	74	70
10	CT_S	-	-	-	-	77
	CT_L	-	-	83	83	83
	WL_S	-	-	-	-	79
	WL_L	-	-	84	84	84
	WT	-	-	-	-	70
11	CT_S	-	-	-	-	77
	CT_L	-	-	-	-	83
	WL_S	-	-	-	-	79
	WL_L	-	-	-	-	84
	WT	-	-	-	-	70
12	CT_S	80	80	80	80	77
	CT_L	-	-	83	83	83
	WL_S	82	82	82	82	79
	WL_L	-	-	84	84	84
	WT	77	77	77	77	74
13	CT_S	-	-	-	-	77
	CT_L	-	-	83	83	83
	WL_S	-	-	-	-	79
	WL_L	-	-	84	84	84
	WT	-	-	-	-	74
14	CT_S	-	-	-	-	77
	CT_L	-	-	-	-	83
	WL_S	-	-	-	-	79
	WL_L	-	-	-	-	84
	WT	-	-	-	-	74

TABLE 5-1
SUMMARY OF REGULATORY SCHEDULES
(continued)

Regulatory Schedules	Machine Types	Level Effective Dates 1980	1981	1982	1983	1984
	CT_S	80	80	80	80	80
	CT_L	-	-	-	-	80
15	WL_S	82	82	82	82	82
	WL_L	-	-	-	-	80
	WT	77	77	77	77	77
	CT_S	80	80	80	80	80
	CT_L	86	86	86	86	86
16	WL_S	82	82	82	82	82
	WL_L	86	86	86	86	86
	WT	77	77	77	77	77
	CT_S	-	77	77	77	74
	CT_L	-	-	-	-	80
17	WL_S	-	79	79	79	76
	WL_L	-	-	-	-	80
	WT	-	74	74	74	70
	CT_S	-	77	77	77	74
	CT_L	-	83	83	83	80
18	WL_S	-	-	-	-	76
	WL_L	-	-	-	-	80
	WT	-	-	-	-	70
	CT_S	-	77	77	77	74
	CT_L	86	86	86	86	83
19	WL_S	-	79	79	79	76
	WL_L	86	86	86	86	84
	WT	-	-	-	-	74
	CT_S	-	-	77	77	77
	CT_L	-	-	83	83	83
20	WL_S	-	-	79	79	79
	WL_L	-	-	84	84	84
	WT	-	-	74	74	74
	CT_S	-	-	-	-	77
	CT_L	-	-	-	-	83
21	WL_S	-	-	-	-	79
	WL_L	-	-	-	-	84
	WT	77	77	77	77	74

TABLE 5-1
SUMMARY OF REGULATORY SCHEDULES
(continued)

Regulatory Schedules	Machine Types	1980	1981	1982	1983	1984
		Levels Effective Date				
22	CT_S	-	77	77	77	74
	CT_L	-	-	-	-	80
	WL_S	-	79	79	79	76
	WL_L	-	-	-	-	80
	WT	-	-	-	-	70
23	CT_S	-	77	77	77	74
	CT_L	-	83	83	83	80
	WL_S	-	79	79	79	76
	WL_L	-	84	84	84	80
	WT	-	74	74	74	74
24	CT_S	-	-	77	77	74
	CT_L	-	-	83	83	80
	WL_S	-	-	79	79	76
	WL_L	-	-	84	84	80
	WT	-	-	74	74	74

* CT_S - Crawler Tractors (20 HP to 199 HP)
CT_L - Crawler Tractors (200 HP to 450 HP)
WL_S - Wheel Loaders (20 HP to 249 HP)
WL_L - Wheel Loaders (250 HP to 500 HP)
W_T - Wheel Tractors

Definition of L_{eq} and L_{dn}

This analysis utilizes a noise measure that condenses the information contained in the noise environment into a simple indicator of both quantity and quality of noise. This general measure for environmental noise is the equivalent A-weighted sound level in decibels. The general symbol for equivalent level is L_{eq}. This indicator correlates well with the overall long-term effects of noise on the public health and welfare and was initially developed as a result of the Noise Control Act of 1972, which required EPA to present information on noise levels "requisite to protect the public health and welfare with an adequate margin of safety." The basic definition of L_{eq} is:

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

where $t_2 - t_1$ is the interval of time over which the pressure levels are evaluated, p(t) is the time varying sound pressure of the noise, and p_o 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:

$$L_{eq} = 10 \log_{10} \left\{ \frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} 10^{\left[L_A(t)/10\right]} \cdot dt \right\} \quad (5\text{-}2)$$

In describing the impact of noise on people, the measure called the day-night average sound level (L_{dn}) is used [6]. 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-hr period, with a 10 dB weighting applied to the equivalent noise during the nighttime hours of 10 p.m. to 7 a.m. This may be expressed by the following equation:

$$L_{dn} = 10 \log_{10} \frac{1}{24} \cdot \left\{ \int_{0700}^{2200} 10^{L_A(t)/10} \cdot dt + \int_{2200}^{0700} 10^{(L_A(t)+10)/10} \cdot dt \right\} \quad (5\text{-}3)$$

or,

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

where L_d is the "daytime" equivalent level, obtained between 7:00 a.m. and 10:00 p.m. and L_n is the "nighttime" equivalent obtained between 10:00 p.m. and 7:00 a.m. of the following day.

In construction site situations, where the daytime level, L_d, usually consists of an eight hour construction site contribution combined with an external ambient sound level, equation 5-3 may be rewritten as:

$$L_{dn} = 10 \log_{10} \left(\frac{1}{24} \left[8 \times 10^{L_d^c/10} + 15 \times 10^{L_d^a/10} + 9 \times 10^{\left(L_n^a + 10\right)/10} \right] \right) \quad (5\text{-}4)$$

or

$$L_{dn} = 10 \log_{10} \frac{1}{24} \left[8 \times 10^{L_d^c/10} + 24 \times 10^{L_{dn}^{Ambient}/10} \right]$$

where: L_d^c = daytime equivalent level due to the construction site

L_d^a = daytime equivalent ambient level

L_n^a = nighttime equivalent ambient level

$L_{dn}^{Ambient}$ = equivalent day-night ambient level =

Hence, equation 5-4 allows computation of the day-night average sound levels in areas around construction sites taking into account construction site noise as well as ambient noise levels predominant during those hours when construction activity is not taking place.

Relationship of L_{dn} to Health and Welfare Criteria

To assess the impact of construction noise, a relation between the changes in construction site noise and the responses of the people exposed to the noise is needed. The responses may vary depending upon previous exposure, age, socioeconomic status, political cohesiveness, and other social variables. In the aggregate, however, for residential locations, the average response of groups of people is related to cumulative noise exposure as expressed in a measure such as L_{dn}. For example, the different forms of response to noise, such as hearing damage, speech or other activity interference, and annoyance, were related to L_{eq} or L_{dn} in the EPA Levels Document [6]. For the purposes of this study, criteria based on L_{dn} presented in the EPA Levels Document are used. Furthermore, it is assumed that if the outdoor level of L_{eq} = 55 dB, which is identified in the EPA Levels Document as requisite to protect the public health and welfare, is met, no adverse impact in terms of general annoyance and community response exists.

The intelligibility of sentences (first presentation to listeners) drops to 90 percent when the level of the noise environment is increased approximately 19 dB above the level identified in the EPA Levels Document and to 50 percent when the level is increased approximately 24 dB. The intelligibility of sentences (known to listeners) drops to 90 percent when the level is increased approximately 22 dB above the identified level and to 50 percent when the level is increased approximately 26 dB [15]. Thus, since normal conversation contains a mixture of some new and some familiar material, it is clear that when the level of environmental noise is increased more than 20 dB above the identified level, the intelligibility of conversational speech deteriorates rapidly with each decibel of increase. For this reason a level 20 dB above L_{dn} = 55 dB is considered to result in 100 percent impact on the people exposed. For environmental noise levels that are between 0 and 20 dB above L_{dn} = 55 dB, the impact is assumed to vary linearly with level.

A similar conclusion can be drawn from the community reaction and annoyance data contained in Appendix D of the Levels Document [6]. The community reaction data show that the expected reaction to an identifiable source of intruding noise changes from "none" to "vigorous" when the day-night average sound level increases from 5 dB below the level existing without the presence of the intruding noise to 19.5 dB above the level before intrusion. Thus 20 dB is a reasonable value to associate with a change from 0 to 100 percent impact. Such a change in level would increase the percentage of the population that is highly annoyed by 40 percent of the total exposed population [6]. Further, the data in the Levels Document [6] suggest that within these upper and lower bounds the relationship between impact and level varies linearly; that is a 5 dB excess (L_{dn} = 60 dB) constitutes a 25 percent impact and a 10 dB excess (L_{dn} = 65dB) 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:

$$FI = \begin{cases} .05(L-C) & \text{for } L > C \\ 0 & \text{for } L < C \end{cases} \qquad (5\text{-}6)$$

where L is the observed or measured L_{dn} of the environmental noise.

In this study, C = 55 dB (L_{dn}) for residential and public works construction, and 65 dB for industrial and nonresidential construction

The impact of construction 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 explictly accounts for both the extent and severity of impact.

The equivalent noise impact (ENI) associated with a given level of construction noise (L_{dn}^{i}) may be assessed by multiplying the number of people impacted by that level of construction noise by the fractional impact associated with the level as follows:

$$ENI_i = (FI_i)P_{i}, \qquad (5\text{-}7)$$

where ENI_i is the magnitude of the impact on the population exposed to construction noise L_{dn}^{i} and is numerically equal to the number of people, all of which would have a fractional impact equal to unity (100 percent impacted). FI_i is the fractional impact associated with a day-night noise level L^{i}_{dn}, and P_i is the population exposed to this level of construction 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 thus are 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 (100 x 25% = 250 x 100%).

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

$$ENI = \sum_{i} P_i \cdot FI_i \qquad (5\text{-}8)$$

where FI_i is the fractional impact associated with L^{i}_{dn} and P_i is the population exposed at each L^{i}_{dn}.

The change in impact associated with regulations of the noise emissions from wheel and crawler tractors may be assessed by comparing the magnitude of the impacts, both with and without regulations, in terms of the percent reduction in impact ( ), which is calculated from the following expression:

$$\Delta = \frac{[ENI\ (before) - ENI\ (after)]}{ENI\ (before)} \qquad (5-9)$$

Construction Site Model

The analysis that follows considers various construction site types including residential and nonresidential buildings, city streets, and public works which normally occur in places where population density is high. Heavy construction such as highways and civil works has been omitted from the study since the bulk of this activity generally occurs in thinly populated areas where the extensiveness of potential noise effects on people are minor. In the framework of the analysis, construction is viewed as a process that can be categorized according to the type of construction as well as to the separate and distinct activity phases that occur.

The basic unit of construction activity is the construction site. A construction site exists in both time and space. Four different types of construction sites (see section 2) were evaluated in the analysis, as shown in Table 5-2.

Table 5-2

Construction Site Types

Construction Site Type	Total Annual Number Throughout United States
o Residential & Domestic Housing	728,000
o Non - Residential	87,100
o Industrial/Commercial	235,000
o Public Works	485,224

Construction activity is generally carried out in several discrete steps, each of which has its own mix of equipment and attendant noise output. The phases of construction were those utilized in previous analyses [13, 1]. The process involved in characterizing the noise at each site consists of identifying the equipment found at each site in each construction activity phase in terms of:

1. The number of equipment types typically present at the site in a given phase.
2. The duty cycle of each type of equipment
3. The average noise emission level of each equipment type during the construction activity operation.

Equipment type usage, and noise emission information is presented in Tables 5-3 through 5-6 for each type of construction. These Tables present updated data for wheel and crawler tractors combined with that previously published [13]. Appendix E contains a description of the

Table 5-3
USAGE FACTORS OF EQUIPMENT IN DOMESTIC HOUSING CONSTRUCTION

Equipment		Construction phase					Leq.@50' — Work Periods
		Clearing	Excavation	Foundation	Erection	Finishing	
Air compressor	(81)*	-	0.1	-	-	0.25	68.7
Backhoe	(85)	0.02	0.2	-	-	0.02	69.5
Concrete mixer	(85)	-	-	0.4	0.08	0.16	76.5
Concrete pump	(82)	-	-	-	-	-	-
Concrete vibrator	(76)	-	-	-	-	-	-
Crane, derrick	(88)	-	-	-	-	-	-
Crane, mobile	(83)	-	-	-	0.10	0.04	69.5
Crawler tractor <200HP	(80)	0.65[2]	0.95	-	-	0.38	-
Crawler tractor ≥200HP	(83)	0.06	0.04	-	-	0.02	-
Generator	(78)	0.4	-	-	-	-	64.5
Grader	(85)	0.05	-	-	-	0.02	65.0
Paving Breaker	(88)	-	-	-	-	0.01	61.0
Wheel loaders <250HP	(81.5)	0.61	0.30	-	-	0.12	-
Wheel loaders ≥250HP	(84)	0.16	0.08	-	-	0.03	-
Paver	(89)	-	-	-	-	0.025	66.0
Pile driver	(101)	-	-	-	-	-	-
Pneumatic tool	(85)	-	-	0.04	0.1	0.04	72.5
Pump	(76)	-	0.1	0.2	-	-	63.0
Rock drill	(98)	-	0.005	-	-	-	65.5
Roller	(80)	-	-	-	-	0.04	59.0
Saw	(78)	-	-	0.04[2]**	0.1[2]	0.04[2]	68.5
Scraper	(88)	0.05	-	-	-	0.01	67.0
Shovel	(82)	-	0.2	-	-	-	65.5
Truck	(88)	0.04	0.1	-	-	0.04	70.0
Wheel tractor	(77)	0.86[2]	0.87	-	-	0.35	-
Hours at site		24	24	40	80	40	Σ≈208 hrs. ≈26 days

Total number of sites≈728,000 (see appendix K)

* Numbers in parentheses () represent average noise levels (dBA) at 50 ft.
** Numbers in brackets [] represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

Table 5-4
USAGE FACTORS OF EQUIPMENT IN NONRESIDENTIAL CONSTRUCTION
($190K-4000K)

Equipment		Construction phase: Clearing	Excavation	Foundation	Erection	Finishing	Leq.@50' — Work Periods
Air compressor	(81)*	-	1.0[2]**	1.0[2]	1.0[2]	0.4[2]	83.5
Backhoe	(85)	0.04	0.16	0.4	-	0.04	76.5
Concrete mixer	(85)	-	-	0.4	0.4	0.16	79.0
Concrete pump	(82)	-	-	0.08	0.4	0.08	74.5
Concrete vibrator	(76)	-	-	0.2	0.2	0.04	67.0
Crane, derrick	(88)	-	-	-	0.16	0.04	76.0
Crane, mobile	(83)	-	-	-	0.16[2]	0.04[2]	74.0
Crawler tractor <200HP	(80)	0.49	0.59[2]	-	-	0.46	-
Crawler tractor >200HP	(83)	0.09	0.22	-	-	0.09	-
Generator	(78)	0.4[2]	1.0[2]	-	-	-	75.0
Grader	(85)	0.08	-	-	-	0.02	63.5
Paving breaker	(88)	-	0.1	0.04	0.04	0.04	75.0
Wheel loader <250HP	(81.5)	0.175	0.42	-	-	0.16	-
Wheel loader >250HP	(84)	0.04	0.09	-	-	0.04	-
Paver	(89)	-	-	-	-	0.1	70.0
Pile Driver	(101)	-	-	0.10	-	-	85.0
Pneumatic tool	(85)	-	-	0.04	0.16[2]	0.04[2]	76.0
Pump	(76)	-	1.0[2]	1.0[2]	0.4	-	76.5
Rock drill	(98)	-	0.04	-	-	0.005	78.0
Roller	(80)	-	-	-	-	0.1	60.5
Saw	(78)	-	-	0.04[3]	1.0[3]	-	76.5
Scraper	(88)	0.55	-	-	-	-	73.0
Shovel	(82)	-	0.4	-	-	-	72.0
Truck	(88)	0.16[2]	0.4	-	-	0.16	80.0
Wheel tractor	(77)	0.30	0.725	-	-	0.28	-
Hours at site		80	320	320	480	160	Σ=1360 hrs. =170 days

Total number of sites=87,100 (see appendix E)

* Numbers in parentheses () represent average noise levels (dBA) at 50 ft.
** Numbers in brackets [] represent average number of items if number is greater than one. Blanks indicate zero or very rare usage.

Table 5-5
USAGE FACTORS OF EQUIPMENT IN INDUSTRIAL CONSTRUCTION
($30K-820K, no high-rise)

Equipment		Construction phase					Leq,@50' — Work Periods
		Clearing	Excavation	Foundation	Erection	Finishing	
Air compressor	(81)*	-	1.0	0.4	0.4	0.4	78.0
Backhoe	(85)	0.04	0.16	0.4	-	0.04	76.5
Concrete mixer	(85)	-	-	0.4	0.16	0.16	77.5
Concrete pump	(82)	-	-	0.05	0.16	0.08	71.0
Concrete vibrator	(76)	-	-	0.2	0.1	0.04	65.5
Crane, derrick	(88)	-	-	-	0.04	0.02	70.0
Crane, mobile	(83)	-	-	-	0.08	0.04	68.0
Crawler tractor <200HP	(80)	0.01	0.07	-	-	0.007	-
Crawler tractor ≥200HP	(83)	0.004	0.008	-	-	0.007	-
Generator	(78)	0.4	0.4	-	-	-	68.5
Grader	(85)	0.05	-	-	-	0.02	62.5
Paving Breaker	(88)	-	0.1	0.04	0.04	0.04	75.0
Wheel loader <250HP	(81.5)	0.04	0.1	-	-	0.009	-
Wheel loader ≥250HP	(84)	0.005	0.12	-	-	0.001	-
Paver	(89)	-	-	-	-	0.12	70.5
Pile driver	(101)	-	-	0.04	-	-	81.0
Pneumatic tool	(85)	-	-	0.04	0.1[3]**	0.04	76.0
Pump	(76)	-	0.4	1.0[2]	0.4	-	53.0
Rock drill	(98)	-	0.02	-	-	0.003	75.0
Roller	(80)	-	-	-	-	0.1	60.5
Saw	(78)	-	-	0.04[2]	0.1[2]	-	67.5
Scraper	(88)	0.14	-	-	-	0.08	70.5
Shovel	(82)	-	0.4	-	-	0.06	72.0
Truck	(88)	0.16[2]	0.26[2]	-	-	0.16	78.5
Wheel tractor	(77)	0.24	0.57	-	-	0.05	-
Hours at site		80	320	320	480	160	Σ=1360 hrs. =170 days

Total number of sites=235,500 (see appendix F)

* Numbers in parentheses () represent average noise levels (dBA) at 50 ft.
** Numbers in brackets [] represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

TABLE 5-6

USAGE FACTORS OF EQUIPMENT IN PUBLIC WORKS CONSTRUCTION
(Municipal streets and sewers)

Equipment		Construction phase					Leq.@50' — Work Periods
		Clearing	Excavation	Foundation	Erection	Finishing	
Air compressor	(81)*	1.0	1.0	0.4	0.4	0.4[2]**	79.0
Backhoe	(85)	0.04	0.4	-	-	0.16	74.5
Concrete mixer	(85)	-	-	0.16[2]	0.4[2]	0.16[2]	81.0
Concrete pump	(82)	-	-	-	-	-	-
Concrete vibrator	(76)	-	-	-	-	-	-
Crane, derrick	(88)	-	0.1	0.04	0.04	-	74.0
Crane, mobile	(83)	-	-	-	0.16	-	69.5
Crawler tractor <200HP	(80)	0.42	0.51	0.20	-	0.20	-
Crawler tractor >200HP	(83)	0.03	0.04	0.02	-	0.02	-
Generator	(78)	1.0	0.4	0.4	0.4	0.4	75.0
Grader	(85)	0.08	-	-	0.2	0.08	74.0
Paving breaker	(88)	0.5	0.5	-	0.04	0.1[2]	80.5
Wheel loader <200HP	(81.5)	0.48	0.40	0.32	-	0.24	-
Wheel loader >200HP	(84)	0.0004	0.0004	0.0003	-	0.0003	-
Paver	(89)	-	-	0.1	0.5	-	81.5
Pile driver	(101)	-	-	-	-	-	-
Pneumatic tool	(85)	-	-	0.04[2]	0.1	0.04	72.5
Pump	(76)	-	0.4[2]	1.0[2]	0.4[2]	-	75.5
Rock drill	(98)	-	0.02	-	-	-	82.5
Roller	(80)	-	-	0.01	0.5	0.5	73.5
Saw	(78)	-	-	0.04[2]	0.04	-	63.5
Scraper	(88)	0.08	-	0.2	0.08	0.08	78.0
Shovel	(82)	0.04	0.4	0.04	-	0.04	71.0
Truck	(88)	0.16[2]	0.16	0.4[2]	0.2[2]	0.16[2]	84.5
Wheel tractor	(77)	0.53[2]	0.52[2]	0.7[2]	-	0.52	-
Hours at site:		12	12	24	24	12	Σ =84 hrs. =10½ days

Total number of sites=485,224 (see appendix E)

* Numbers in parentheses () represent average noise levels (dBA) at 50 ft.
** Numbers in brackets [] represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

information collected during the course of this analysis to update previously published equipment type, noise emission and usage data.

The noise emission and usage factors presented in Tables 5-3 through 5-6 were combined with typical periods of use (hours) of equipment operated for each phase of construction, to yield a total site L_{eq} at 50 feet. For the purpose of this analysis, a construction site is viewed as a complex source in which equipment is centered 50 feet from an observer.

The L_{eq} obtained using this model was converted to an L_{dn} for a 24-hour day and then converted to an annual day-night average sound level by adding 10 log (H/(8x365). Thus, each construction site was viewed as a complex noise source with a fixed annual value of L_{dn}. The analysis was repeated for each type of site.

The health/welfare impact of construction noise was entered into the analysis by taking into account the number of construction sites of various types in a number of geographic regions as well as the population densities within these regions (Table 5-7) [1].

The number of sites per year was updated (see Appendix E) from that previously published [13] and the population density data were taken from Table XI of Reference 1. For the nonresidential building category, the transfer of people from the suburbs to the central city during the average working day was considered by adjusting the population data, consistent with the model presented in Reference 1, which is summarized in Table XI of the reference. This adjustment was necessary to account for the fact that most construction in cities occurs during the working day. Thus, population estimates were obtained for 20

Table 5-7
Summary of Construction Activity and Population Density
Data Inputs to Construction Site Model

Hours of Construction Per Day

	Clearing		Excavation		Foundation		Erection		Finishing	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Residential	8	0	8	0	8	0	8	0	8	0
Non-Residential	8	0	8	0	8	0	8	0	8	0
Industrial/ Commercial	8	0	8	0	8	0	8	0	8	0
Public Works	8	0	8	0	8	0	8	0	8	0

Number of Days of Construction Activity

	Clearing	Excavation	Foundation	Erection	Clearing
Residential	3	3	5	10	5
Non-Residential	10	40	40	60	20
Industrial/ Commercial	10	40	40	60	20
Public Works	1.5	1.5	3	3	1.5

Table 5-7
Continued

Population Density (People per Square Mile)

	Large High Density Central Cities	Large Low Density Central Cities	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	15,160	4,410	3,710	3,380	125
Non-Residential	16,650	4,860	4,070	3,100	114
Industrial/ Commercial	16,650	4,860	4,070	3,100	114
Public Works	15,160	4,410	3,710	3,380	125

Number of Sites

	Large High Density Central Cities	Large Low Density Central Cities	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	8,708	21,578	102,559	262,800	118,779
Non-Residential	390	980	2,404	6,183	2,752
Industrial/ Commercial	1,561	3,922	9,617	24,731	11,006
Public Works	3,184	25,120	96,600	134,920	252,400

different cases corresponding to the four construction types (residential, nonresidential, industrial and public works) and five categories of regions, as follows:

1. Large high-density central city
2. Large low-density central city
3. Other Standard Metropolitan Statistical central cities
4. Urban Fringe
5. Metropolitan areas outside the urban fringe

Two models have been used for the propagation of site noise into the community. For residential and public work site types which are representative of lightly built up areas, noise has been assumed to be attenuated at the rate of 6 dB per doubling of distance away from the source. Accordingly, around each site there exists a series of annuli, each of which represents successive areas of 1 dB decrease due to attenuation as indicated in Figure 5-1.

A mean annual L_{dn} has been associated with each annulus, as well as the total area. The area, when multiplied by the population density typical of the region yields the average number of people, (P), living within the annulus. It has been assumed that, on the average, only half of the rooms in structures in proximity to these site types are assumed to face the site. This assumption appears reasonable but must be recognized as being somewhat arbitrary.

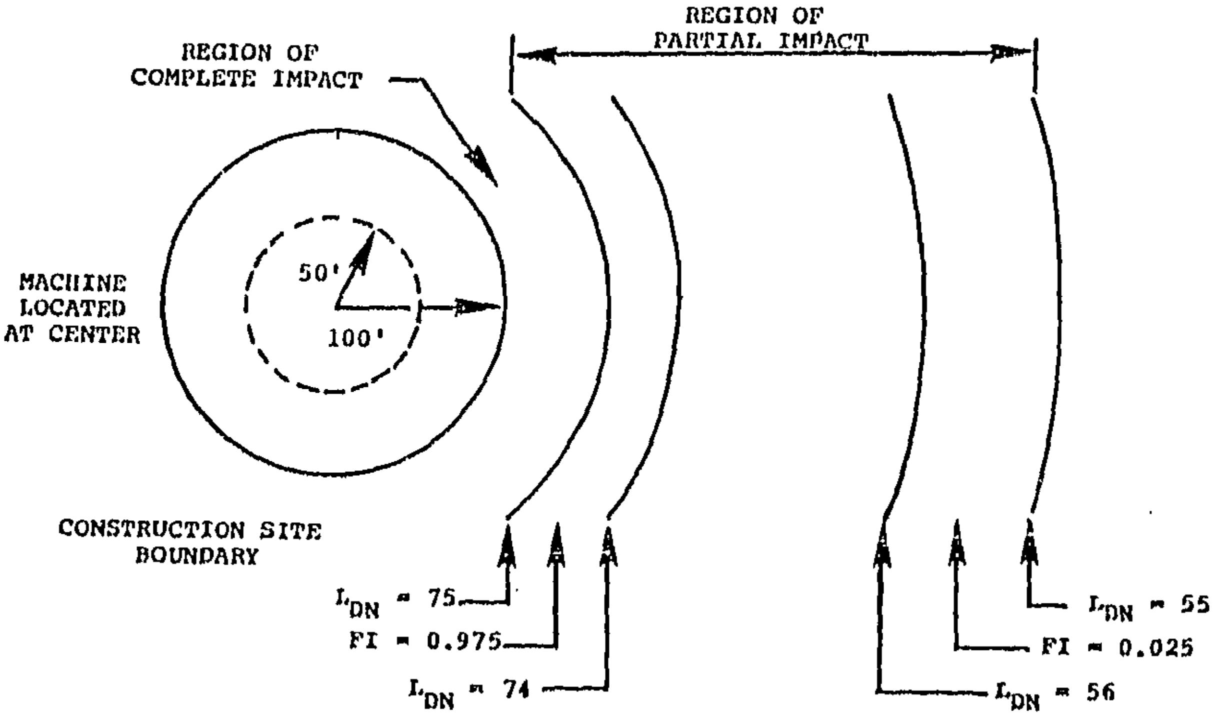


FIGURE 5-1
Schematic of Construction Site
Model Used to Compute ENI

In case of the nonresidential (office) building and industrial/commercial site types, a different model was considered. For these situations, it was assumed that noise confined in a built up area is attenuated by only 3 dB per doubling of distance for the first 400 feet, due to the canyon effect which prevents noise decay by classical spherical divergence, and then attenuates at 6 dB per doubling of distance, since at that point noise is free to decrease by classical spherical divergence. Further, it was assumed that only 33 percent of the people in each annulus were affected by the construction noise since in most office industrial/commercial buildings less than half of the rooms have outside exposure. This assumption appears reasonable, but it is also somewhat arbitrary.

For all site types, it was assumed that no residences or affected activities were located closer than 50 feet from the construction site boundary.

As indicated earlier, EPA has incorporated into the model a provision for including daytime and nighttime ambient levels external to the construction site. Table 5-8 provides the levels used for each site type and region. [14] Where ambient levels exceeded the criteria levels, the ambient levels were arbitarily set instead to a level of 1 dBA under the criteria level under the assumption that the ambient levels would be lowered as a result of other regulations, e.g., cars, buses, trucks, etc. Otherwise, the distance from the center of a construction site at which L_{dn} reaches the criteria level would mathematically approach infinity and thereby nullify the utility of the model.

Table 5-8
Background Ambient L_{dn} (dBA) Used in Construction Site Model

	Large High Density Central Cities	Large Low Density Central Cities	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	64.00	59.35	58.70	58.35	46.11
Non-Residential	64.35	59.71	59.05	58.03	45.77
Industrial/ Commercial	64.35	59.71	59.05	58.03	45.77
Public Works	64.00	59.35	58.70	58.35	46.11

CONSTRUCTION SITE NOISE IMPACT

As discussed earlier, the impact of an environmental noise source has two basic dimensions: extensiveness and intensiveness. Extensiveness of imact is measured in terms of the total number of people impacted irrespective of the severity of individual impact. Tntensiveness, or severity, of an individual's impact is measured in terms of the level of the environmental noise.

For analytic purposes, it is desirable to have a single number representing the magnituded of the total noise impact in terms of both extensiveness and intensiveness in a specific environmental situation. With a single number descriptor of noise impact, relative changes in impact can be described in terms of simple percentage changes in relief from an initial population impact value.

In the procedure presented in this section, the intensity of an environmental noise impact at a specific location is characterized by the Fractional Impact (FI). In the computation of the FI associated with each annulus around a site involving residential or public works constructrion, computations were performed relative to an exterior threshold of L_{dn} = 55 dB. This is the outdoor noise level where impact may begin in a community (assumming an interior L_{dn} attributable to outdoor noise sources of 45 dB) [6]. For office building (nonresidential) and industrial type construction, on the other hand, computations were performed relative to an exterior threshold of L_{dn} = 65 dB. The rationale for this assumption was that in office buildings adjoining these construction sites, windows are normally closed which increases the noise reduction between outside and inside [15]. The window closed condition provides approximately 10 dB more attenuation than does the window open condition. Accordingly, exterior noise levels of 65 dB in the window closed condition, and 55 dB in the window open condition, could produce identical interior noise levels.

From determination of the outdoor noise levels and the number of people contained within each 1 dB annulus of successive levels as described in Figure 5-1, the equivalent population impacted within each annulus was obtained and the summed over all annuli contained within the region extending from the construction site boundary out to a radius at which L_{dn} is equal to the threshold value for each site type to obtain the total impact (ENI). Computations were first performed to assess the change in ENI of construction site noise due to implementation of each of the regulatory schedules presented in Table 5-1 relative to a baseline with air compressor noise reduced to levels of 76 dB(A) at seven meters and trucks reduced to 80 dB(A) at 50 feet. Furthermore, total cumulative benefits attributable to regulations of trucks, air compressors, and wheel and crawler tractors relative to a pre-regulatory baseline were also computed. The benefits of reducing wheel and crawler tractor noise (from a baseline with regulated air compressors and trucks) are summarized in Table 5-9 and Table 5-10. Table 5-9 shows the projected percent reductions in construction site ENI for the years 1978, 1980, 1983, 1985, 1987, 1990 and 2000 for each of the regulatory schedules constucted for new wheel and crawler tractors. Table 5-10 indicates the actual reduction in ENI for the corresponding years.

Table 5-9. Percent Reduction in Impact Due to Regulation of Wheel and Crawler Tractors*

Regulatory Schedule	Year						
	1978	1980	1983	1985	1987	1990	2000
1	0	0	8.8	12.6	13.9	13.9	13.9
2	0	0	0	8.1	13.4	13.9	13.9
3	0	0.3	8.3	11.6	13.0	13.2	13.2
4	0	0	8.7	12.0	13.0	13.1	13.1
5	0	0	0	7.4	12.6	13.1	13.1
6	0	1.5	9.3	12.3	12.3	12.3	12.3
7	0	0	0.7	10.3	12.3	12.3	12.3
8	0	0	0	7.05	11.9	12.3	12.3
9	0	1.0	6.1	9.6	11.3	11.4	11.4
10	0	0	0.7	6.6	10.9	11.4	11.4
11	0	0	0	6.4	10.9	11.4	11.4
12	0	1.4	5.6	6.5	7.1	7.3	7.3
13	0	0	0.7	6.2	10.2	10.6	10.6
14	0	0	0	6.0	10.2	10.6	10.6
15	0	1.4	4.8	6.5	6.8	6.8	6.8
16	0	1.0	3.6	3.8	3.8	3.8	3.8
17	0	0	7.9	12.5	13.8	13.9	13.9
18	0	0	4.0	10.0	13.4	13.9	13.9
19	0	0	6.1	10.1	12.1	12.5	12.5
20	0	0	6.0	10.2	10.6	10.6	10.6
21	0	0.3	1.3	6.9	10.4	10.6	10.6
22	0	0	6.1	10.9	13.4	13.9	13.9
23	0	0	8.8	12.3	13.2	13.2	13.2
24	0	0	6.0	11.9	13.2	13.2	13.2

* Baseline (6.9 million) assumes portable air compressors and medium and heavy trucks have been regulated.

Table 5-10. Reduction in ENI (Thousands)*

Regulatory Schedule	1978	1980	1983	1985	1987	1990	2000
1	0	0	610	871	916	959	959
2	0.	0	0	556	924	959	959
3	0	23	575	798	894	906	906
4	0	0	597	824	894	901	901
5	0	0	0	509	866	901	901
6	0	106	644	848	848	848	848
7	0	0	50	713	848	848	848
8	0	0	0	486	821	848	848
9	0	72	418	661	778	786	786
10	0	0	50	452	750	786	786
11	0	0	0	439	750	786	786
12	0	94	383	449	487	500	500
13	0	0	50	429	705	733	733
14	0	0	0	416	705	733	733
15	0	94	333	446	470	470	470
16	0	67	250	265	265	265	265
17	0	0	548	858	952	959	959
18	0	0	272	689	924	959	959
19	0	0	424	695	839	867	867
20	0	0	416	705	733	733	733
21	0	23	91	476	720	733	733
22	0	0	424	749	924	959	959
23	0	0	610	848	906	906	906
24	0	0	416	820	906	906	906

* Baseline (ENI = 6.9 million) assumes portable air compressors and medium and heavy trucks have been regulated.

Table 5-11 shows the estimated percent reduction in the magnitude of the impact from construction noise achievable to a pre-regulatory baseline in which portable air compressors and trucks are regulated. Hence, these benefits are due to regulation of both the portable air compressor and the new truck as well as wheel and crawler tractors. Table 5-12 shows the actual reduction in ENI for the corresponding years for the preregulatory baseline.

Table 5-11. Overall Percent Reduction in Impact due to Regulation of Construction Equipment from Pre-Regulatory Baselines*

Regulatory Schedule	1978	1980	1983	1985	1987	1990	2000
1	0	27.4	33.8	36.5	37.5	37.5	37.5
2	0	27.4	27.4	33.3	37.1	37.5	37.5
3	0	27.6	33.4	35.8	36.8	37.0	37.0
4	0	27.4	33.7	36.1	36.8	36.2	36.2
5	0	27.4	27.4	32.8	36.5	36.2	36.2
6	0	28.5	34.2	36.3	36.3	36.3	36.3
7	0	27.4	27.9	34.9	36.3	36.3	36.3
8	0	27.4	27.4	32.5	36.0	36.3	36.3
9	0	28.1	31.8	34.4	35.6	35.7	35.7
10	0	27.4	27.9	32.2	35.3	35.7	35.7
11	0	27.4	27.4	32.0	35.3	35.7	35.7
12	0	28.4	31.5	32.1	32.6	32.7	32.7
13	0	27.4	27.9	31.9	34.8	31.5	31.5
14	0	27.4	27.4	31.8	34.8	31.5	31.5
15	0	28.4	30.9	32.1	32.3	32.3	32.3
16	0	28.1	30.0	30.2	30.2	30.2	30.2
17	0	27.4	33.1	36.5	37.4	37.5	37.5
18	0	27.4	30.3	34.7	37.1	37.5	37.5
19	0	27.4	31.8	34.7	36.2	36.5	36.5
20	0	27.4	31.8	34.8	35.1	35.1	35.1
21	0	27.6	28.3	32.4	35.0	35.0	35.0
22	0	27.4	31.8	35.3	37.1	37.5	37.5
23	0	27.4	33.8	36.3	37.0	37.0	37.0
24	0	27.4	31.8	36.0	37.0	37.0	37.0

* Baseline (ENI = 9.5 million) assumes wheel and crawler tractors, portable air compressors and medium and heavy trucks have not been regulated.

Table 5-12. Reduction in ENI (Thousands)*

Regulatory Schedule	1978	1980	1983	1985	1987	1990	2000
1	0	2611	3221	3482	3527	3570	3570
2	0	2611	2611	3167	3535	3570	3570
3	0	2634	3186	3409	3505	3517	3517
4	0	2611	3208	3435	3505	3512	3512
5	0	2611	2611	3120	3477	3512	3512
6	0	2717	3255	3459	3459	3459	3459
7	0	2611	2661	3324	3459	3459	3459
8	0	2611	2611	3097	3432	3459	3459
9	0	2683	3029	3272	3389	3397	3397
10	0	2611	2661	3063	3361	3397	3397
11	0	2611	2611	3050	3361	3397	3397
12	0	2705	2994	3060	3098	3111	3111
13	0	2611	2661	3040	3316	3344	3344
14	0	2611	2611	3027	3316	3344	3344
15	0	2705	2944	3057	3081	3081	3081
16	0	2678	2861	2876	2876	2876	2876
17	0	2611	3159	3469	3563	3570	3570
18	0	2611	2883	3300	3535	3570	3570
19	0	2611	3035	3306	3450	3478	3478
20	0	2611	3027	3316	3344	3344	3344
21	0	2634	2702	3087	3331	3344	3344
22	0	2611	3035	3360	3535	3570	3570
23	0	2611	3221	3459	3517	3517	3517
24	0	2611	3027	3431	3517	3517	3517

* Baseline (9.5 million) assumes wheel and crawler tractors, portable air compressors and medium and heavy trucks have not been regulated.

It should be noted in Table 5-9 that the percent reductions in impact due to wheel and crawler tractors by the year 2000 range from 3.8 percent for regulatory schedule #16 to 13.9 percent for several of the regulatory schedules (Schedules 1, 2, 17, 18, and 22). Also, Table 5-9 shows that several of the regulatory schedules provide near-term benefits in the years 1980 and 1983 (Schedules 3, 6, 9, 12, 15, 16, and 21), while others have their benefits delayed as a result of the long lead times associated with the effective dates of compliance. It should also be noted that benefits increase yearly at a constant rate until maximum benefits are reached. This is attributable to the phasing in of new regulated equipment, which replaces old unregulated equipment, until the point in time is reached where no old unregulated equipment remains in the fleet. Table 5-10 shows that the number of people removed from impact (ENI) by the year 2000 due to regulation of wheel and crawler tractors ranges from 265 thousand for regulatory schedule #16 to 959,000 for several of the options.

Correspondingly, Table 5-11 shows that by the year 2000 the overall percent reduction in construction site noise resulting from the regulation of wheel and crawler tractors, portable air compressors and medium and heavy duty trucks ranges from 30.1 to 37.5 percent. It may be seen in Table 5-12 that by the year 2000 the reduction in ENI from the 9.5 million baseline ranges from 2,876,000 for regulatory schedule #16 to 3,570,000 for several of the other schedules.

As seen in Table 5-13, the most significant reductions in impact resulting from the alternative regulatory schedules limiting wheel and crawler tractor noise emissions occurs in residential site types where the percent reduction in impact is as large as 44.3 percent for certain schedules. Conversely, the smallest percent reductions occur in industrial/commercial site types where the maximum percent reduction for any of the schedules is 3.6 percent. Table 5-14 similarly shows that for each site type the relative percent reduction in impact is quite different for each phase of construction. For residentail construction, the greatest noise relief will occur during the clearing phase where as much as a 96.2 percent reduction in impact will occur for some regulatory schedules. On the other hand, the finishing phase of construction offers the lowest potential benefit with a maximum reduction of 62.5 percent. Similarly, it may be seen that for the non-residential construction, the finishing phase offers the highest potential percent reduction in impact. For the remaining two site types, the clearing phase again offers the highest potential percent reduction in impact.

Table 5-13. Relative Percent Reduction and Change in ENI (Thousands) in Year 2000*

Regulatory Schedule	Residential % Reduction	Residential ΔENI	Non-Residential % Reduction	Non-Residential ΔENI	Industrial/Commercial % Reduction	Industrial/Commercial ΔENI	Public Works % Reduction	Public Works ΔENI
1	44.3	556	8.6	192	3.6	93	13.7	118
2	44.3	556	8.6	192	3.6	93	13.7	118
3	42.1	528	8.4	187	3.2	82	12.7	110
4	41.6	523	7.8	173	3.5	89	13.4	116
5	41.6	523	7.8	173	3.5	89	13.4	116
6	39.4	495	7.5	167	3.1	79	12.5	108
7	39.4	495	7.5	167	3.1	79	12.5	108
8	39.4	495	7.5	167	3.1	79	12.5	108
9	36.2	455	6.7	149	3.2	82	11.6	100
10	36.2	455	6.7	149	3.2	82	11.6	100
11	36.2	455	6.7	149	3.2	82	11.6	100
12	23.0	289	4.2	94	2.2	56	7.1	61
13	34.0	426	6.4	143	2.8	71	10.7	92
14	34.0	426	6.4	143	2.8	71	10.7	92
15	21.9	275	4.6	103	1.6	42	5.8	50
16	12.6	161	2.1	48	1.0	27	3.3	29
17	44.3	556	8.6	192	3.6	93	13.7	118
18	44.3	556	8.6	192	3.6	93	13.7	118
19	39.7	501	7.9	177	3.1	79	12.6	109
20	34.0	426	6.4	143	2.8	71	10.7	92
21	34.0	426	6.4	143	2.8	71	10.7	92
22	44.3	556	8.6	192	3.6	93	13.7	118
23	42.1	528	8.4	187	3.2	82	12.7	110
24	42.1	528	8.4	187	3.2	82	12.7	110

* Baseline (6.9 million) ENI assumes portable air compressors and medium and heavy trucks have been regulated.

Table 5-14. Relative Percent Reduction in Impact in Year 2000 by Phase of Construction and Site Type*

Regulatory Schedule	Residential					Non-Residential					Industrial/Commercial					Public Works				
	CLR	EXC	FOU	ERE	FIN	CLR	EXC	FOU	ERE	FIN	CLR	EXC	FOU	ERE	FIN	CLR	EXC	FOU	ERE	FIN
1	96.2	90.9			62.5	46.0	46.8			61.2	89.8	25.9				65.2	45.7	23.9		36.6
2	96.2	90.9			62.5	46.0	46.8			61.2	89.8	25.9				65.2	45.7	23.9		36.6
3	93.4	88.5			60.2	43.2	46.3			57.8	80.0	23.8				61.2	43.1	22.3		34.3
4	93.0	87.7			59.5	43.2	41.8			57.7	89.3	24.8				64.5	44.9	23.6		36.1
5	93.0	87.7			59.5	43.2	41.8			57.7	89.3	24.8				64.5	44.9	23.6		36.1
6	89.6	85.0			57.0	40.3	41.3			54.1	79.2	22.6				60.4	42.3	21.9		33.7
7	89.6	85.0			57.0	40.3	41.3			54.1	79.2	22.6				60.4	42.3	21.9		33.7
8	89.6	85.0			57.0	40.3	41.3			54.1	79.2	22.6				60.4	42.3	21.9		33.7
9	85.8	79.2			52.1	39.6	35.3			53.0	88.2	22.2				57.5	39.2	20.5		31.5
10	85.8	79.2			52.1	39.6	35.3			53.0	88.2	22.2				57.5	39.2	20.5		31.5
11	85.8	79.2			52.1	39.5	35.3			53.0	80.2	22.2				57.5	39.2	20.5		31.5
12	60.5	53.6			33.6	28.3	21.6			38.0	74.5	14.8				37.3	24.4	12.6		19.7
13	81.3	75.9			49.6	36.5	34.8			49.0	77.7	20.1				53.2	36.5	18.8		29.1
14	81.3	75.9			49.6	36.5	34.8			49.0	77.7	20.1				53.2	36.5	18.8		29.1
15	57.2	52.1			32.6	26.2	26.0			35.1	49.8	12.3				29.8	20.5	10.2		16.1
16	31.0	32.6			20.2	15.7	10.6			20.6	44.7	6.6				16.6	12.3	5.9		9.4
17	92.2	90.9			62.5	46.0	46.8			61.2	89.8	25.9				65.2	45.7	23.9		36.6
18	96.2	90.9			62.5	46.0	46.8			61.2	89.8	25.9				65.2	45.7	23.9		36.6
19	89.7	85.3			57.4	41.6	42.8			55.4	79.3	22.9				60.7	42.7	22.2		34.0
20	81.3	75.9			43.6	36.5	34.8			49.0	77.7	20.1				53.2	36.5	18.8		29.1
21	81.3	75.9			49.6	36.5	34.8			49.0	77.7	20.1				53.2	36.5	18.8		29.1
22	96.2	90.9			62.5	46.0	46.8			61.2	89.8	25.9				65.2	45.7	23.9		36.6
23	93.4	88.5			60.2	43.2	46.3			57.8	80.0	23.8				61.2	43.1	22.3		34.3
24	93.4	88.5			60.2	43.2	46.3			57.8	80.0	23.8				61.2	43.1	22.3		34.3

* Baseline (8.9 million) ENI assumes portable air compressors and medium and heavy trucks have been regulated.

Phases: CLR = Clearing
EXC = Excavation
FOU = Foundation
ERE = Erection
FIN = Finishing

Section 6

NOISE CONTROL TECHNOLOGY

COMPONENT

Noise levels generated during operation of wheel and crawler tractors consist of the superposition of levels from a multiplicity of sources. These sources include those components of the tractor which make it a self-propelled machine and those sources associated with tractor attachments. Although noise levels can be generated by the interaction of the work surface and the tractor attachments (e.g., rippers, dozers, buckets, log clamps), wheel and crawler tractor noise perceived over time is dominated by sources associated with the tractor engine. Table 6-1 lists the major noise producing components of the tractor.

Table 6-1

Major Noise Producing Components of Wheel and Crawler Tractors

- Fan
- Engine Casing
- Exhaust
- Air Intake
- Transmission
- Hydraulics
- Track (for crawler tractors)

While there appears to be considerable disagreement among manufacturers as to the ranking and level of the individual noise sources, there is general agreement that the components listed in Table 6-1 constitute the major noise sources. Accordingly, any scheme with tractor noise reduction as its objective must necessarily address a combination of these components.

Fan and Cooling System Noise

The noise generating mechanisms for axial flow fans have been extensively studied [16, 17, 18, 19]. The fan noise is typically comprised of both pure tones (acoustic energy occurring at discrete frequencies) and broad band noise (acoustic energy occurring at a wide range of frequencies).

The pure tone aspect of fan noise, which is frequently referred to as rotational noise, results from the periodic pulsation of the air each time a blade passes a fixed point. For fans with blades equally spaced around the fan hub, pure tone noise levels commonly occur at integer orders of fan blade passage frequency.

The broadband component of fan noise is commonly referred to as vortex noise. Vortex noise is caused by air turbulence created, in part, by the blade thickness. The turbulence results from vortices shed at the edge of the blades. Disturbances in the flow pattern across the blade cause flow separation and add to the turbulence level. Rivets appearing in proximity to the fan blades or on the blades themselves, non-uniform blade thickness and poor aerodynamic blade design can greatly increase the magnitude of vortex noise. An additional source of vortex noise results from turbulence created as air passes through the fins of the radiator.

In practice both rotational and vortex noise are significant. Equation 6-1 is commonly used to predict the level of fan noise taking into account rotional and vortex noise [8].

$$\text{Fan noise (dBA)} = 50 \log_{10} v_t + 10 \log_{10} (NA_b) + \text{constant}$$

where

v_t = fan tip speed

N = number of blades (6-1)

A_b = area of blades

In Equation 6-1 the contribution of rotational noise is primarily from the 50 log v_t term; the vortex noise contribution obeys the 10 log NA_b relationship and the constant is a function of the geometry of fan placement.

The noise levels generated by a fan are influenced, to a considerable degree, by the fan environment. Additional noise may be generated by the presence of a radiator grill, a fan shroud, radiator hoses, the engine block and any additional items located in proximity to the fan which agitate the air flow.

Other cooling system components that may generate noise are water pumps, belts and pulleys. These, however, contribute relatively little to the total cooling system noise.

The cooling fan is designed to move enough air through the radiator to maintain a required heat transfer from the engine. To the extent that other design parameters of the cooling system allow the heat transfer to be maintained at reduced fan speeds, several design parameters can alter the cooling system noise generation. For example, the axial width (defined in Figure 6-1) of the fan shroud affects both the fan noise and air flow through the radiator. Although both air flow and noise increase as fan coverage increases, the air flow increases much more rapidly than sound level. Thus, with optimum fan shroud coverage a reduction in fan speed is possible which maintains the system cooling capacity and produces significant noise reductions. The cooling fan shroud design can also influence the cooling system noise generation. The fan shroud increases air flow through the radiator and reduces turbulence around the fan blades. Thus, noise is often reduced and cooling capacity is increased, for a given fan speed, by good fan shroud design practice. Figure 6-2 shows two types of fan shroud design (1) cylindrical type and (2) venturi or contour types.

Engine Surface (Casing) Noise

The noise radiated from engine surfaces is caused by the periodic cylinder pressure fluctuations and mechanical impacts generated by the piston slapping against the cylinder liner walls and by mechanical impacts occurring within the whole power train system, the timing gear and the auxiliary drives. The structural vibrations excited by such components within the engine are transmitted through the inner structure of the engine to its outer surfaces and the attached covers, from which they are radiated into the environment. The noise power radiated from the surfaces of a typical engine is 20 to 30 dB lower than the unmuffled exhaust noise.

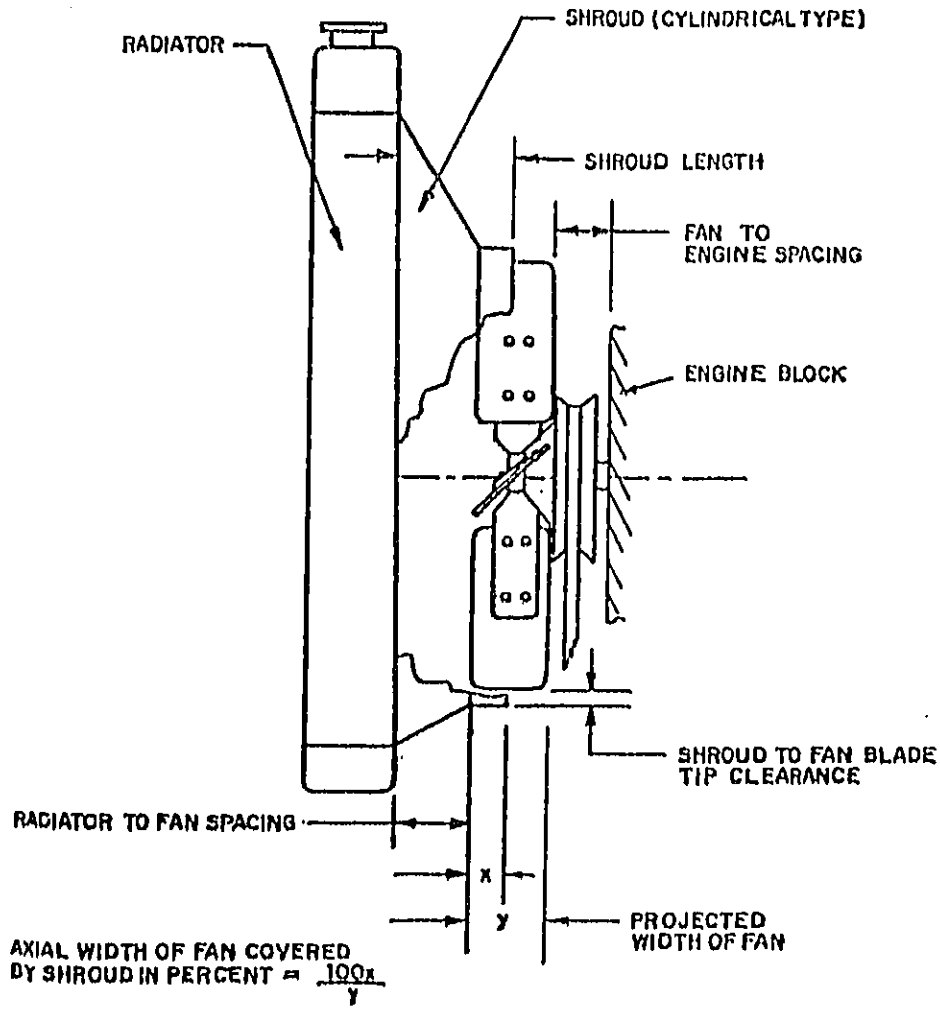


Figure 6-1 COOLING SYSTEM NOMENCLATURE

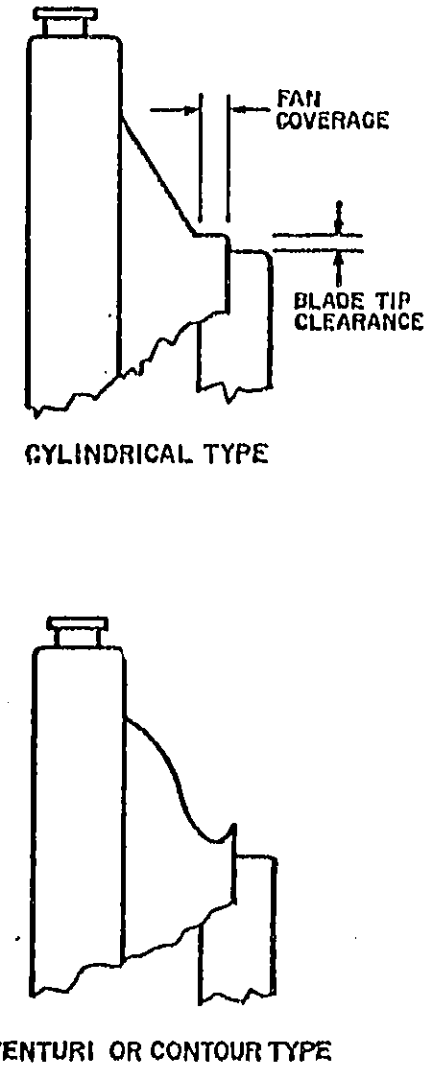


Figure 6-2 FAN SHROUDS

However, with an efficient muffler the exhaust noise can be lowered such that its level and the noise radiated from engine surfaces are about equal and similar to the level of the fan noise.

In addition to noise associated with the engine combustion process, mechanical noise is generated as the pistons contact the sides of the cylinder walls. The impact of the piston against the cylinder wall is termed "piston slap." The lateral motion of the piston in the cylinder results from piston clearance with the cylinder wall. The surface shapes of both pistons and cylinders change due to temperature and pressure variation in the running engine. The variations, along with normal wear, can produce excessive piston-cylinder clearance causing "piston slap." Normally "piston slap" and other mechanical noise are overridden by combustion noise.

If a naturally aspirated, direct injection diesel combustion system is adjusted for optimum performance and minimum fuel consumption, it will produce higher cylinder sound pressure levels than a precombustion chamber system. However, the differences between those combustion systems disappear if a direct injection engine is adjusted for low gaseous emissions, by retarding the injection timing. With all diesel combustion systems the noise excited by the cylinder pressures can be reduced by turbocharging. Retarding the injection timing will reduce fuel economy while turbocharging will normally improve fuel economy [20].

Figure 6-3 [21] shows the contribution of individual outer engine surface components to the total noise of a 6-cylinder diesel engine. The most significant individual contribution of 20 percent is from the crankcase side wall. The intake manifold contributes 18 percent, and the oil pan 10 percent. The remaining parts contribute to a lesser extent . Their total noise is approximately 3 dBA below the total engine noise.

The results of recent investigations [27] show that it is possible to considerably reduce the noise of individual outer engine components. However, after reducing the noise emissions of the dominant components, there still remain a great number of parts which may have only a small individual noise contribution, but which when aggregated often represent 30 percent or more of the original radiated sound power. As a result total engine noise cannot, in general, be reduced by more than 5 dBA by reducing the noise emissions of single engine components.

Exhaust Noise

Exhaust noise includes noise produced by the exhaust gases at the tail pipe discharge, noise radiated from the muffler shell and flanking from the sxhaust system components. The exhaust noise intensity is known to vary with engine speed, is sensitive to engine load, and is a function of engine design parameters the most significant of which appears to be the valve opening characteristics [16, 22]. Exhaust noise is caused by the sudden reease of hot gasses into the exhaust system by the exhaust valves. The noise generated by the gas flow is proportional to the rate of change of the flow velocity.

The opening of the exhaust valves generates a series of noise pulses at the fundemental firing frequency. In addition, a series of noise peaks may occure at frequencies defined by integer orders of the fundamental firing frequency.

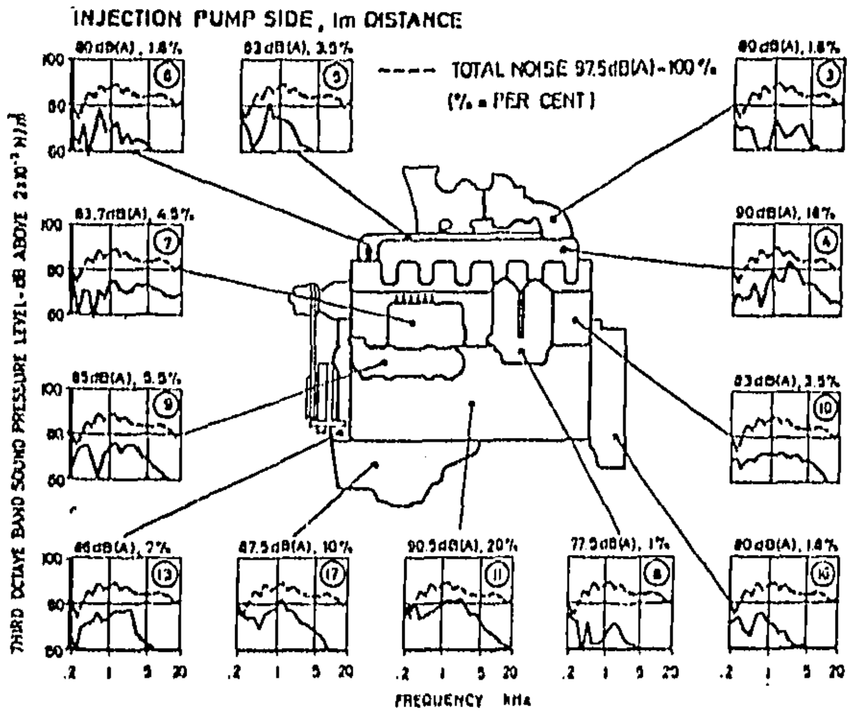


Figure 6-3 WATER-COOLED 6-CYLINDER DIESEL ENGINE, NOISE RADIATED BY THE ENGINE SURFACES

By increasing the amount of air and fuel entering cylinders on each stroke, an increase in diesel engine power may be obtained. In a turbocharged engine a compressor is driven directly by a turbine powered by the exhaust. Since power is extracted from the exhaust flow, there is a small back pressure penalty which is compensated for by reducing allowable muffler back pressure. Because of the expansion of gases within the turbine, unmuffled turbocharged engine exhaust noise is approximately 2 dBA lower than the noise generated by naturally aspirated engines.

Air-Intake Noise

Air-intake noise is quite similar to exhaust noise in its complexity. Air intake noise derives from such components as: the air inlet, the air cleaner shell and ducting in the intake system.

The air intake in the system of a diesel engine is designed to provide dust free air to the cylinders with as little pressure loss as possible. The requirements of being dust free and having little pressure loss mean that a design compromise must be achieved since air filtering tends to cause a pressure loss. The allowable pressure drop for diesel air intake is usually 1.0 to 1.5 inches of mercury, though small pressure losses can have an appreciable effect on the total air intake into the engine.

Intake noise is produced by the opening and closing of the intake valve. At its opening, the pressure in the cylinder is usually above atmospheric and sharp positive pressure pulses set the air in the inlet passage into oscillation at its natural frequency. The oscillation is rapidly damped by the changing volume produced by the piston motion and the air viscosity. Closing of the intake valve produces similar but relatively undamped oscillations. Diesel engine air inlet noise is generally predominant below about 1000 Hz while gasoline engine inlet noise is also predominant at higher frequencies [23].

Air intake filter elements tend to act as silencers for air inlet noise. This leads to the result that inlet noise is not as major a source as the others cited above.

Transmission Noise

The noise generating mechanisms associated with transmissions have been identified and characterized [16, 24]. The mechanisms and the noise characteristics are highly dependent upon such parameters as gear type, diameters, tooth loading, tooth misalignment, tolerances on pitch and profile error, tooth contact frequency (gear speed), and casing vibration. Prediction schemes are available for estimating transmission noise overall levels and spectra [25]. The peaked spectra associated with the tooth contact frequencies can excite a resonant vibration of the body surface and hence reradiate sound.

The noise generated by even simple combinations of gears is quite complex. The sources which contribute to gear noise have been classified into two groups [19]: (1) those which are characteristic of the specific design and manufacturing method, and (2) those which are excited by operation of the gear. Typical noise generation sources resulting from improper design and manufacturing imperfections are:

- o Shape of gear bodies such that the natural frequencies of the gear are excited.

- o Accuracy of the teeth and tooth ring tolerances - tooth spacing and eccentricity causing acceleration and deceleration of the gear in mesh.
- o Axial misalignment due to insufficient stiffness of gear shafts.

The noise generated by the actual operation of gears results from the following mechanisms:

- o Stress waves caused by the engaging and disengaging of the individual gear teeth.
- o Air pocketing - the expulsion of air between the teeth of one gear by the meshing of teeth of corresponding gear.
- o Oil pocketing - similar to air pocketing.
- o Friction excitation - tooth contact frequency and gear-wheel shaft natural frequencies.
- o Impact of gear tooth on gear meshing tooth.

Hydraulic Pump Noise

Pump noise is generated both hydraulically and mechanically. Hydraulic noise is the result of sharp changes in fluid pressure. The changes in fluid pressure excite fittings, valve stems, and other pump parts, which are in the stream of the fluid. The excitation of these parts by the periodic nature of the discharge flow can result in a nearly steady pure tone noise [26]. Other noise may be generated mechanically by dynamic imbalance of rotating parts or by vibrating components caused by direct contact of internal parts.

In addition to noise radiated directly from the pump, fluid borne noise is released from the associated hoses, valves, and reservoir. Pump noise typically does not contribute significantly to the overall noise levels produced in the operation of wheel and crawler tractors.

Track Noise

For crawler loaders and dozers, track noise may be a major noise source for the vehicle while in motion. Measurements taken under J88/ J88A test conditions and construction site conditions show a high variability of track noise due to soil conditions (see Section 3). Direct metal-to-metal contact between track links and between the track, idlers, and drive sprockets result in sound radiated from the vibrating track assembly [28,29 and 30] Track measurements [29] taken approximately 1 foot outboard of drive sprockets and idlers have identified two significant sources associated with track noise. These are: (1) the impacting of track segments against drive sprockets, idlers and guide rollers; and (2) the ringing of drive sprockets and idlers. At low speeds the track noise is relatively low; however, as the track speed increases, both impact noise and ringing noise are increased.

METHODS OF NOISE CONTROL FOR WHEEL AND CRAWLER TRACTOR NOISE

General

Machines can be treated so that either the noise emitted by the machine is reduced (source treatment) or the source remains the same and a barrier is constructed between the source and receiver (path treatment) in order to reduce noise exposure of the spectator. In many cases both methods are engineered simultaneously resulting in efficient noise reduction

In general, source treatment requires major design modifications which may necessitate considerable research and development costs. Once the designs are in production, however, source treatment provides an efficient method of noise control. When a large number of units are sold, the R&D costs can be amortized over a sizable base, so that source noise control can be relatively inexpensive per unit.

Path treatment, for a limited number of units, usually provides a simple method of reducing noise exposure. The research, development and retooling costs (if any) are small compared to source control; however, in large lots, the material cost can be considerable.

Through proper engineering techniques, the best combination of the two methods can be reached.

Currently Used Component Noise Reduction Techniques

Work on noise control for wheel and crawler tractors to be sold in the U.S. has been motivated mostly by the need to reduce operator noise exposure in response to OSHA noise requirements. Spectator noise reduction has been motivated largely by local and state ordinances and also by foreign regulations. Both design improvements and retrofit noise kits have been developed to reduce spectator noise exposure resulting from several of the major machine noise sources. The areas of the machine treated, the technique used, and typical noise reductions resulting from the production verified methods are shown in Table 6-2.

Table 6-2

Currently Used Component Noise Reduction Techniques

Component/Machine Area Treated	Technique	Typical Noise Reduction (dBA)
Cooling System	Cooling system silencer;	2-4
	cooling fan speed reduction;	3-5
	use of sucker fans;	3-5
	fan blade and shroud modification;	3-7
	louvered radiator grille	2-4
Exhaust	Ball joint type connectors for exhaust pipes;	2-4
	double wall muffler construction;	3-5
	optimized exhaust configuration	1-3
Engine Surfaces & Engine Compartment	Side panels;	3-6
	foam lining for the hood;	2-4
	shielding covers;	3-10
	stiffening;	1-3
	turbocharging;	1-3
	vibration isolation;	3-5
	damping	2-3
Air Intake	Silencer	5-10
Machine	Vibration Isolation	1-3
Other Machine Accessories, e.g., Transmissions, Pumps	Component shielding	2-10

* Source: Technology Analysis, Dozers and Loaders, Science Applications, Inc., July 1976.

The French Regulation has prompted investigation into methods of noise reduction which do not require major engine redesign. The French Regulation (Decree of 11 April 1972) imposing a maximum permissible level of 80 dBA at seven meters for machines under 200 metric hp became effective 21 December 1973. (The effective date initially adopted, 2 May 1973, could not be met by most manufacturers.) At the time of the decree, the majority of machines exceeded the 80 dBA limit by 5 to 15 dBA. The severe time constraint forced manufacturers to consider only approaches which did not require major modifications associated with design cycle engineering changes. The most practical solutions were to apply component noise reduction techniques such as treated hoods, slower fan speeds, suction fan configuration, radiator redesign, engine/transmission isolation, noise shields, air intake silencers, and improved mufflers. However, the achievement of the low noise levels by use of component noise reduction techniques in the extremely short lead times available to manufacturers before the French Regulations become effective through basic design has resulted in several problems related to machine performance. The problem areas are:

(1) Cooling capacity - Slower fan speeds, fan silencers and shielding have all tended to restrict air flow and reduce heat exchange from the engine.

(2) Serviceability - Shields and barriers have tended to reduce accessibility for maintenance. Where shields can be removed, they are sometimes permanently eliminated to facilitate service.

(3) Safety - The principal safety risk appears to be fire hazard from inadequate cooling and accumulation of fuel and oil on foams used for noise treatment.

(4) Reliability - The short lead time has led to designs and material selection which have not undergone proper testing before being introduced into production.

Manufacturers who compete in the French market have emphasized repeatedly that the effective date of the regulation did not allow sufficient lead time to achieve the significant noise level reductions required without incurring the associated problems.

Best Available Component Noise Reduction Techniques

The noise abatement technology associated with major component noise sources has been extensively treated in the literature (with the exception of track noise). The U.S. Department of Transportation has sponsored several demonstration programs for quieter highway trucks and buses, which has resulted in a large body of knowledge concerning the abatement of noise sources associated with diesel engines and powered equipment.[6] No such program has been undertaken for construction equipment. Empirical evidence concerning individual noise source reductions can be extrapolated to support the prescribing of "best available technology" levels achievable in future production wheel and crawler tractors. In arriving at projections of machine noise levels associated with the

6 The Bureau of Mines is beginning a demonstration program for certain minining equipment, some of which is used in construction, i.e., loaders [32].

application of best available technology,[7] the available diagnostic evidence concerning component noise sources indicated that noise reductions would be limited by the three principal noise sources, i.e., fan, engine casing and exhaust. However, in specific cases, other component noise sources which are troublesome on individual machine models may have to be treated.

The following discussion summarizes the noise control technology and expected noise reduction for the major component noise sources using best available technology.

Fans and Cooling System. The most promising approaches to reducing fan noise are:

- o Improved fan shrouds and reduced fan tip clearance
- o Increased radiator-to-fan-to engine clearance
- o Radiator redesign
- o Fan redesign

Reported evidence [23,28] of component noise reductions achievable by redesign of the fan and cooling system range between 7 and 13 dBA.

---

7 EPA considered that the level "achievable through the application of the best available technology" is the lower noise level which can be reliably predicted based on engineering analysis, that products subject to the standard will be able to meet by the effective date, through application of currently known noise attenuation techniques and materials. In order to assess what can be achieved, EPA has (1) identified the sources of noise and the levels to which each of these sources can be reduced, using currently known techniques, (2) determined the level of overall machine noise that would result, (3) assured that all such techniques may be applied to the general machine population (4) assured that all such techniques are adaptable to production-line assembly, (5) assured that sufficient time is allowed for the design and application of this technology by the effective dates of the standards.

Engine Casing Noise Components. If the required noise reduction of an engine is less than 5 dBA, it may be sufficient to simply treat those individual engine components which contribute most to the overall engine noise.

Figure 6-4 indicates the potential magnitude of the achievable noise reduction of typical noise reducing measures for a water-cooled inline engine, if applied to the most critical external engine parts.

It can be seen from Figure 6-4 that increasing the damping is relatively ineffective, especially with load carrying parts, since the damping factor of typical engine structures is already quite high. Also, the thickness of the required damping layer relative to the thickness of the engine walls is not practical, especially with regard to the crankcase and cylinder block. With covers, manifolds and oil pans, however, improvements in the range of 2 to 3 dBA can be achieved by increased damping.

Significant reductions of the noise radiated by components attached to the engine can be achieved by vibration isolation. The limited sealing capabilities and the poor durability of the required elastic connections, however, prohibit this technique in some areas. Vibration isolation in general gives very good results when applied to valve covers, manifolds, crankcases, covers and oil pans. However, it is less effective on gear covers and crankshaft pulley.

The technique of stiffening the engine components can be used mainly on the cylinder block, the crankcase and the gear housing. The stiffening of walls by means of ribs makes it possible to raise the lower natural

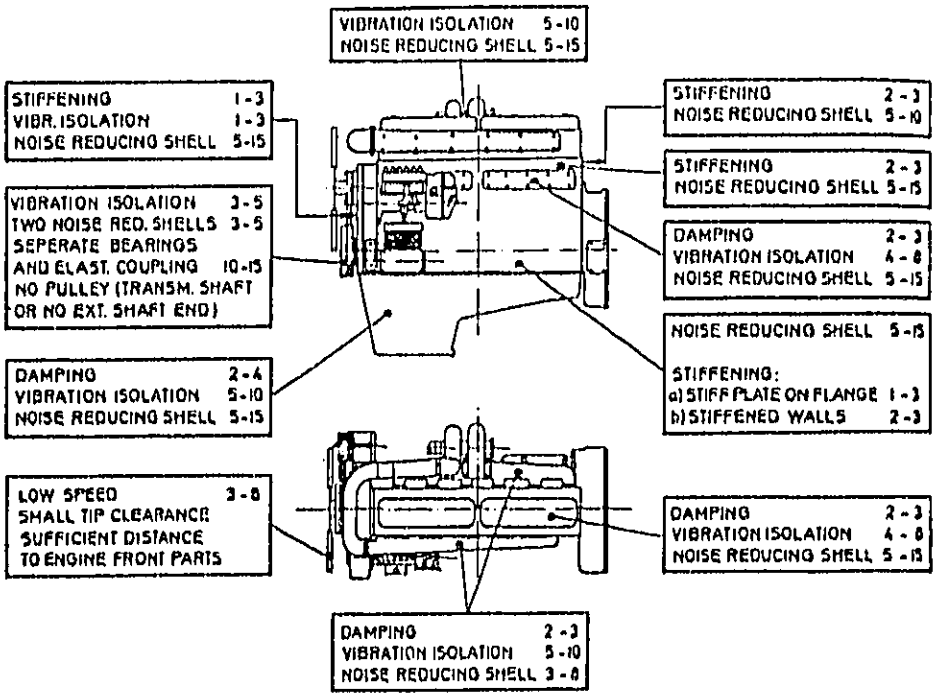


Figure 6-4 WATER-COOLED DIESEL ENGINE, METHODS OF IMPROVEMENT AND EMPIRICAL DATA IN dBA FOR NOISE REDUCTION OF EXTERNAL ENGINE SURFACES

bending frequency of the wall above the predominant frequency range of the total noise. It may be necessary in some cases, however, to stiffen not only the individual areas of a wall, but the whole housing as well as by using, for instance, a stiffening plate attached to the oil pan flange.

Typical noise-level reductions associated with these abatement measures when applied to pans, covers, casing, and accessories range from 2-10 dBA for individual components. In addition, as indicated by Figure 6-4, noise reductions up to 15 dBA can be achieved by thin and flexible sound reducing shells (covers), vibration isolation mounted close to the sound radiating surfaces. In principle such shells can be used on all engine components. Their application, however, is difficult or impractical with certain engine parts having complex shapes such as manifolds or gear covers.

In total, an overall noise level reduction of 5-7 dBA is a reasonable expectation, if various combinations of the above techniques are employed.

Major reductions in engine casing noise must come from the use of enclosures. With engine redesign, the enclosures can be partially or totally integrated into the engine structure, thereby reducing the need for much larger engine components.

Exhaust Noise - The data available [33] indicates that suitable mufflers are available that will lower exhaust noise for all diesel engines to noise levels of the engine or fan, without exceeding manufacturers' limitations for maximum back pressure. Other general conclusions [23] concerning exhaust noise/muffler design are:

- o Exhaust back pressures (a difficulty cited by some manufacturers) of most mufflers are so low that the effect on net horsepower is not measurable with ordinary instruments.
- o The sound reduction properties of mufflers depend more on their internal design, materials, etc., than on physical size.
- o Exhaust pipe should be of heavy material. Flexible joints and pipes should be avoided.

Air Intake - Of the remaining component major noise sources, i.e., air intake, transmission, hydraulics, and track, only air intake noise can be considered to have any significance for a stationary noise measurement procedure. Air intake noise, when it is a problem, can be reduced below other major noise sources by use of air intake silencers.

APPLICATION OF CURRENTLY USED AND BEST AVAILABLE TECHNOLOGY TO ACHIEVE QUIETER WHEEL AND CRAWLER TRACTORS

Manufacturers' design levels have been developed to provide regulatory options for which the costs and economic impacts have been analyzed (section 7). These levels were selected on the basis of both health/welfare analysis, i.e., noise levels requisite to protect the public health and welfare (section 5), and the noise reduction technologies discussed above. Table 6-3 lists the design goal study levels and potential lead times for their imposition. The previously described "currently used" and "best available" technologies when applied to wheel and crawler tractors result in sound levels which are designated Level II and Level III, respectively, in Table 6-3. The Level I study level of Table 6-3 is based upon small reductions from the average noise levels of wheel and crawler tractors in existence today sufficient to achieve a significant health and welfare benefit as described in section 5.

TABLE 6-3

Wheel and Crawler Tractor Study Levels

Machine Type	Classification	Design* Levels (dBA @15 Meters)		
		Level 1	Level II	Level III
Crawler Dozer	20-89	77	74	71
	90-199	78	75	72
	200-259	82	80	77
	260-450 Limit	84	81	78
Crawler Loader	20-89	77	74	71
	90-275+	78	75	73
Wheel Loader	20-134	79	76	73
	135-241	80	77	74
	242-348	83	81	77
	349-500 Limit	84	82	78
Wheel Tractors	20-90+	75	72	68
	Lead times (years) For all classifications	2	3 4 5 6	6

*Regulatory levels are 2 dBA higher because of manufacturing and testing variations as discussed in section 6.

Noise Control Techniques to Achieve Level I

For typical machines, as shown by Table 6-4, noise levels must be reduced 0 to 2.5 dBA to achieve proposed regulatory noise Level I. For most machine types this will require only minor machine modifications. For machines of less than 100 hp, a good quality muffler and shielding of the engine compartment with side panels will provide the required noise reduction. Currently, small machines (under 200 hp) with operator kits are usually realizing more than the necessary noise reduction required for Level I spectator noise.

Some machines of greater than 100 hp may require modifications of the fans or cooling system. Machines of 100 to 300 hp can be expected to have engine casing noise and fan noise as the major contributors to the overall noise levels. Manufacturers should be able to attain the required cooling system noise reduction by use of slower but larger fans or improved fan shrouds. In many cases it is possible to maintain the required airflow without using a larger fan blade. Tests with a standard production shroud [5] have shown that by carefully sealing gaps between the fan shroud and radiator the fan speed can be reduced while maintaining the same radiator airflow and heat transfer. The reduction in sound level due to decreased fan speed was approximately 3 dBA.

Machines of over 300 hp will in general require no noise reduction to achieve Level I from the current average noise levels except for a nominal 1 dBA reduction for wheel loaders. There may be some machines which are above average in noise emissions and will require treatment. However, machines which are far noisier than average are generally found to have a specific design defect (such as a muffler with insufficient insertion loss) which can readily be treated.

Table 6-4

Wheel and Crawler Tractor Sound Level Reduction to Achieve Level Level I, Level II, and Level III Study Levels*

Machine Type	Current Noise Level (dBA) 4 side arithmetic average of high idle	Noise Reduction Required (dBA) Level I	Level II	Level III
Crawler Dozer				
20-89	79.5	2.5	5.5	8.5
90-199	80.0	2.0	5.0	8.0
200-259	84.0	2.0	4.0	7.0
260-450	84.0	0.0	3.0	6.0
Crawler Loader				
20-89	79.5	2.5	5.5	8.5
90-275	80.0	2.0	5.0	8.0
Wheel Loader				
20-134	81.5	2.5	5.5	8.5
135-241	81.5	0.5	4.5	7.5
245-348	84.0	1.0	3.0	7.0
349-500	84.0	0.0	2.0	6.0
Utility Tractor				
20-90+	77.0	2.0	5.0	9.0

*Study Levels are listed in Table 6-3.

Noise Control Techniques to Achieve Level II

Level II represents noise levels manufacturers are currently achieving with the application of existing retrofit technology. The technology required to achieve these levels is being applied in current production by some manufacturers. Although most machines now being sold do not incorporate all the necessary noise abatement as standard equipment, many manufacturers have integrated some of the suggested noise control features to achieve Level II noise emissions into their standard production. In addition, some manufacturers now offer noise abatement kits which do achieve the postulated levels.

At present, wheel and crawler tractor sound levels must be reduced 2 to 5.5 dBA in order to achieve the proposed Level II levels. It can be seen from Table 6-4 that the larger reductions are required on the lower horsepower machines. Machines of 100 hp or less require noise reductions of approximately 5.5 dBA, while machines of greater than 200 hp require noise reductions of 2 to 4 dBA.

For machines of up to 200 hp, engine casing noise can be reduced by a combination of component treatments and barriers such as engine side shields [5]. Isolation of radiating surfaces such as valve covers, oil pans and intake manifolds can be accomplished by using silicone-impregnated cork gasket 1/8 inch thick. In addition, damping material (1/4 inch butyl rubber) bonded to valve covers will help eliminate vibration excitation. To further reduce noise radiation from the engine compartment, the use of foam lining for the hood and installation of shielding covers consisting of a high density barrier material and lined with an absorbant material to eliminate resonant build-up can be installed as shown in Figure 6-5 on engine surface components such as valve covers, oil pans, etc., and also attached parts such as the transmission. Such treatments should provide a reduction of approximately 6.5 dBA (the required reduction as shown in Table 6-5) in the engine casing noise.

As indicated in Table 6-5 for machines above 200 hp, it will be necessary to reduce noise from the engine casing by approximately 2.5 dBA. This will be possible for nearly all manufacturers without major machine redesign. The measures described for achieving a 6.5 dBA reduction in engine casing noise for machines under 200 hp can be applied to machines of greater than 200 hp to achieve a 2 dBA noise reduction. Damping, however, cannot be expected to be as effective as in the lower horsepower machines because of the considerable mass of vibrating engine related components in the larger machines.

For most machines in the 20-200 hp, fan noise will also have to be reduced by approximately 2 to 5 dBA. Such a reduction in fan noise is well within the limits of what can be expected on a typical machine without major redesign of the cooling system. Machines at the lower end of the 20-200 range which may only require 2 dBA reduction in fan noise can be treated using a fan shroud or improved fan shroud as explained under Noise Control techniques to Achieve Level 1.

For machines of greater than 200 hp, fan noise is the major noise source so that fan or cooling system modification will provide the most effective means of noise reduction. A reduction of fan noise to approximately 76 dBA at 50' (an average reduction of 5 dBA) will be possible for most manufacturers without major redesign of the machine. However, to achieve a noise reduction of this magnitude may require several

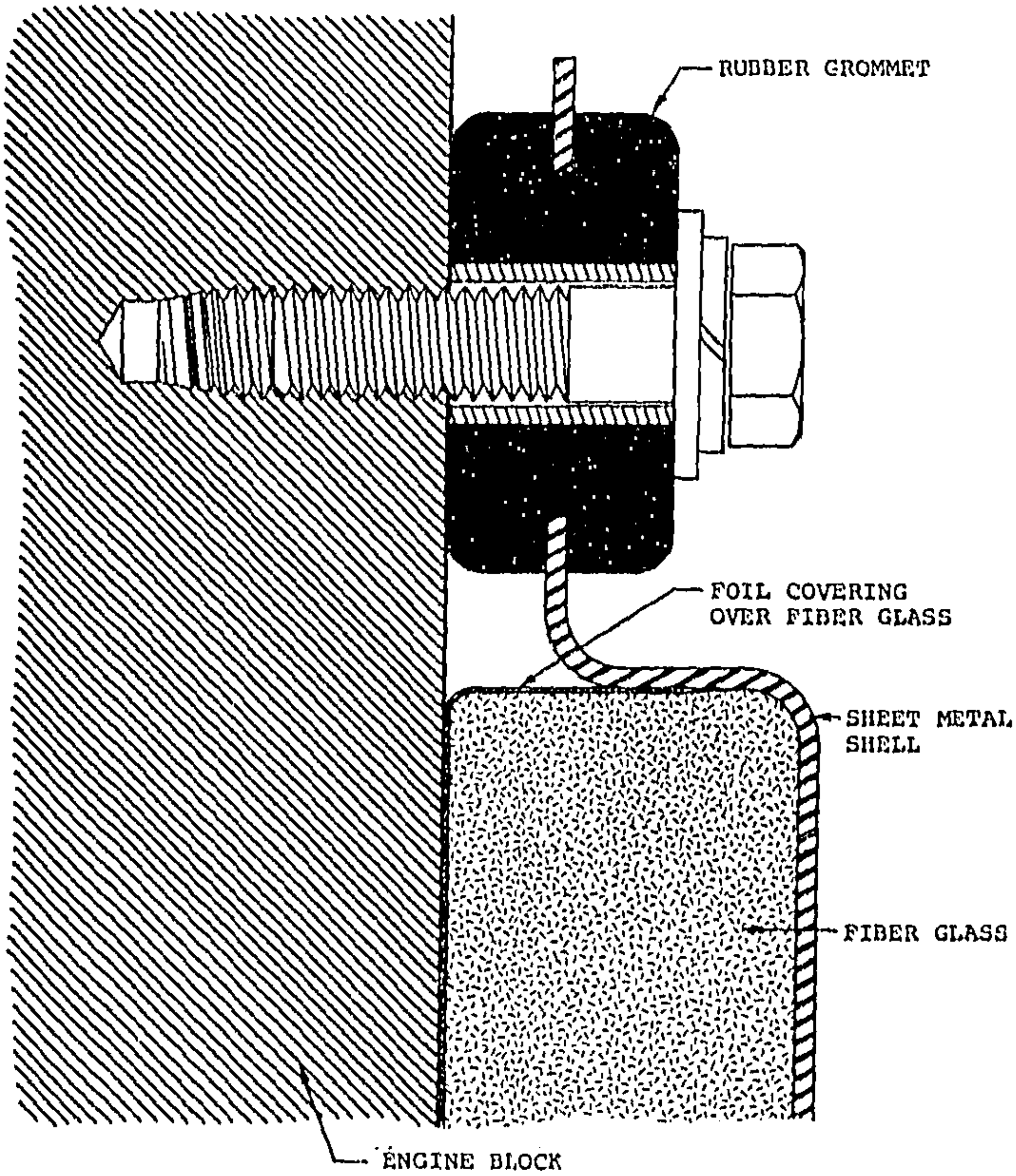


Figure 6-5 ILLUSTRATION OF AN ENGINE COMPONENT SHIELDING COVER

Table 6-5

Typical Noise Source Reductions Used to Develop Estimate of Level II Design Goals (dBA)

Component	Noise Level Reduction Under 200 HP	Noise Level Reduction Above 200 HP
Fan	5	5
Engine	6.5	2.5
Exhaust	6	2
Air Intake	6	3
Other	0	0

modifications in the fan, fan shroud, and possibly radiator. By use of more fan blades and greater projected blade width, the fan is able to deliver the same airflow at reduced rpm.

A further reduction by increasing blade pitch from 30 degrees to 50 degrees allows for speed to be reduced approximately 400 rpm without reducing airflow. This results in an additional noise reduction of 2 to 4 dBA. Thus, a reduction of 6 to 8 dBA in noise may be obtained by increasing the number of blades and the blade pitch. If insufficient airflow occurs due to the reduced fan speed, proper airflow can be restored by improved fan shroud design and reduced fan tip clearance. The extent of fan coverage by the shroud and the clearance between the fan tip and shroud affect both airflow and noise. The airflow with the cylindrical shroud is increased up to 25 percent with shroud coverage optimized at 50 percent to 60 percent of blade projected width. When small tip clearance (1/4 to 1/2 inch) can be maintained the venturi fan shroud (Figure 6-3) has been found to be particularly effective giving both a reduction in noise and an increase in airflow.

As indicated in Table 6-5, for most machines of under 200 hp, exhaust noise levels will have to be reduced by approximately 6 dBA. At present there is a large range of exhaust noise levels among machine models due to the noise generation differences inherent in the various engine types and due to insertion loss differences in available mufflers. A third factor is the configuration and design of the exhaust system components. One manufacturer recommends for its engines a configuration with the tailpipe approximately twice the length of the exhaust pipe. If this is impractical, the next best configuration recommended is the tailpipe one-fourth the length of the exhaust pipe. A further decrease in noise emission due to configuration has been noted by the Department of Transportation in a study of exhaust and intake noise [33]. It was found that the best performing exhaust systems were those with a vertical tailpipe; the least effective configuration was the horizontal tailpipe and horizontal muffler. The sound level differences due to orientation appeared significant, indicating up to 5 dBA spectator noise reduction (at 50') with the vertical tailpipe and vertical muffler orientation.

Direct radiation from the muffler shell can be reduced by double wall muffler construction. Exhaust and tailpipe should be of heavy wall construction and should be isolated from structural members which tend to radiate noise. In an exhaust pipe area where expansion joints and connection are required, ball joint type connectors should be used. Flexible pipes tend to have insufficient noise attenuation. For most machines of greater than 200 hp exhaust noise requires little additional treatment (approximately a 2 dBA reduction) to achieve the Level II requirements. An exhaust noise emission of approximately 73 dBA in combination with the fan and engine casing treatments described above will achieve the 81 dBA design objective.

The final noise source which for some manufacturers may require treatment in the machines over 200 hp is the air intake system. The air intake sound levels vary tremendously with the selection of the air cleaner used to filter engine air intake. Studies sponsored by Department of Transportation [33] comparing unmuffled sound levels with levels achieved when air cleaners were installed indicate that the insertion loss varied from 9 dBA to 22 dBA on the air cleaners tested. An additional variation of 1.5 dBA to 2 dBA was observed for engine versus remote mount of air cleaner. In every case the sound level for the engine mount was less than the remote mount. Additional air intake silencing should not be required with the careful selection of air cleaner.

Noise Control Techniques to Achieve Level III

Level III is the most severe level studied. To achieve the design noise levels associated with proposed Level III would require major machine design changes incorporating noise abatement as a machine design parameter. Noise reduction required from existing average noise levels would range from 6 dBA to 9 dBA with the larger reductions required for lower horsepower machines. As indicated in Table 6-6, to achieve the total machine design noise level representing the use of best available technology techniques, noise from the engine casing would be required to be reduced 6 to 10 dBA.

For machines of less than 200 hp, engine casing noise would be reduced an average of 10 dBA; for machines of greater than 200 hp, a 6 dBA reduction would be expected. One design feature reducing engine noise at its source would be improved pistons. Expansion controlled pistons of Autotheronic, Duothermic and other designs are available to reduce piston fitting clearances and reduce piston noise by 1 to 3 dBA. However, the major reduction in engine noise would require the use of a casing enclosure partially or totally integrated into the engine structure. The casing would be isolated from the engine structure and would attenuate airborne sound originating from the inner engine structure. The treatment of the whole engine surface in this way is more effective

Table 6-6

Typical Noise Source Reductions Used to Develop the Level III Design Goals (dBA)

Component	Noise Level Reduction Under 200 HP	Noise Level Reduction Above 200 HP
Fan	9	6
Engine	10	6
Exhaust	8	4
Air Intake	6	6
Other	0	0

than treatment of individual components if a noise reduction of greater than 4 to 6 dBA is desired. The enclosures [21] can be designed for high volume production using deep drawn sheet metal. The enclosure typically would consist of a supporting frame elastically connected to the engine and covers which can be easily removed and replaced for servicing of the engine. Pipes, hoses and tubing would penetrate the supporting frame and would not obstruct maintenance covers. The enclosures would add slightly to the size of the engine compartment and negligibly to the overall weight of the machine. No accoustical lining or side panels would be required. Sound attenuating engine mounted enclosures as described above have been designed with existing engines to yield noise reduction of 15 to 20 dBA [21].

Fan noise reduction of approximately 6 dBA to 9 dBA would likely be required for all horsepower classes to achieve the Level III design objectives and could be accomplished somewhat easier than for Level II because the additional lead time would permit redesign of the cooling system. All of the design factors which would be optimized for Level II would also be optimized in design for Level III, but in addition, the basic machine design for the cooling system would be modified.

For example, increased radiator to fan and fan to engine spacing can be employed to give reductions of 2 to 4 dBA over the close spacing design now utilized. By increasing the radiator frontal area, heat transfer requirements can be maintained with significant reductions in rpm and noise. A 10 percent increase in radiator area can give 4.5 dBA reduction in sound levels. Use of increased number of fins, increased radiator thickness, and corrugated or louvered fins will increase the heat transfer for a given airflow and will permit the same overall heat flow with lower velocities.

Because the current design features have a wide range of parameter values for a specific machine class, it is likely that different manufacturers will find that major noise reductions are obtained from different aspects of the cooling systems. In some machines, radiator size now limits the operator's view of his work area. Manufacturers with this problem may vary cooling system parameters which do not require repositioning of the cab and increase of machine width unless these features are also needed for other design requirements.

As indicated in Table 6-6 exhaust noise reduction across all machine types would range from 4 to 8 dBA with the maximum exhaust noise reduction occurring in machines of less than 100 hp. These machines have especially good potential for noise reductions because of the low quality mufflers currently employed on them. Machines of higher horsepower are currently utilizing more effective exhaust system mufflers. The noise from engine exhaust is one of the easiest of the major noise sources to control. The methods previously described in Noise Control Techniques to Achieve Level II are all applicable. Direct radiation from the muffler shell can be reduced by double wall muffler construction. Exhaust and tailpipe should be of heavy wall construction and should be isolated from structural members which would tend to radiate noise. In an exhaust pipe area where expansion joints and connection are required, ball joint type connectors should be used, not flexible pipes which tend to have insufficient noise attenuation.

After noise levels from the cooling system, engine casing, and exhaust systems have been reduced, noise from the air intake will be the major noise source. As indicated in Tables 6-6, noise from this source would be reduced by 6 dBA. Air intake noise is easily controlled and these levels should not be difficult to attain. An air inlet silencer may be required for some machine models in addition to selection of a more effective noise attenuating cleaner. As with exhaust piping, the air intake piping should be heavy-wall construction and should avoid rubber components to maximize noise attenuation.

SUMMARY

Using the noise control techniques discussed above, it is believed that typical existing machine configurations can be quieted to the proposed design levels if sufficient lead time is provided. It is noted that individual manufacturers would not necessarily choose to use the typical methods and techniques described above since many alternative methods and techniques are possible to reach these levels. Most manufacturers would first assess each of their machine types/classifications to determine the dominant noise sources associated with each machine configuration. The necessary noise reductions applied to each component source to reach the overall design goals would then be determined and manufacturers would use either the most cost-effective techniques available or else those which, within the limitations of their technological expertise, they believe to be most suitable.

Section 7

COST AND ECONOMIC IMPACT

To address the potential economic impact of noise emission regulations upon those affected (producers, users, suppliers), EPA acquired detailed data on pricing and sales of wheel and crawler tractors. Additional information was developed on the estimated costs of reducing noise emissions of that equipment, using current production technology and best available quieting technology.

This section is divided into three major parts. The first presents an analysis of the data presented in Section 2 with the specific objective of estimating price elasticities of demand for segments of the tractor market. The second part presents the cost and compliance information, followed by the economic impact analyses performed using these data.

DATA ANALYSIS

Market Trends - Short Run Outlook

The increase in prices in the last two years has been due largely to the lifting of price controls and the resulting shortage of materials. The costs of components, specialty steel and energy are expected to continue to rise. International Harvester, which manufactures all four types of impacted equipment, expects these costs to result in a 6 to 7 percent across-the-board increase in 1976 in the wholesale price of its construction tractors and loaders.

Growth in the end-user industries will vary. Table 7-1 shows the distribution by sector of an estimated overall 10.5 percent increase in value of new construction between 1975 and 1976. A 34 percent increase in new housing, a 15 percent increase in new systems

TABLE 7-1

ESTIMATED VALUE OF NEW CONSTRUCTION
PUT IN PLACE 1975-1976
($ billions)

CONSTRUCTION INDUSTRY SEGMENTS	Value		PERCENT CHANGE
	1975	1976	
PRIVATE CONSTRUCTION	90.01	103.9	+15.3
Residential Buildings	43.6	55.4	+27.1
Nonresidential Buildings	46.5	48.5	+ 4.3
PUBLIC CONSTRUCTION	40.8	40.8	---
Residential Buildings	1.0	.8	-20.0
Nonresidential Buildings	14.6	14.5	- 0.7
Highways & Streets	11.7	11.1	- 5.1
Military Facilities	1.3	1.2	- 7.7
Conservation and Development	2.9	2.8	- 3.4
Water Systems	1.3	1.9	+46.2
Sewer Systems	4.8	5.5	+14.6
Misc. Public Construction	3.2	3.0	- 6.3
TOTAL NEW CONSTRUCTION	130.9	144.7	+10.5

Source: Cahner's Economics Research.

and an 8 percent increase in public utilities construction are leading elements in the construction industry recovery. Increased mining activity (up to 20 percent) will also help boost sales of large loaders and tractors.

1976 Demand

The Construction Industry Manufacturing Association (CIMA) expects to see a 14 percent increase in 1976 real dollar value of total shipments within the industry (Table 7-2), provided that increased rates do not skyrocket and dampen capital spending. The crawler tractor market is up and expected to continue its rise (Table 7-3). The wholesale prices and inventory level increases in these machines are both considerably below the industry-wide figures. The tractor shovel loader figures, on the other hand, more nearly resemble the industry-wide figures except that they are less than the industry figures for 1975 domestic and overseas shipments (Table 7-4).

EFFECT OF PRICE ON DEMAND

Noise regulations will impose increased costs on manufacturers and should result in higher market prices. The basic tool for analyzing this effect is the price elasticity of demand.[8]

---

[8]The price elasticity of demand for a machine's services is defined as:

$$\eta_{mp} = \frac{\Delta m^d}{\Delta p} \quad \frac{p}{m^d}$$

Where p is price and m^d is the amount demanded at price p. η_{mp} measures the percentage increase in demand associated with a 1 percent increase in price. As such, it is generally a negative number. If η_{mp} is close to zero, demand is not sensitive to price and is said to be inelastic; if η_{mp} is close to, or greater than unity, in absolute value, demand is responsive to price and is said to be elastic.

TABLE 7-2

1975-1976 CONSTRUCTION MACHINERY SALES
(Percent Change)

SHIPMENTS TO	1975 DOLLAR VALUE	ESTIMATED 1976 REAL DOLLAR VALUE
U.S.	- 3.2[a]	+14.1[b]
Canada	+11.3	+ 0.8
Overseas	+20.9	- 0.5

[a]As a function of 1974 dollar value.
[b]As a function of 1975 dollar value.

BETWEEN JULY 1974 AND JULY 1975
(Percent Change)

Wholesale machinery prices increased	20.3
Inventory levels rose	60.3

Source: Outlook '76

Note: The Outlook '76, a forecast of 1976 sales by the $8 billion construction equipment manufacturing industry, is the Association's sixth annual report and forecast and is based on data obtained in a survey of 39 CIMA member companies between Septmber 1 and October 15, 1975. The numerical responses of the contributors were weighted according to the size of each company's annual sales. Unfortunately, this report does not contain any dollar or unit figures; it only contains percentage figures (of change from 1974 to 1975 and from 1975 to 1976).

TABLE 7-3

1975-1976 CRAWLER TRACTOR SALES
(Percent Change)

SHIPMENTS TO	1975 DOLLAR VALUE	ESTIMATED 1976 REAL DOLLAR VALUE
U.S.	+ 5.2	+15.0
Canada	+15.8	+ 0.1
Overseas	+ 9.0	+ 6.5

BETWEEN JULY 1974 AND JULY 1975
(Percent Change)

Wholesale machinery prices increased	14.5
Inventory levels rose	38.2

Source: Outlook'76

TABLE 7-4

1975-1976 WHEEL LOADER SALES
(Percentage Change)

SHIPMENTS TO	1975 DOLLAR VALUE	ESTIMATED 1976 REAL DOLLAR VALUE
U.S.	- 7.3	+17.4
Canada	+15.6	+ 1.8
Overseas	+ 4.3	- 1.9

BETWEEN JULY 1974 AND JULY 1975
(Percent Change)

Wholesale machinery prices increased	21.3
Inventory levels rose	57.8

Source: Outlook '76 (november 1975): 10.

The determination of an elasticity allows an assessment of the percent change in sales that could be expected if certain hypothesized changes in prices occur, all other things being equal. EPA estimated such elasticities using time series data in a regression model. The absence of previous estimates of this elasticity has prevented comparisons.

Due to the limitation of historical data, only crawler tractors and wheel loaders were studied for a 15-year period. Both machine classes were studied as a whole, and, in addition, one size category within each class was also studied. The analysis was complicated by the fact that during this 15-year period changes in price were accompanied by changes in machine size and quality. Under such conditions, all other things are not equal, which required lengthy development of size and quality variables to separate these effects from "true" price increase. A price variable was developed, as well as a stock variable, and these factors were included in the estimate of elasticity.

The activity levels in at least four industry segments -- construction, mining, forestry, and agriculture -- also affect the demand for wheel and crawler tractors. These effects were accounted for in the development of a single user activity variable.

The complete list of variables used in the analysis are:

- Average machine demand
- Average machine size
- Average machine price
- Average machine productivity
- Existing stock of machines
- User industry activity levels
- Substitution price ratio.

It has not been possible to pinpoint demand elasticities with the information available for this study. The sample size was small, quality adjustments could not be exact, price variation was limited, and the prices of substitutable factors of production, notably labor and other construction machinery, could not be controlled in the desired manner.

The best-guess values and likely bracketing values for the true elasticities are reported in Table 7-5. The ranges reported are weak confidence intervals, one standard error in both directions from the point estimate. They should be interpreted as being more likely to contain the true elasticity than to exclude it. The range of uncertainty about the true elasticities remains large.

TABLE 7-5

Best-Guess Values and Likely Brackets on the Price Elasticity of Demand for Construction Machine Services, 1960-1974

PRODUCT	BEST GUESS	PRICE ELASTICITY RANGE MINIMUM	MAXIMUM
CRAWLER TRACTOR			
60 hp to 89 hp	-1.35	-0.52	-2.18
all sizes	-1.50	-0.95	-2.05
WHEEL LOADERS			
2.50 BA 3.5-yd^3	-1.00	-0.30	-1.70
all sizes	NA	NA	NA

The analysis suggests that the price of the services of crawler tractors has a moderately strong influence on demand. The absolute value of the price elasticity of demand appears to have been close to, and perhaps somewhat greater than, unity in the years between 1960 and 1974.[9] The evidence for wheeled loaders points in the same direction although it is less definitive. Consequently, a pro rata reduction in the demand for new machines can be expected to follow any increases in price resulting from EPA noise emission regulations: e.g., 5 percent (or more) reduction in demand will result from a 5 percent increase in price , etc.[10]

[9]This refers to the short-run (same year) elasticity; if there are significant lags in the adjustment of demand to market conditions, the final long-run elasticity will be correspondingly greater.

[10]The reduction in demand for machine services will translate directly into an equivalent reduction in new machine demand (in size units) if the productivity of machines is unchanged at that time, as appears likely. If competing machines (e.g., scrapers for tractors, tracked loaders for wheeled loaders) are also regulated, the demand reductions will be less marked.

COST OF COMPLIANCE

Introduction

To examine the costs associated with noise control of the identified machines, two major subdivisions have been adopted. The first covers basic costs of producing machines which comply with noise standards, excluding testing costs. The second is devoted entirely to the costs of testing the ultimately quieted wheel and crawler tractors.

Based upon health and welfare considerations discussed in section 5, and technology considerations discussed in section 6, the Agency chose three study levels for detailed cost and economic impact analysis. The first level (Level I) corresponds, in general, to the average present day levels and requires only a slight reduction in noise emissions. It has been included in this study because of the large health and welfare benefits associated with it.[11] As discussed in section 6, the other levels include one based upon commonly used retrofit technology (Level II), and the other based on an engineering analysis of what is believed to be the levels achievable using the Best Available Technology (Level III). The costs developed for each of the levels were predicated on the application of the technologies discussed in section 6 to treat typical machines within the various horsepower categories. As can be seen from Table 7-6, costs for achieving Level I have been estimated for a 2-year lead time, i.e.,

11 This level is not based on any state-of-the-art technology, and it only applies to the noisiest machines currently produced. Since it is the first -- and easiest -- level to reach, it is called Level I.

Table 7-6
Estimated R&D, Capital, L&M, O&M Costs to Achieve Level 1, Level 2 and Level 3

Costs	Level 1 2 Yrs.	Level 2 3 Yrs.	Level 2 4 Yrs.	Level 2 5 Yrs.	Level 2 6 Yrs.	Level 3 6 Yrs.
R&D (For costliest model in horsepower category, by machine type)	$=24,900 + HP[1] $=19,900 -19HP[2]	$=67,750 -27.5HP	$=63,313 -27.3HP	$=58,877 -27.1HP	$=54,440 -26.9HP	$=94,250 -42.5HP
Capital (For each model manufactured)	$ 5,000	$ 10,000	$ 8,333	$ 6,667	$ 5,000	$ 5,000
L&M (For each unit manufactured)	$= 296 +1.24HP[1] $= 249 +0.7HP[2]	$= 415 +1.8HP	$= 394 +1.7HP	$= 374 +1.6HP	$= 353 +1.5HP	$= 1,319 +2.26HP
O&M (For each unit manufactured)	$= 170 +0.16HP	$= 210 +0.70HP	$= 200 +0.66HP	$= 190 +0.62HP	$= 180 +0.58HP	$= 610 +1.15HP

Source: EPA Estimates - See Text.

[1] HP $\leq$ 350   [2] HP > 350

an effective date two years subsequent to promulgation of a regulation. Four lead time scenarios were studied for Level II — 3 years through 6 years — in order to show the sensitivity of these costs to variations in the lead time and to allow for the analysis of regulatory options involving phased levels of increasing severity. Level III costs have been estimated with an associated 6-year lead time.

Basic Compliance Costs

Costs of compliance were broken up into the following components:

1. Research and Development (R&D)
2. Capital Cost
3. Labor and Materials (L&M)
4. Operating and Maintenance (O&M)

Manufacturer costs of abatement were estimated as a function of horsepower using procedures described below. Table 7-6 displays the equations used to develop estimates of the various costs for each unit, model, and firm as well as for the industry as a whole.

The total of the various manufacturers' cost components implies an average manufacturer's cost[12]/list price ratio ranging from nearly 1 percent for Level I to over 3 percent for Level III. Level II cost increases are estimated at from 1 to 1.3 percent, depending upon the lead time. Worst case estimates of price increases have also been developed based upon the assumption that full pass through of cost increases would occur.

[12] Manufacturer's cost refers to amortized capital, direct labor, direct materials, overhead and G&A. It does not include manufacturer's profit or dealer's margin.

General Methodology. Cost estimates (in 1976 dollars) have been derived for implementing the various technologies discussed in section 6, given the lead times shown in Table 7-6. These estimates were derived from several sources, including:

1. The DOT Noise Control Handbook for Diesel Powered Vehicles, [35] which includes costs of mufflers and air intake filters, together with performance rating of different materials on various engines.

2. Industry suppliers, for data on increased fan efficiency, shrouds, and pulley changes for lowering fan speeds.

3. Published industrial sources, for specific dollar figures for individual quieting materials.

With the assistance of industry experts, estimates were made of the manpower -- in terms of both time and expertise -- and materials required to achieve each of the three study levels within the specified lead times.

Table 7-6 summarizes the basic cost matrix developed for wheel and crawler tractors for the three noise emission levels and their associated lead times. Manufacturer costs were developed for the following three basic cost components:

1. Research and Development (R&D) cost
2. Capital cost
3. Labor and Materials (L&M) cost

R&D costs are incurred in determining the specific means to be used in quieting a given machine. Since a manufacturer's models within any machine category are similar, it is assumed that the same techniques may be used for all of a firm's models within any category. For this reason, R&D costs for each firm are calculated once for each category in which the firm manufactures products.

The cost of quieting any given machine depends upon the machine's current noise emission level, the decibel reduction planned, and the time alloted to accomplish this reduction. Present emission levels vary significantly from machine to machine; thus, the costs of quieting machines could vary markedly from manufacturer to manufacturer, as well as among the machine types and sizes produced by an individual firm. The noise reductions specified here, together with the abatement costs derived, are based on average machine noise levels and average obtainable reduction from current levels. The cost matrix used is based on a straight line interpolation of the costs of quieting a small machine and the costs of quieting a large machine.

The cost matrix displayed in Table 7-6 has been used to estimate average manufacturer and industry costs of abatement. The costs have been calculated independently for each study level. The costs do not assume that expenditure for Level I is prerequisite to the costs of Level II or Level III.

Research and Development Costs. The research and development costs due to noise abatement include the costs of manpower, materials, and facilities which are used in determining the techniques and approaches best suited to quieting a given machine to a specific level. Also included in R&D costs are the costs of component noise testing and the Production Verification testing required prior to sale for all impacted equipment.

These costs are incurred by the manufacturer before the quieted machine is marketed, and accounting practice requires that they be expensed in the period in which they are incurred. Therefore, R&D costs of abatement would actually be reflected in the cost of producing existing machines, rather than in the costs of new quieted machines.

Estimates have been made of the total manufacturers' R&D costs. Figure 7-1 displays the total manufacturers' R&D costs by horsepower size for each study level and for the range of lead times studied. This figure shows that the R&D costs to achieve each study level decrease with increasing horsepower. This is because larger machines, with their large engine enclosure volumes and available interior enclosure surface area, more readily lend themselves to the incorporation of noise control features. Small machines often have space limitations and, as such, may require additional engineering time in order to incorporate design features which may accommodate a noise control device such as a muffler. The one exception to this pattern of decreasing costs for larger machines is in the Level I costs for machines under 350 hp. Here the rise in costs is due to the increasing expenses associated with engine enclosures.

Additionally, for use in the analysis of regulatory alternatives, Table 7-7 indicates the total R&D costs aggregated for each of the five machine classifications.

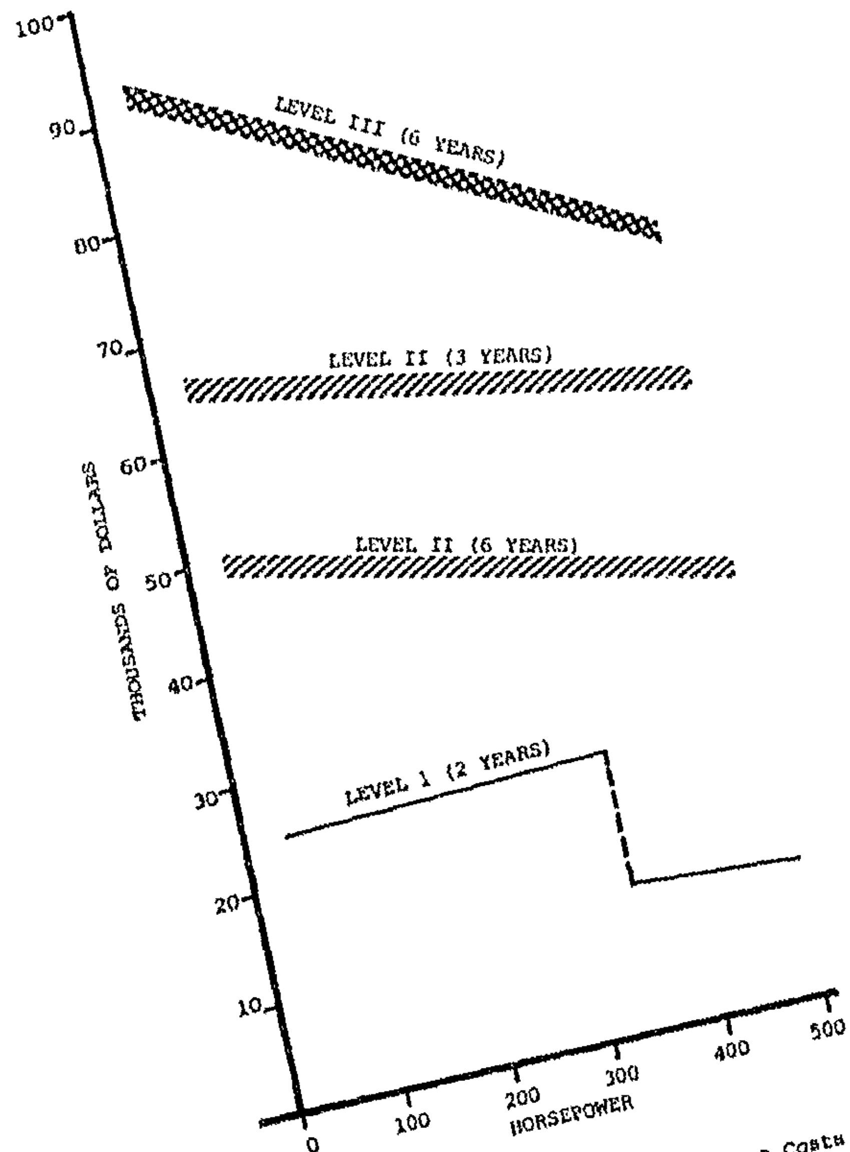


Figure 7-1 Research and Development Costs by Study Level

Table 7-7
Manufacturer's Total R&D Costs by Machine Type/Classification Category
(Thousands of Dollars)

Machine Type	Classification Category (HP)	Level 1	Level 2				Level 3
		2 Yrs.	3 Yrs.	4 Yrs.	5 Yrs.	6 Yrs.	6 Yrs.
Crawler Tractor	20-199	$594.5	$1726.4	$1563.4	$1400.3	$1237.3	$1879.3
	200-450	164.1	433.0	401.3	369.5	337.8	593.2
Wheel Loader	20-249	717.5	2016.4	1861.5	1707.5	1553.0	2614.0
	250-500	200.8	533.1	493.7	454.3	414.9	729.8
Utility Tractor	20-90+	125.0	332.6	310.4	288.3	266.1	461.7
Totals		$1801.9	$5041.5	$4630.3	$4219.9	$3809.1	$6278.0

Capital Costs. Capital costs are the costs incurred in applying the various abatement technologies to each model. These costs are the result of the required increases in parts inventories, the changes in machine specifications, and the preparation of new manuals to reflect machine changes due to noise abatement. They also include estimates of the costs attributable to the slight modifications which would be made in production lines. Because these costs are for such standard items as manuals and specifications, which are needed for any model, they do not vary with machine size or type. Increases in inventories and changes in specifications and manuals are more extensive for Levels II and III than they are for Level I. These costs are completely reflected only in the estimate for Level II with a 3-year lead time because most capital cost items are a standard part of the regular redesign costs which manufacturers will incur normally in their design cycle. Generally competitively inspired redesign will absorb these costs given lead time sufficiently large to accommodate this redesign.

Since most firms in the industry use minimal tooling, the estimates of capital costs given in Table 7-6 assume that there will be either no tooling costs or only minimal tooling costs due to noise abatement. While larger firms may find it economical to build dies and jigs for larger scale production, it is assumed that this expensive process would not be undertaken unless it resulted in a substantial reduction in L&M costs, thus accounting for an overall lowering of total unit cost. Table 7-8 indicates the total capital costs for each machine classification.

Table 7-8
Total Manufacturer's Capital Costs by Machine Type/Classification Category
(Thousands of Dollars)

Machine Type	Classification Category (HP)	Level 1	Level 2				Level 3
		2 Yrs.	3 Yrs.	4 Yrs.	5 Yrs.	6 Yrs.	6 Yrs.
Crawler Tractors	20-199	$310	$620	$516.7	$413.3	$310	$310
	200-450	40	80	66.7	53.3	40	40
Wheel Tractors	20-249	345	690	575.0	460.0	345	345
	250-500	70	140	116.7	93.3	70	70
Utility Tractors	20-90+	120	240	200.0	160.0	120	120
Totals		$885	$1770	$1475.0	$1180.0	$885	$885

Labor and Material Costs. The L&M cost estimates reflect the additional funds which would be spent on labor and materials[13] in order to produce machines which meet the three study levels. Figure 7-2 displays the total L&M costs to achieve Level I, II, and III. This figure shows that the per unit costs of abatement increase significantly as more sophisticated techniques are used to reduce noise emissions. It is estimated that L&M costs to achieve Level II in 6 years should be 15 percent lower than that required with a 3-year lead time. It is presumed that the longer lead time will allow the industry to incorporate basic design changes which will mitigate the need for some of the L&M intensive retrofit-type techniques which will be required if only a three-year lead time is provided. Table 7-9 indicates the increase in Labor and Material costs for each classification category.

Operating and Maintenance Cost Increases. The operating and maintenance cost increases reflect the additional material and labor costs incurred by users resulting from such activities as the insertion, replacement or repair of noise suppression devices, the removal of engine enclosure to access engine components, etc. Additionally, increased operating costs have been included to reflect the possible 1 to 3 percent reductions in fuel economy. These reductions are due to the use of noise suppression devices, e.g., improved mufflers, heavy engine enclosures, changes in direct injection timing, etc. Figure 7-3 displays the O&M cost increases

---

[13]Including burden, but excluding profit and dealer margin.

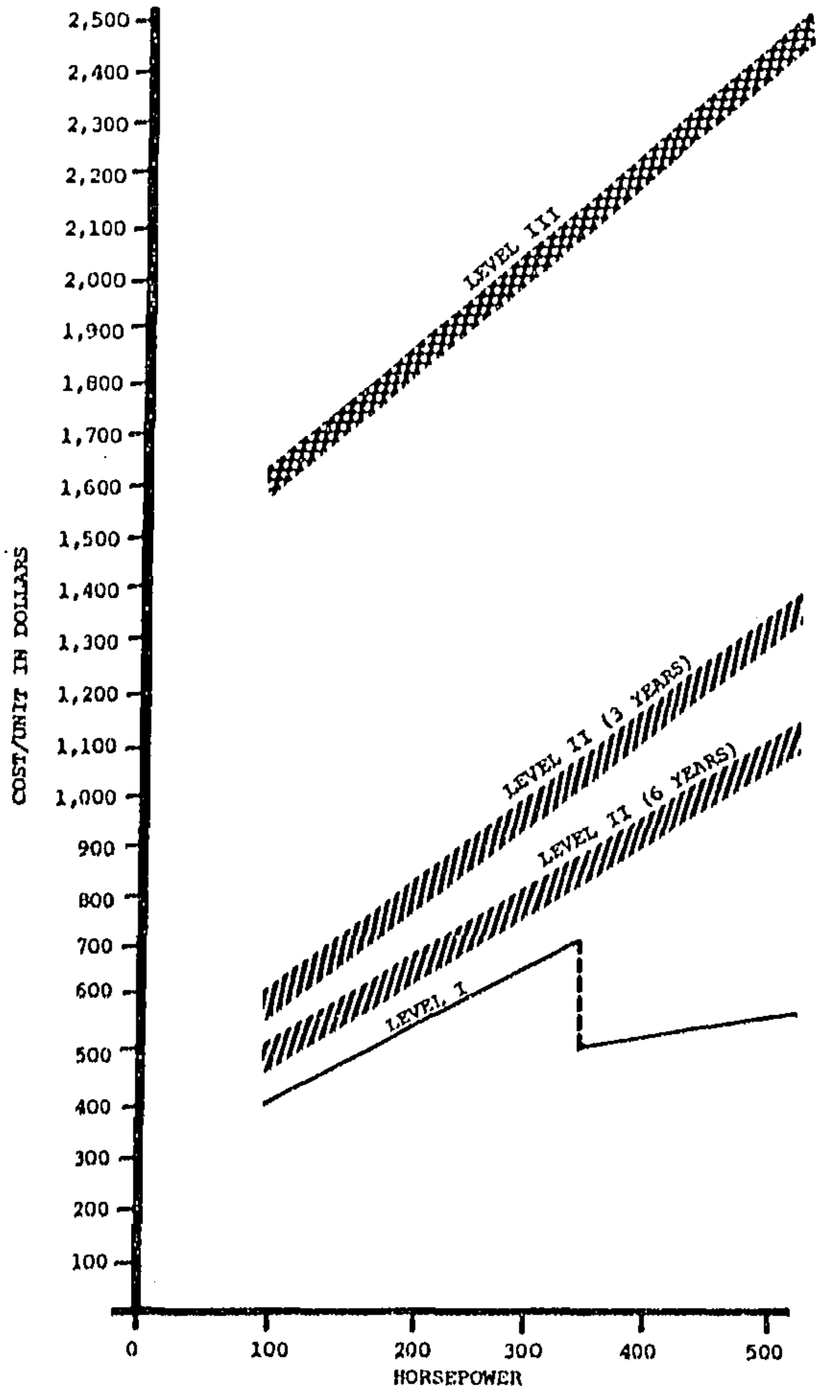


Figure 7-2 Labor and Material Costs by Study Level

Table 7-9
Manufacturer's Average Increase in Labor and Material Costs
by Machine Type/Classification Category

Machine Type	Classification Category (hp)	Level 1	Level 2				Level 3
		2 Years	3 Years	4 Years	5 Years	6 Years	6 Years
Crawler Tractor	20-199	410	585	552	525	445	1529
	200-450	490	950	900	852	803	1980
Wheel Loader	20-249	445	625	590	555	525	1534
	250-500	615	974	570	870	845	2010
Utility Tractor	20-90 +	370	520	490	465	440	1450

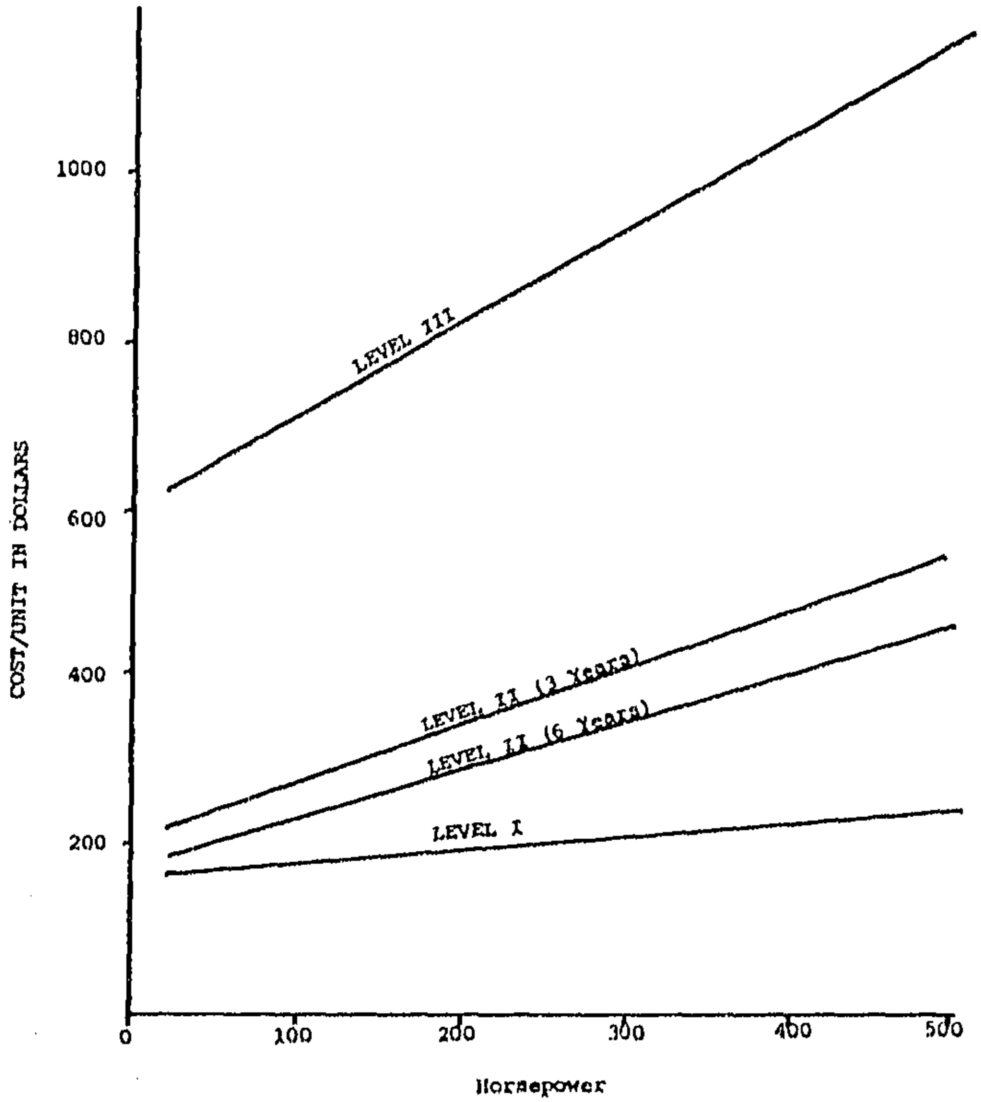


Figure 7-3 Operating and Maintenance Costs by Study Level

Table 7-10
Average Annual Increase in Operating and
Maintenance Cost Per Machine
(in Dollars)

Machine Type	Classification Category (hp)	Level 1		Level 2								Level 3	
		2 Years		3 Years		4 Years		5 Years		6 Years		6 Years	
		$	%	$	%	$	%	$	%	$	%	$	%
Crawler Tractor	20-199	180	1.342	284	2.177	270	2.013	256	1.908	241	1.796	742	5.531
	200-450	238	1.115	462	2.165	439	2.057	416	1.949	393	1.842	964	4.517
Wheel Loader	20-249	208	0.5736	294	0.8107	278	0.7666	262	0.7225	246	0.6784	720	1.985
	250-500	284	1.270	450	2.012	427	1.909	404	1.807	382	1.708	930	4.159
Utility Tractor	20-90 +	160	1.451	224	2.031	213	1.932	202	1.832	190	1.723	624	5.659

Table 7-11
Baseline Data (Prior to Effective Date of Regulation)

Machine Type	Classification Category (hp)	No. of Machines in Existence	Average No. Sold Per Year	Average List/Purchase Price Per Machine ($)	Total List/Purchase Price —All Machines Sold Annually ($ Million)	Average O&M Cost Per Machine ($)	Total O&M Cost—Entire Fleet ($ Million)
Crawler Tractor	20-199	111,595	23,321	42,783	997.756	13,415	1,497.047
	200-450	20,588	3,432	141,091	484.224	21,341	439.369
Wheel Loader	20-249	65,935	13,355	45,436	606.800	14,923	983.948
	250-500	14,652	2,704	124,974	337.931	22,362	327.684
Utility Tractor	20-90+	195,000	27,516	12,672	348.675	11,027	2,150.265
TOTAL		407,770	76,899		2,775.385		5,398.303

to achieve Levels I, II, and III. Table 7-10 indicates the increased Operating and Maintenance costs for each classification category. The percentage increases are also indicated relative to baseline data which is shown in Table 7-11.

Variation in Lead Time. The costs presented in Table 7-6 are applicable to the three study levels only for the lead times indicated. Altering the lead time, particularly shortening it, can dramatically change the associated costs. Industry sources have noted that overall costs for Level I and Level II could double if the lead times are reduced significantly. The allocation of these increased costs among the components of R&D, capital, and L&M are not clear, but it is anticipated that the shortened time allowed to quiet machines would force most of the costs to accrue to L&M. With short lead times, suppliers may perform much of the R&D and charge higher unit costs for their components. Also, manufacturers may purchase inefficient quieting components and install poorly matched parts; this misuse of equipment may result in increased L&M costs.

In the case of Level III, a reduction in lead time would diminish the likelihood that its implementation would coincide with a regular design cycle. In this event, an estimated $350,000 to $500,000 per model design cost would have to be included in the estimated costs of achieving the third study level.

Noise Emission Testing Costs

The following discussion pertains to the costs associated with the measurement of the noise emission levels of newly quieted products. The costs associated with this activity will include test site construction as well as operating costs.

The manufacturers will also test noise levels of existing machines, and also conduct additional testing in connection with R&D programs. These costs have already been considered in the preceding discussion of R&D costs of compliance.

Test Requirements. Tests will be performed to fulfill two requirements: (1) Production Verification and (2) Selective Enforcement Auditing. Production Verification (PV) is the testing of early production models to verify that a manufacturer has the requisite noise control technology in hand and has successfully applied the technology in the manufacturing process. Selective Enforcement Auditing (SEA) is the testing, pursuant to an administrative request, of a statistical sample of wheel and crawler tractors of a particular category selected from a particular assembly plant in order to determine whether the equipment produced conforms to the established standards and to provide a basis for further action in the case of nonconformity. Only PV costs have been included in the R&D cost estimates.

Proposed Test Procedure. The proposed test procedure described in section 6 is based upon current industry practices for measuring exterior sound levels at spectator locations. Machines are to be tested in the stationary mode only, at high idle, with no load. All sound levels are to be reported as A-weighted sound levels. The noise emission level of a machine is the arithmetic average of four sound level readings taken at 15 meters from the front, rear, and both sides of the machine.

Test Costs - General. The costs associated with the proposed test procedure involve the capital costs for constructing the test site and purchasing the measurement equipment, and the costs for labor and materials used in conducting tests and maintaining equipment. (Additional transport charges will be incurred in delivering machines to the test site and returning them to the storage yard. These will vary with the size of the machine and the distance to the test site and are not included in testing cost estimates.)

Test Costs - Capital. The cost of constructing a hard reflecting plane of smooth and sealed concrete large enough ($557m^2$) to accommodate the largest machine in the scope of this study has been estimated. The costs given in Table 7-12 are for a 6-inch slab of concrete with reinforcing steel. The total cost of site construction is estimated at about fifteen thousand dollars.

The second component of capital costs associated with the proposed test procedure is for measurement equipment. Table 7-13 describes the equipment required. The sound level meter and calibration equipment are the most expensive items required.

The total capital costs associated with the proposed test procedure are estimated at $20,000. These costs include approximately $15,000 for site construction and $5,000 for instrumentation. The latter figure is used to cover the cost of measurement kits.

Table 7-12
Cost Estimate for Construction of
Test Site Measurement Area

CONCRETE

$$557\ m^2 \times 10.764\ \frac{ft^2}{m^2} \times 0.5\ ft \times \frac{\$30}{yd^3} \times \frac{yd^3}{27\ ft^3} = \$3,330$$

STEEL REBAR (3/4-inch diameter rods laid on 6-inch centers in both directions)

65.6 ft	x	197 bars	=	12,923 ft	
98.4 ft	x	131 bars	=	12,890 ft	
				25,813 ft	

25,813 ft x 1.502 lb/ft x $15/100 lb = $5,815

LABOR (Aggregate Trades)

40 hr/wk x 6 men x $11.00 hr/man x 1 wk = $ 2,640

SUBTOTAL	11,785
CONTRACTOR (G&A & Profit)	x1.3
TOTAL	$15,320

TABLE 7-13

MEASUREMENT EQUIPMENT REQUIRED FOR
THE PROPOSED TEST PROCEDURE

SOUND LEVEL METER

For all sound level measurements, a sound level meter and microphone system that conforms to the Type 1 requirements of the American National Standard Institute (ANSI) Specification S1.4-1971, "American National Standard Specification for Sound Level Meters," and to the requirements of the International Electrotechnical Commission (IEC) Publication 179, "Precision Sound Level Meters," shall be used.

MICROPHONE WINDSCREEN

For all sound level measurements, a microphone windscreen shall be used that shall not change measured sound levels in excess of ± 0.5 dB to 5 kHz and ± 2.0 dB to 12 kHz.

CALIBRATION

The entire acoustical instrumentation system shall be calibrated before and after each test series on a given machine. A sound level calibrator accurate within ± 0.5 dB shall be used. A complete frequency response calibration of the instrumentation over the entire range of 25 Hz to 12.5 kHz, shall be performed at least annually using a technique of sufficient precision and accuracy to determine compliance with ANSI S1.4-1971 and IEC 179 Standards. This calibration shall consist, at a minimum of an overall frequency response calibration and an attenuator (gain control) calibration plus a measure of dynamic range and instrument noise floor.

ANEMOMETER

An anemometer or other device, accurate to within ± 10 percent, shall be used to measure ambient wind velocity.

POWER SOURCE SPEED INDICATOR

An indicator, (e.g. a stroboscope) accurate to within ± 2 percent shall be used to measure power source speed (rpm).

BAROMETER

A barometer accurate to within ± 1 percent shall be used to measure atmospheric pressure.

THERMOMETER

A Thermometer accurate to within ± 1 percent shall be used to measure ambient temperature.

Some firms may not incur these costs because they may already have adequate test sites. It is possible that a firm may have a parking lot or other area[14] which may require little or no modification to satisfy the requirements of the test procedure.[15]

Test Cost - L&M. The costs involved in testing machines have been estimated by an independent testing firm.[16] Their estimate of the labor cost for test setup and performance, and reporting is:

Technician -- 1 hr per test	$15.00
Administrative & Reporting -- per test	15.00
	$30.00

The test requires a minimum of two technicians, one operating the machine and the other reading the sound level meter, and the entire procedure can be completed in 20 minutes if there are no delays. This estimate does not include the cost of transportation associated with moving machines to and from test sites. It is expected that in

[14]One firm uses the turnaround area at the end of its private airstrip as a test site.

[15]It is also possible for firms to use the EPA Enforcement Test Facility at Sandusky, Ohio, but the industry's concern with the privacy of information makes it unlikely that this government-owned site will be used by manufacturers.

[16]The Transportation Research Center of Ohio (TRC), East Liberty, Ohio.

most cases the test site -- whether it is a parking lot or a site specifically constructed for testing -- will be at the assembly plant.[17] If this is not the case, the cost of transportation should be included. Industry estimates are somewhat higher than the independent firm's estimate of $30.00 for technician and reporting services, but this is because the industry includes the cost of transporting the machine from the assembly line to the test site. With these considerations, a best-guess estimate of the L&M costs per test is $59, with $44 for technician and operator labor and $15 to cover the costs of record keeping and reporting.

Maintenance costs per test are negligible. The upkeep of meters and transducers requires occasional replacement of batteries and periodic maintenance and cleaning of the equipment. These costs are estimated at $10.00 per month, $120 per year, which would add only a small amount to the cost of any given test. The optional use of high quality tape recorders could increase the cost of a test by approximately $8.00.

---

[17] If the test site is not at the plant, then transportation costs could be included in the cost per test. However, even these costs need not be attributed solely to testing costs. If, as expected, the machines are shipped to dealers in the vicinity of the test site, the transport could be partly accommodated in shipping costs to the dealer.

Costs Applicable to Existing Machines

Some of the costs of producing quieter machines will be incurred by firms prior to their marketing of those new machines. The costs involved include manufacturer's R&D capital and test site costs incurred during the research and development phase. Since these costs are expensed in the period in which they occur, they must be paid for by the sales of existing machines. Estimates of these costs have been calculated separately for each firm and for the industry as a whole for each of the study level and lead time combinations discussed in section 6. For the purpose of the analysis, it has been assumed that each firm's existing machines, when averaged across all models, represent typical machines for which the available noise abatement technologies requisite to achieve the study levels, as discussed in section 6, are applicable. It is noted, however, that individual firms and/or machine models may incur higher or lower costs than the average costs considered in this analysis. Table 7-14 summarizes these costs for each machine classification category.

Costs Applicable to Quieted Machines

Costs applicable to new machines are the costs which are incurred after the completion of the research and development phase. These include manufacturer's capital costs, test site costs, and L&M costs. These costs have been fully burdened to produce average increases in list prices for machines in each classification category as indicated in Table 7-15. The percentage increases indicated are relative to baseline prices listed in Table 7-11.

Table 7-14
Total Increase in Manufacturer's Initial Investment Cost Prior to Regulation
by Machine Type/Classification Category (Dollars)

MACHINE TYPE	CLASSIFICATION	LEVEL 1	LEVEL 2				LEVEL 3
		2 YRS.	3 YRS.	4 YRS.	5 YRS.	6 YRS.	6 YRS.
CRAWLER TRACTOR	20-199	1,004,600	2,446,500	2,180,134	1,913,768	1,647,400	2,289,400
	200-450	22,900	529,800	484,733	439,666	394,600	650,000
WHEEL LOADER	20-249	1,339,100	2,963,000	2,700,200	2,437,400	2,174,600	3,235,600
	250-500	301,800	704,100	641,367	578,634	515,900	830,800
UTILITY TRACTOR	20-90+	290,600	618,200	-56,033	493,866	431,700	627,300

Table 7-15
Average Annual Increase in List Price Per Machine
(Dollars)

Machine Type	Classification Category (hp)	Level 1		Level 2								Level 3	
		2 Years		3 Years		4 Years		5 Years		6 Years		6 Years	
		$	%	$	%	$	%	$	%	$	%	$	%
Crawler Tractor	20-199	538.1	1.258	767.0	1.7930	727.4	1.7000	687.7	1.6070	647.4	1.5130	1994.2	4.661
	200-450	639.6	.4533	1238.9	.8781	1176.5	.8339	1114.1	.7897	1051.7	.7456	2590.9	1.836
Wheel Loader	20-249	581.1	1.279	817.7	1.7990	772.9	1.7010	728.0	1.6020	683.3	1.5030	3006.0	4.401
	250-500	804.7	.6439	1270.1	1.0170	1203.8	.5992	1137.5	.9100	974.2	.8827	2618.0	2.095
Utility Tractor	20+	483.6	3.816	679.9	5.3650	645.50	5.0930	611.0	4.8210	576.6	4.5500	1890.2	14.920

ECONOMIC IMPACT ANALYSIS

In analysis of the potential economic effects associated with environmental noise regulations the major focus is on the 19 firms which produce impacted equipment. Additionally, the anticipated effects on the regional and national economies are considered. The same basic scenarios discussed earlier are analyzed: (1) Level I — 2 years, (2) Level II — 3 through 6 years, and (3) Level III — 6 years. As described below, the economic impacts of the various basic noise regulation scenarios may vary significantly with regard to both overall magnitude and the distribution of impacts across the firms. However, regional and national effects appear to be negligible. The analysis of the basic regulatory scenarios discussed in this section have been used as the basis for constructing more complete options consisting of staged levels and lead times.

The average annual manufacturer's cost increase as a percentage of sales at list price are displayed in Table 7-16. The table shows that these ratios range from 0.9 percent to 3.3 percent of annual dollar sales at list prices of impacted equipment.[18]

TABLE 7-16
Average Annual Manufacturer's Cost Increase for Noise Abatement

	LEVEL I	LEVEL II				LEVEL III
	1-2 YRS	3 YRS	4 YRS	5 YRS	6 YRS	6 YRS
Manufacturer's Added Cost as a Percent of Annual Sales at List Price	0.9%	1.3%	1.2%	1.2%	1.1%	3.3%

[18] Does not include manufacturer's profit or dealer margin.

Thus, a typical firm doing an annual business if $1 million in retail loader sales would expect to incur an additional yearly cost of $13,000 to comply with Level II imposed with a 3-year lead time. The use of list price in this ratio understates the percentage cost increase. List price includes manufacturer's profits and dealer margins which need to be excluded to get a true estimate of the resulting cost increase. It is estimated that a true cost estimate will, on the average, increase the percentages indicated in Table 7-16 by 30 percent. The various postures that a firm may adopt with regard to passing on the cost increases via price increases are discussed later.

Table 7-17 shows the impacts on the wheel and crawler tractor firms with regard to capital costs. The table is organized according to the following breakdown. When manufacturer's capital costs are less that 1 percent of sales at list price, a firm can easily raise the required amounts. Between 1 percent and 5 percent, some fund raising difficulty may be experienced. Over 5 percent will present a serious financial burden.

TABLE 7-17
Capital Cost Impacts

	LEVEL I	LEVEL II				LEVEL III
	1-2 YRS	3 YRS	4 YRS	5 YRS	6 YRS	6 YRS
Number of firms Raising Capital with						
No Difficulty	13	12	12	12	12	11
Some Difficulty	6	3	3	4	5	4
Serious Difficulty	0	4	4	3	2	4

With respect to total manufacturer's costs, no firm will experience an increase greater than 5 percent of sales (at list price) in complying with Level I and II. For Level III, 10 firms will experience cost increases of 5% or more of sales. The competitive significance of this increase is not clear due to the higher degree of product differentiation with a concomitant lack of product substitutablity.

At the regional and national level, findings show negligible economic impacts.

Sales will fall roughly in proportion to price increases, which follow from elasticity estimates approximating - 1.0. Employment and income impacts will therefore be minimal, if noticeable at all, on a regional or national level since price increases, even if full pass through of costs is assumed, are expected to be under 5 percent for most models. The added burden to the costs of construction may contribute to a small decrease in the outputs of this sector. EPA calculations based on data collected for this study suggest an average increase in costs of 0.4 percent for construction projects which use impacted tractors and loaders as a major factor of production.

Cost Increases

Manufacturers of impacted equipment will be faced with cost increases both to existing equipment (due to R&D expenses) as well as to the new quieted models (due to increased production expenses). Figures 7-4 through 7-7 display the expected percentage increase in manufacturer's cost to sales at list price ratios to produce existing models for each of the nineteen impacted firms. These cost increases

FIGURE 7-4
R&D Expenses as a Percent of Wheel and Crawler Tractor Sales at List Price for Level I

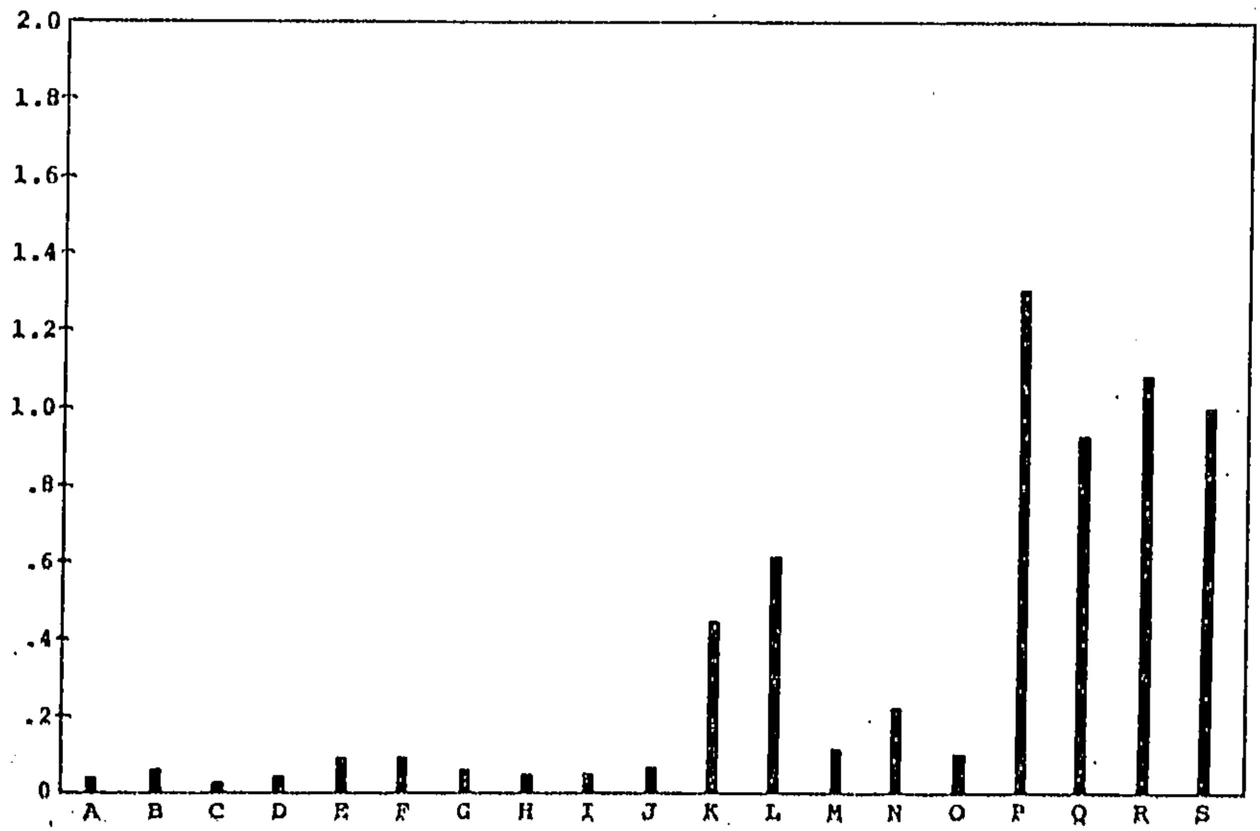


FIGURE 7-5
R&D Expenses as a Percent of Wheel and Crawler Tractor Sales at List Price for Level II in 3 Years

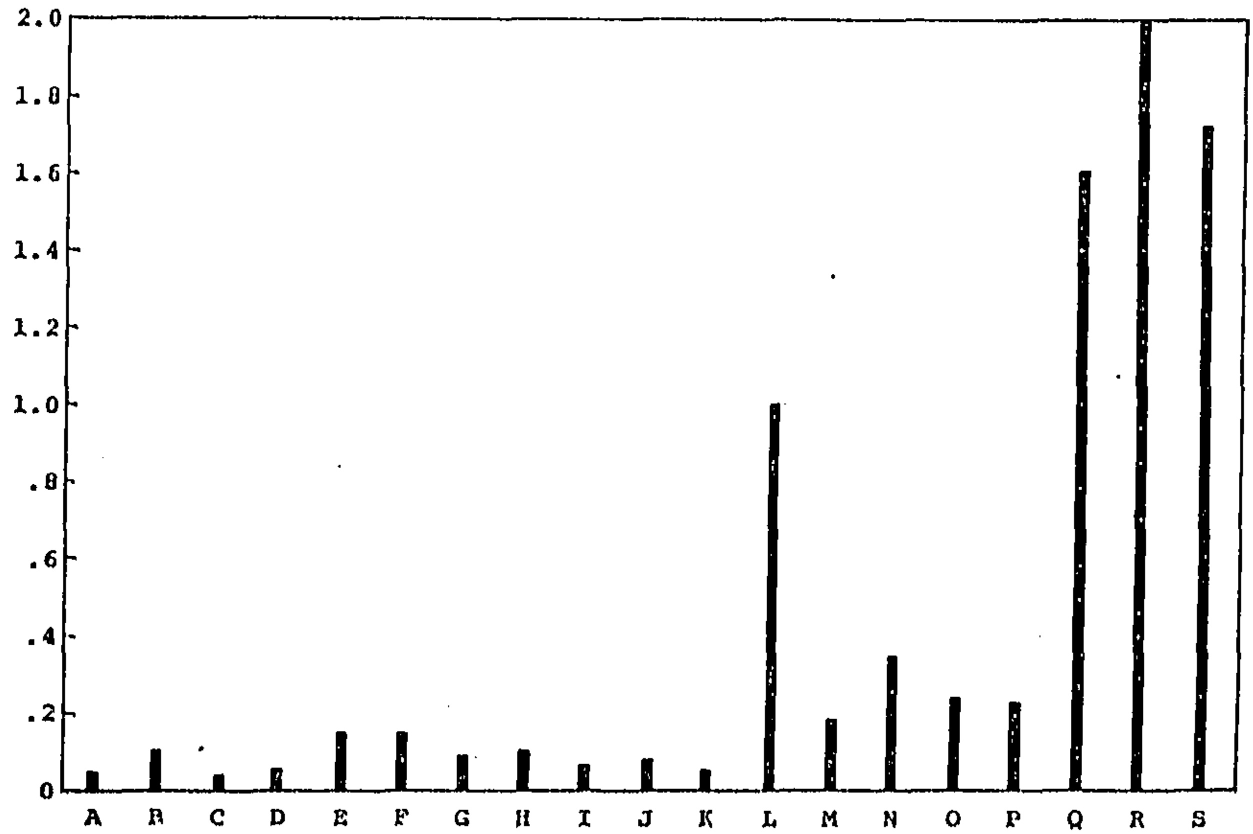


FIGURE 7-6
R&D Expenses as a Percent of Wheel and Crawler Tractor Sales at List Price for Level II in 6 Years

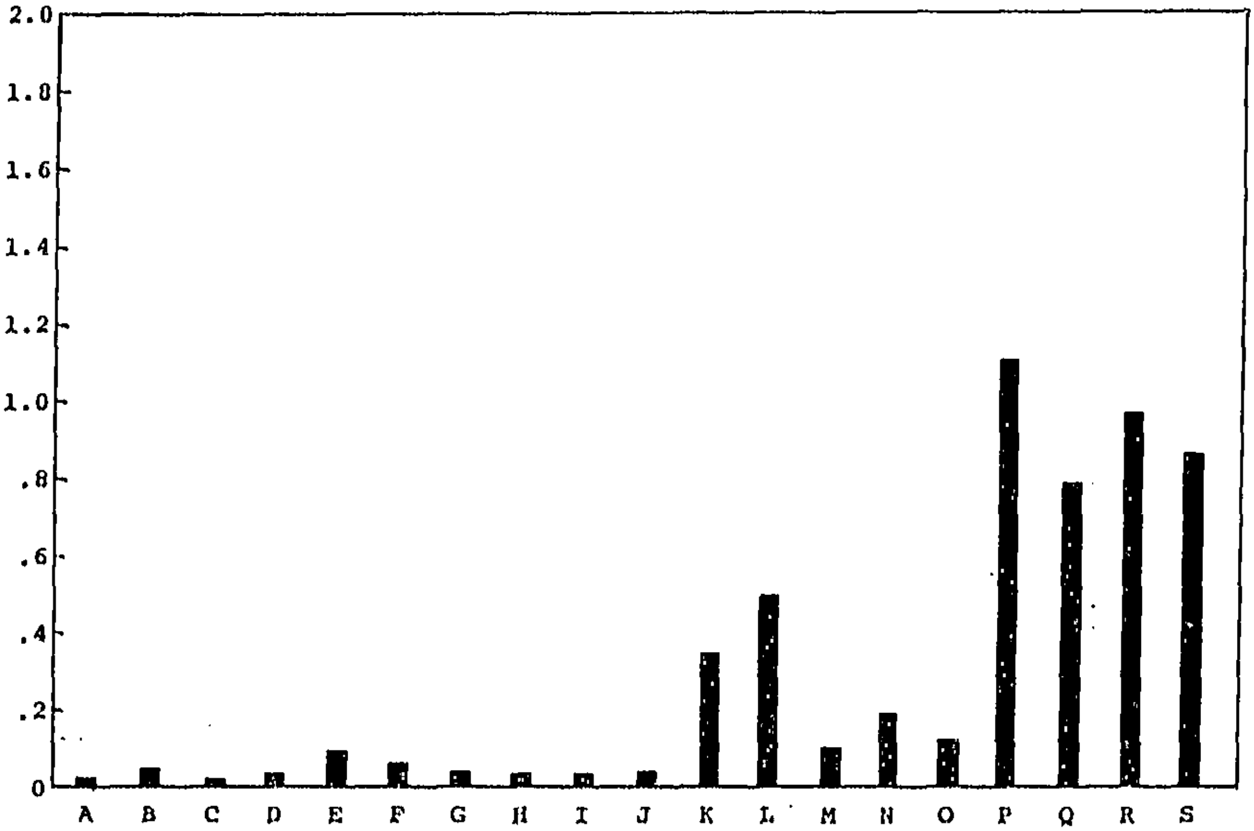
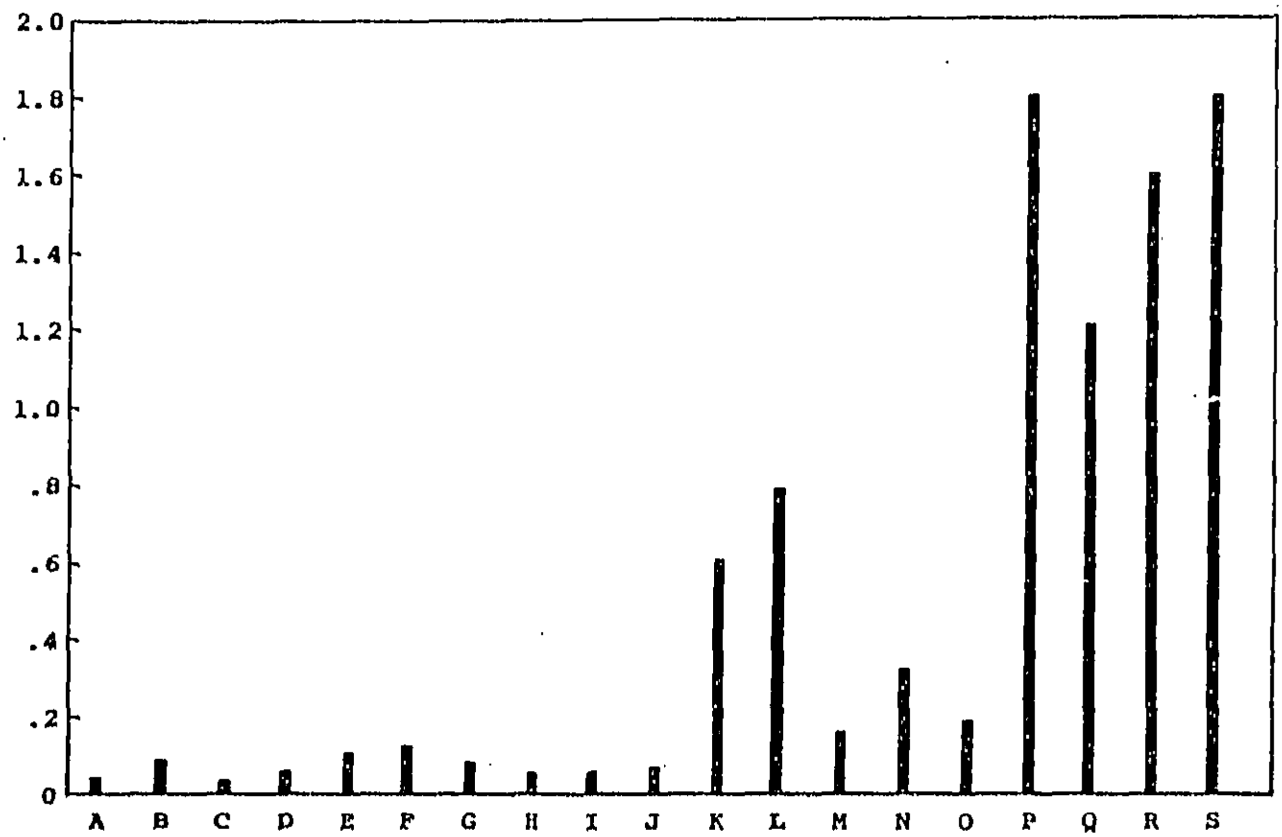


FIGURE 7-7
R&D Expenses as a Percent of Wheel and Crawler Tractor Sales at List Price for Level III in 6 Years



are due to R&D expenses incurred prior to starting production of the quieted models. As before, the calculation method is additional costs divided by sales at list price, expressed in percent.

The figures show that R&D cost increases for existing models produced by large firms would generally be less than one-tenth of a percent of impacted equipment sales. All small and medium firms face cost increases greater than those faced by large firms.

Table 7-18 displays percentage manufacturer's cost increases to list price ranges by firm size for wheel loaders. Due to the wide variety of loader models, the range for small firms is not dramatically higher than for large firms. Only medium firms stand out with an upper bound value nearly half of both the small and large firm maximums. These percentage cost increases actually vary more as a function of machine price than of firm size or market share.

Manufacturer's cost increase ranges, as a percent of sales at list price for crawler tractors, crawler loaders, and utility tractors are displayed in Table 7-19, 7-20, and 7-21 for all firms. (Only large firms produce these items.) Here again, the figures are particularly sensitive to the large numbers of wheel tractors which are generally the lowest priced of all impacted equipment.

Paying for the Cost Increases

The cost increases discussed above can be dealt with by manufacturers in a variety of ways. Two extremes are:

1. Retain the present prices to maintain volume, thereby reducing profit margins.

Table 7-18
Manufacturer's Abatement Cost/Machine List Price Percentage
by Firm Size for Wheel Loaders

Size of Firm	HP Class	Level/Lead Time Level I 2 Years	Level II 3 Years	Level II 6 Years	Level III 6 Years
Small	20-134	1.9-4.5	2.7-6.7	2.6-6.2	7.2-17.5
	135-249	-*	-	-	-
	250-348	-	-	-	-
	349-500	-	-	-	-
Medium	20-134	1.2-2.4	1.7-3.3	1.7-3.3	4.1-8.7
	135-249	0.9	1.3	1.2	2.8
	250-348				
	349-500				
Large	20-134	0.7-4.0	1.0-5.7	1.0-5.6	2.5-16.4
	135-249	0.6-1.1	0.9-1.6	0.9-1.6	1.5- 3.4
	250-348	0.3-0.7	0.7-1.0	0.7-1.0	1.4- 2.1
	349-500	0.2	0.5-0.7	0.6-0.7	1.1- 1.3
All Firms	20-134	0.7-4.5	1.0-6.7	1.0-6.2	2.5-17.5
	135-249	0.6-1.1	0.9-1.6	0.9-1.6	1.5- 3.4
	250-348	0.3-0.7	0.7-0.9	0.7-1.0	1.4- 2.1
	349-500	0.2	0.5-0.7	0.6-0.7	1.1- 1.3

* - Indicates that small firms do not manufacture high hp wheel loaders

Table 7-19
Manufacturer's Abatement Cost/Machine List Price Percentages for Firms Manufacturing Crawler Tractors

HP CLASS	LEVEL	LEVEL I	LEVEL II	LEVEL II	LEVEL III
	LEAD TIME	2 YEARS	3 YEARS	6 YEARS	6 YEARS
20-89		1.0-2.0	1.4-2.9	1.4-2.9	3.7-8.2
90-199		0.5-1.3	0.7-1.8	0.6-1.7	1.4-5.8
200-259		0.5-0.6	0.8	0.8-0.9	1.7-1.9
260+		0.2-0.5	0.6-0.8	0.6-0.8	1.1-1.6

Table 7-20
Manufacturer's Abatement Cost/Machine List Price Percentages for Firms Manufacturing Utility Tractors

HP CLASS	LEVEL	LEVEL I	LEVEL II	LEVEL II	LEVEL III
	LEAD TIME	2 YEARS	3 YEARS	6 YEARS	6 YEARS
ALL		1.7-5.1	2.4-7.1	2.4-7.1	6.1-19.9

2. Raise the prices to maintain profit margins, thereby reducing volume.

Calculations based on the price elasticity of demand show that total profits will be reduced under either situation, although the decline in profit for each extreme will be different for each firm. Assuming full pass-through of burdened costs and a price elasticity of demand equal to -1, decreases in total profit will occur due to the decrease in volume. Table 7-21 shows the decrease in wheel and crawler tractor profits for each firm as a percent of its present profit for 3 percent, 7 percent, and 10 percent gross margins (taxes ignored).

Absorbing some of the cost may be necessary, particularly on an individual model basis. Several firms may find that their cost increases are significantly higher than those of their competitors for certain models, possibly as a result of differences in existing noise emission levels. In order to maintain their competitive positions, some part of the difference may be absorbed. The problem may be more marked for small firms who face higher relative cost increases as a percent of their total sales. Additionally, in cases where a particular model's current noise level is significantly greater than the average for its class, the costs of abatement may be much larger than the average costs considered in this analysis. If the increases are so great that passing them on may erode a firm's competitive position, absorption is likely to occur. In such situations, firms facing strong competitive pressure on the one hand and profit pressure n the other may opt to shut down production on certain models.

Table 7-21
Estimated Decrease in Profit by Firm Under Full Pass-Through of Costs
($ Thousands)

Firm	Assumed Current Profit Margin Scenario											
	3 Percent				7 Percent				10 Percent			
	Level I 2 Years	Level II 3 Years	Level II 6 Years	Level III 6 Years	Level I 2 Years	Level II 3 Years	Level II 6 Years	Level III 6 Years	Level I 2 Years	Level II 3 Years	Level II 6 Years	Level III 6 Years
A	250.8	388.2	388.2	992.7	604.0	904.8	904.8	2,315.0	862.7	1,294.1	1,294.1	3,307.2
B	91.9	138.3	138.3	405.1	219.0	322.8	322.8	945.2	312.9	461.1	461.1	1,350.3
C	332.3	531.6	531.6	1,196.0	776.0	1,240.3	1,240.3	2,790.0	1,107.5	1,771.9	1,771.9	3,986.9
D	104.0	156.1	156.1	377.1	242.8	364.1	364.1	880.1	346.8	520.3	520.3	1,257.2
E	142.9	202.4	202.4	559.6	333.4	472.4	472.4	1,306.0	476.3	674.8	674.8	1,865.6
F	21.2	33.9	33.9	76.3	49.5	79.2	79.2	178.2	70.7	113.1	113.1	254.5
G	121.8	173.2	173.2	400.9	284.3	403.9	403.9	1,122.2	406.1	577.1	577.1	1,603.0
H	102.1	143.8	143.8	394.2	238.2	335.5	335.5	920.0	340.2	479.3	479.3	1,314.3
I	43.4	62.0	62.0	148.7	101.3	144.7	144.7	347.1	144.7	206.7	206.7	495.5
J	23.9	32.9	32.9	77.9	55.9	76.8	76.8	181.5	79.8	109.7	109.7	259.3
K	2.6	3.5	3.5	8.3	6.0	8.3	8.3	19.5	8.4	11.8	11.8	27.9
L	3.8	5.5	5.2	14.0	8.7	12.6	12.1	32.6	12.5	18.1	17.3	46.7
M	7.5	10.8	10.3	27.7	17.7	25.3	24.0	64.6	25.3	36.1	34.3	92.3
N	7.0	10.0	10.0	27.7	16.4	23.3	23.3	64.2	23.4	33.1	33.1	91.8
O	2.7	3.6	3.6	9.4	6.2	8.3	8.3	22.0	9.0	12.0	12.0	31.3
P	1.3	1.8	1.7	4.7	3.0	4.3	4.0	11.0	4.3	6.2	5.8	15.9
Q	1.4	1.9	1.8	4.8	3.2	4.5	4.3	11.2	4.7	6.5	6.2	16.0
R	1.3	1.8	1.8	4.7	3.0	4.2	4.2	10.9	4.3	6.0	6.0	15.6
S	1.3	1.9	1.8	4.8	3.1	4.4	4.3	11.2	4.4	6.4	6.1	16.0
All Firms	1,273.2	1,903.2	1,902.1	4,814.6	2,971.7	4,439.7	4,437.3	11,233.3	4,244.0	6,344.3	6,340.7	16,047.3

Capital Availability

Even if full cost increases can be passed through as price increases, firms may still be prevented from adjusting to regulations by an inability to obtain sufficient capital to finance the abatement investment. The capital required by each firm is displayed in Table 7-22 for the various scenarios.

Table 7-23 displays the expected capital required for abatement as a percent of impacted equipment sales at list price for six study scenarios. These ratios reflect the expected degree of difficulty in raising the necessary capital. While the actual dollar amounts of Table 7-22 would not represent a burden for the larger firms, the investment still must be considered on its own merits, particularly with respect to investment alternatives within the firm. To adjust for firm sizes the ratio of required investment to total wheel and crawler tractor sales is seen as the best indicator for evaluating capital availability.

The relative impact of financing the costs of abatement for each level can be seen in Figure 7-8 which displays the frequency with which the capital required for abatement/sales ratios falls into various ranges. It is assumed that firms with ratios less than or equal to 1 percent will undergo only small financing impact, while firms with ratios between 1 and

Table 7-22
Total Capital Cost of Abatement for Wheel and Crawler Tractors

Firm	Total Capital Cost of Abatement ($ Thousands)					
	Level I	Level II				Level III
	2 Years	3 Years	4 Years	5 Years	6 Years	6 Years
A	438	1,007	913	820	726	1,136
B	400	871	793	715	637	979
C	385	870	793	715	638	1,009
D	351	770	698	626	554	855
E	290	670	607	545	482	662
F	220	545	498	450	403	654
G	205	468	426	384	342	535
H	145	316	286	256	226	341
I	135	291	271	242	212	324
J	130	280	255	231	206	318
K	80	168	156	144	132	207
L	60	117	108	98	89	128
M	60	116	107	97	88	127
N	55	107	99	91	83	123
O	53	106	98	91	83	122
P	50	96	90	84	78	117
Q	50	96	90	84	78	116
R	50	96	90	84	78	117
S	50	86	83	80	78	116
All Firms	3,207	7,076	6,461	5,837	5,213	7,966

Table ·23
Total Capital Cost of Abatement as Percent of Wheel and Crawler Tractor Sales

Firm	Lead Time					
	Level I		Level II			Level III
	2 Years	3 Years	4 Years	5 Years	6 Years	6 Years
A	.08	.18	.16	.15	.13	.21
B	.32	.69	.63	.56	.50	.77
C	.02	.05	.046	.043	.04	.06
D	.11	.23	.21	.19	.17	.26
E	.10	.22	.20	.18	.16	.22
F	.20	.50	.45	.41	.37	.60
G	.12	.28	.26	.23	.21	.33
H	.12	.27	.24	.22	.19	.29
I	.09	.18	.16	.15	.13	.20
J	.17	.36	.33	.30	.27	.41
K	1.2	2.6	2.4	2.2	2.0	3.2
L	2.1	4.1	3.0	3.4	3.1	4.5
M	.43	.84	.77	.70	.63	.91
N	.73	1.4	1.3	1.2	1.1	1.6
O	.48	.93	.85	.78	.70	1.1
P	4.1	7.9	7.4	6.9	6.4	9.6
Q	2.9	5.6	5.2	4.9	4.5	6.8
R	3.6	7.0	6.6	6.1	5.7	8.5
S	3.1	5.3	5.1	5.0	4.8	7.2
All Firms	.09	.19	.17	.16	.14	.22

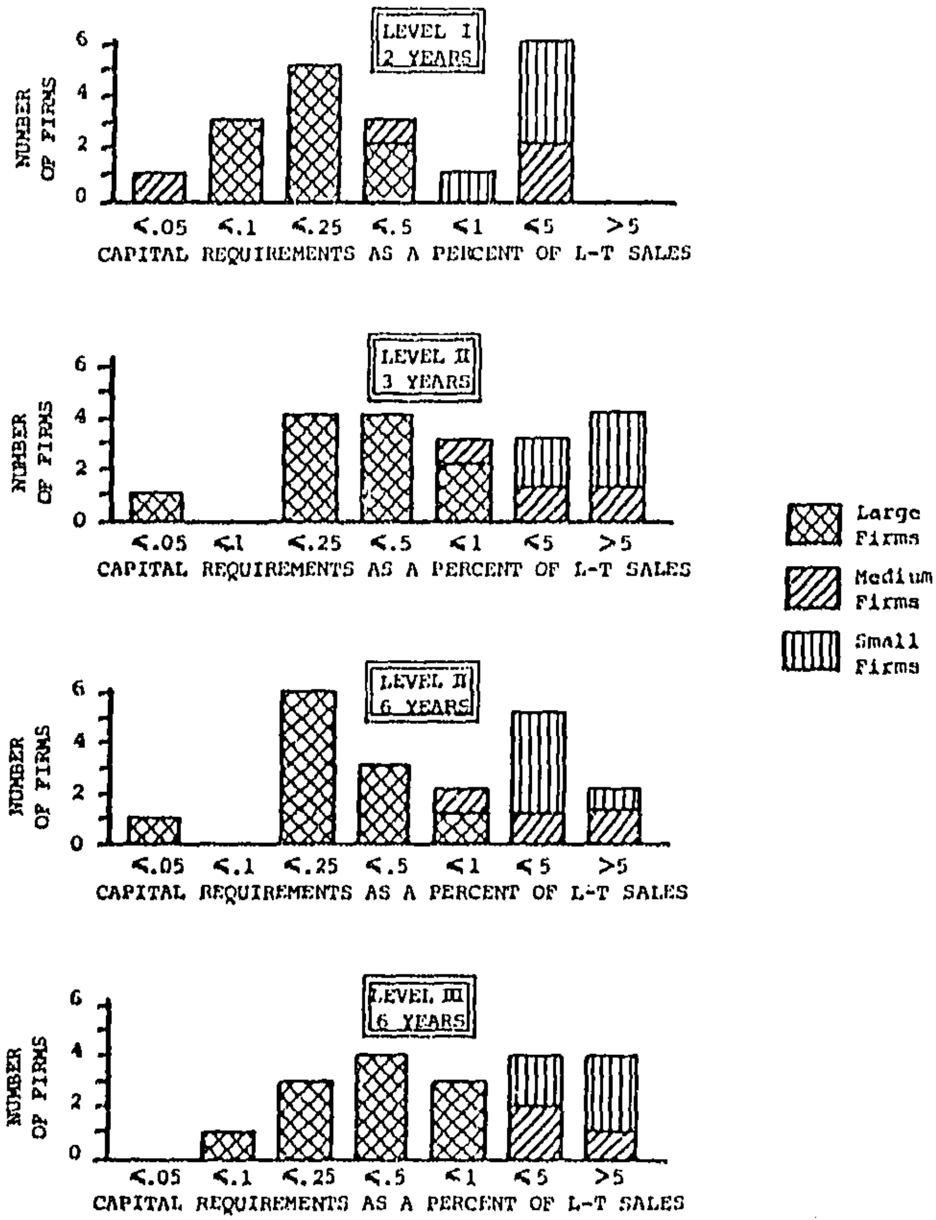


Figure 7-8 Capital Availability Impact of Abatement.

5 percent will have moderate difficulty in obtaining the necessary financing. Small and medium firms in this category may be obliged to pay a higher cost for capital. Firms with ratios greater than 5 percent are considered to be heavily impacted. Their cost of capital will certainly rise, if they can obtain the necessary financing.

Investment requirements could be reduced by purchasing the necessary components from other firms, thus raising L&M expenses. Additionally, impacted firms may obtain R&D assistance from component suppliers for developing and fitting abatement components to their own equipment. Allowing the supplier to undertake this R&D burden will undoubtedly result in higher unit prices for the quieted components (engine, exhaust, fan, etc.). The supply industry appears to already have the facilities for this R&D effort without large additional investments and has developed much of the general technology for abatement. Thus, the problem of raising capital can be sidestepped, but again at a penalty to the small manufacturer.

COMPETITION

There may be two major impacts of noise emission regulations on competition in the construction wheel and crawler tractor industry -- brand switching and production line closures. The latter is often a result of the former. Both impacts will be felt more strongly by smaller firms. However, it cannot be asserted summarily that industry concentration will be significantly altered.

Brand Switching. Determination of the impact on competition of compliance with the various study scenarios is obscured by the significant levels of product differentiation found in the industry. Differential cost increases will occur, due to the variation in present noise levels of machines.

Some loss of sales may occur for both small wheel loaders and for wheel tractors.

Small Wheel Loaders. As noted earlier, all the small and medium firms produce wheel loaders under 134 hp. These machines tend to comprise a unique market, particularly those below 50 hp which do not compete with the loaders of the major manufacturers. Rather, most compete with the less efficient skid steer loader. Skid steer loaders, however, are not intended to be regulated at this time, with the result that the cost of noise abatement for individual models of small wheel loaders could place them at a competitive disadvantage if their existing noise levels are substantially higher than the average for their classification category. The estimated average cost increases for the various study scenarios, which range from $350 to $1500 for machines in the 20-134 hp range, represent a significant percent of the list prices which are as low as $1800 and have a median around $15,000.

The prices of skid steer loaders are generaly below $10,000, but in terms of horespower they are comparable with small wheel loaders.

Wheel Tractors. At present, wheel tractors with integral backhoes are not covered under the propose regulation. (These items may well be regulated later under a possible backhoe regulation.) Accordingly, they will not be subject to the upward cost pressure of abatement. While intergal backhoe units are all larger and more costly than the utility tractors alone, marginal contractors who desire large utility tractors with backhoe attachments may prefer to spend the extra money to purchase one with an integral backhoe, rather than purchasing the top of the line utility tractor and paying a cost penalty for its noise abatement features.

Production Line Closures

Two factors will dominate pressure to shut down plant operations: (1) difficulty in obtaining necessary capital, and (2) difficulty in passing costs through to customers. This latter factor is dependent on the magnitude of the cost increase imposed on the affected firm relative to the magnitude imposed on the price leader. This, in turn, will depend on present noise levels, which are not fully known for all machines at this time. In general, however, both difficulties place the strongest pressure on the small producers.

Figures 7-9 through 7-12 display the relationship between cost pressure and financing difficulty anticipated for each firm for several study scenarios, using the model costs discussed earlier. In these figures, highly impacted firms will plot towards the upper right while negligibly impacted firms will fall to the lower left. The figures show that, indeed, the smaller producers are subject to the highest impacts. In particular, five producers, four small firms and one medium firm, appear to be well above the main cluster of firms in each of the four figures. Under the requirements of Level III, all but one of these firms falls into the "heavy impact" category for financing difficulties and the remaining firm faces the highest average rise in cost.

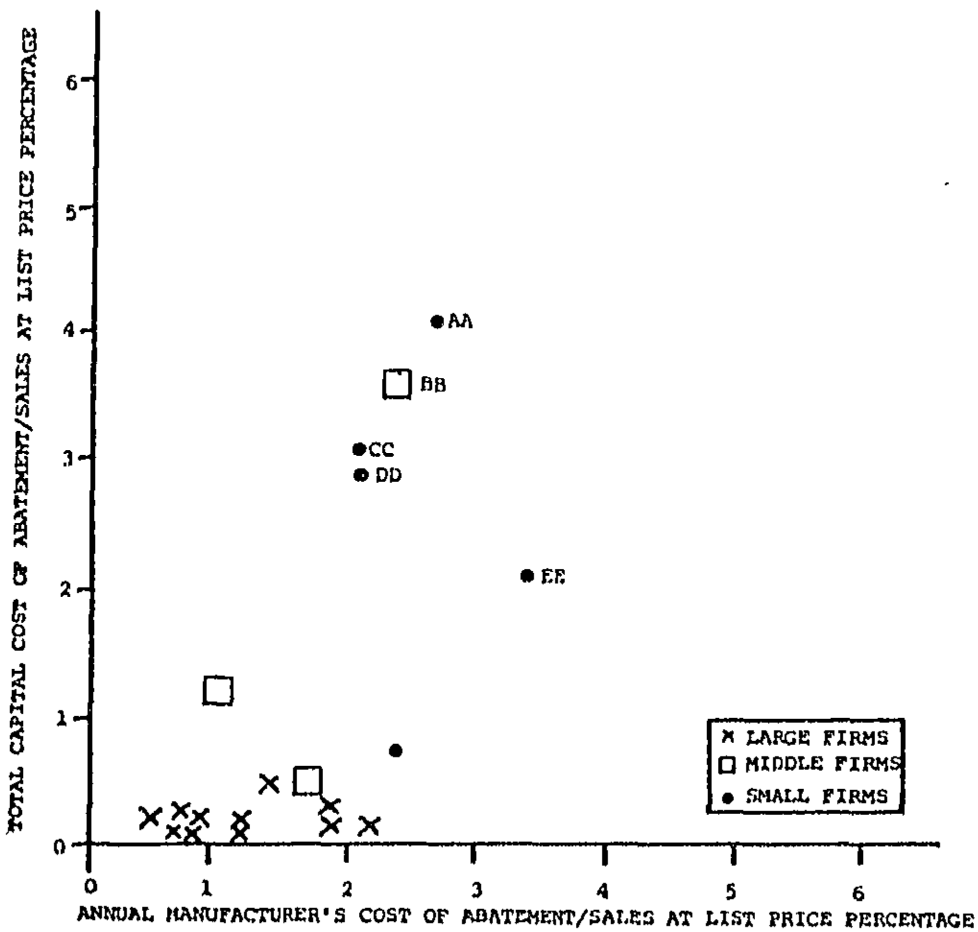


Figure 7-9 Relative impact to firms of achieving Level I in 2 years.

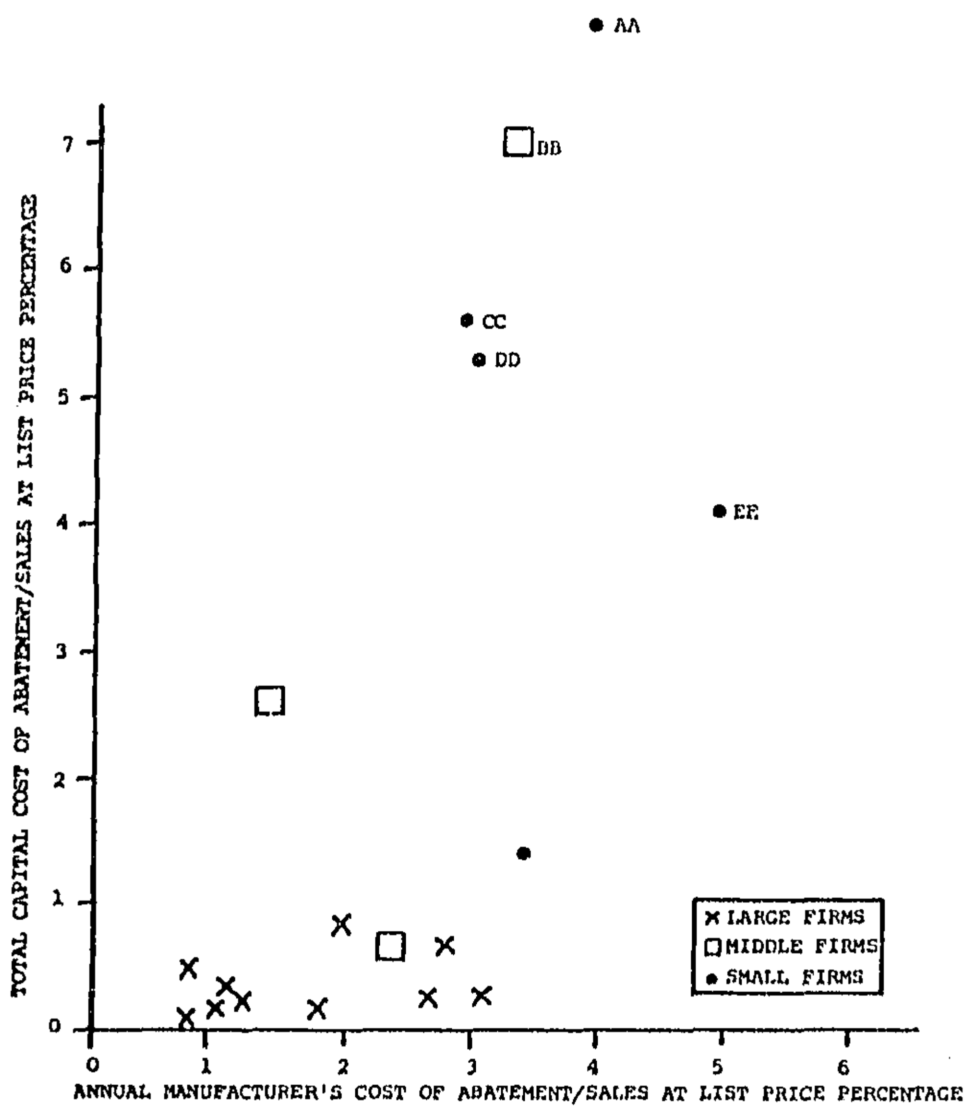


Figure 7-10 Relative impact to firms of achieving Level II in 3 years.

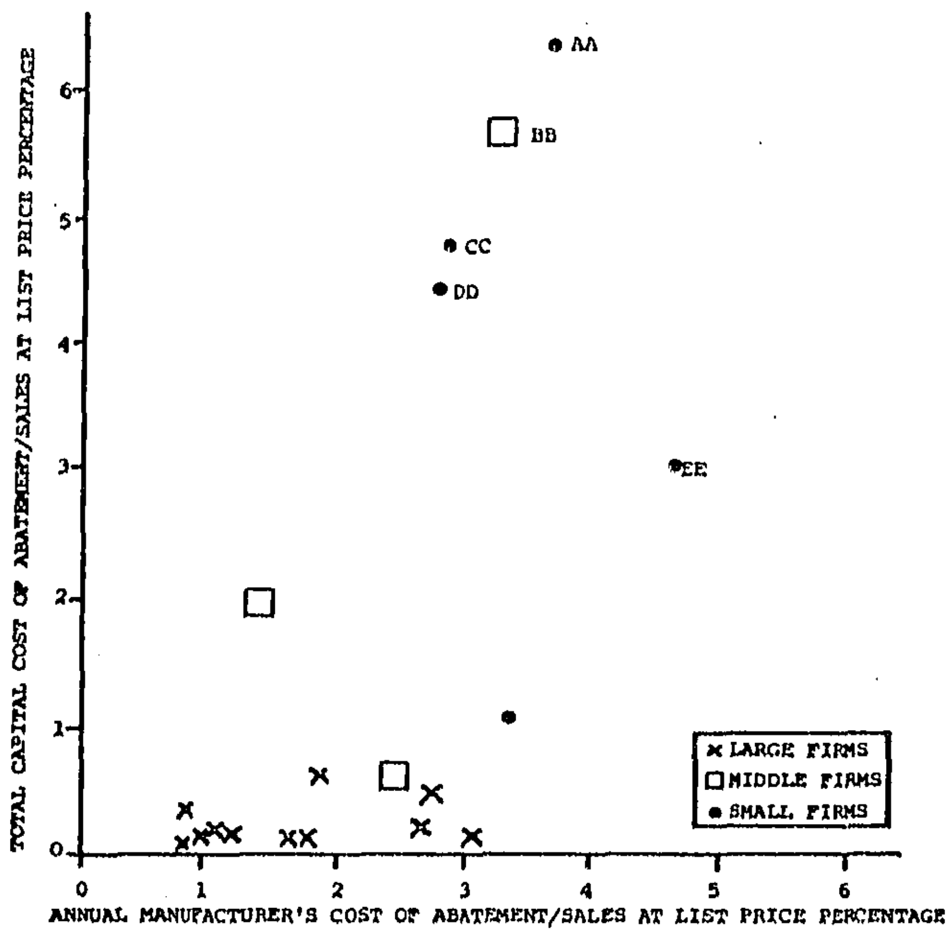


Figure 7-11 Relative impact to firms achieving Level II in 6 years.

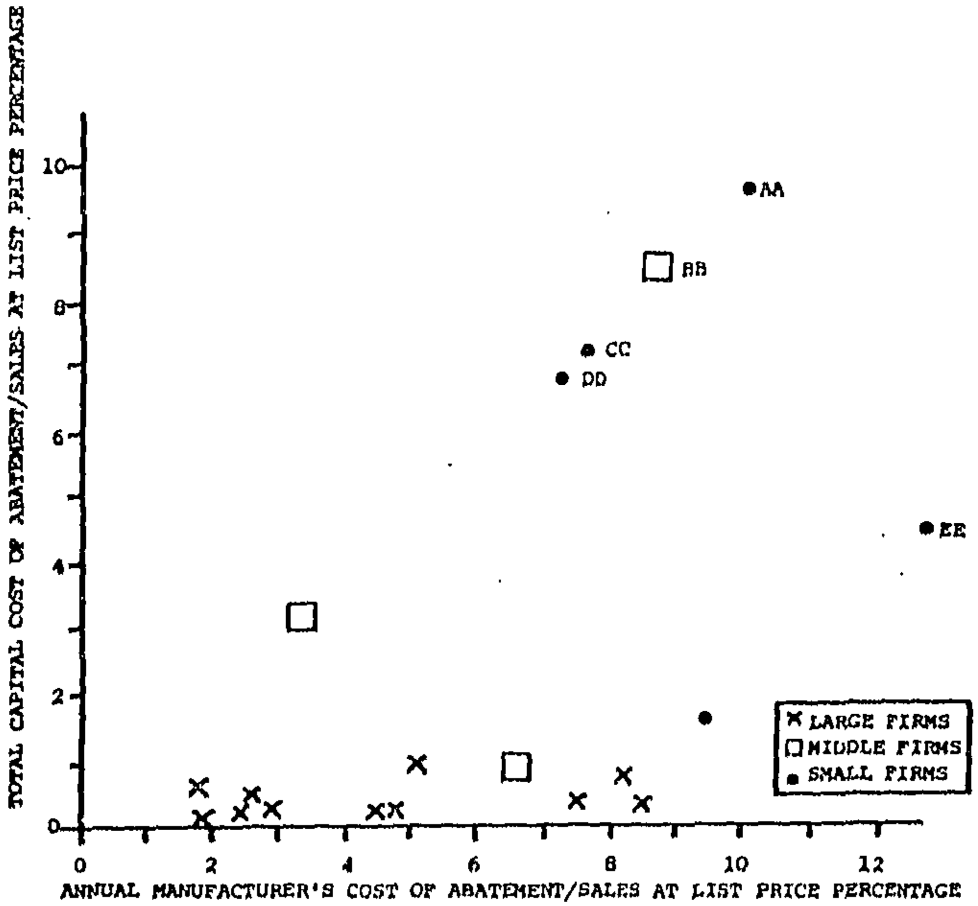


Figure 7-12 Relative impact to firms of achieving Level III in 6 years.

Of these five firms, only Firm EE disclosed noise level data. These data indicate that its machines are already in compliance with Level I and the firm has an optional muffler that will bring the machines beneath Level II. This muffler has been sold on several models already and the firm believes that after a regulation is promulgated, the additional costs of the muffler will be borne by its customers without dramatically altering demand. Beginning at a below average noise level, Level III costs are expected to be considerably lower than the cost model estimates, minimizing, therefore, the financing burden as well as the cost input.

Firm BB does not believe additional cost impacts will be a serious problem, but the remaining three firms are already suffering from a shortage of capital. These firms do not anticipate that they will be able to finance the investment necessary for compliance.

INFLATIONARY IMPACTS

Because no increases in machine productivity will accompany the increased costs of abatement, regulations at all levels will be inflationary. The inflationary effects will be most widespread in construction but will also be significant in forestry and mining.

The estimated average manufacturer's cost increase list price ratios for each machine type are shown in Table 7-24 for several scenarios.

TABLE 7-24
Annual Manufacturer's Abatement Costs as a Percent of Estimated Wheel and Crawler Tractor Sales at List Price, by Machine Type for Each Study Scenario

	LEVEL	LEVEL I	LEVEL II				LEVEL III
MACHINE CLASS	LEAD TIME	2 YRS	3 YRS	4 YRS	5 YRS	6 YRS	6 YRS
Wheel Loaders		0.8	1.2	1.2	1.1	1.0	2.8
Crawler Tractor		0.6	1.0	1.0	0.9	0.9	2.1
Crawler Loaders		1.0	1.4	1.4	1.3	1.2	3.5
Wheel Tractors		2.9	4.1	3.9	3.7	3.5	11.5

The table shows wheel tractor prices will increase much more than other equipment prices. Crawler tractor prices increase the least. This, again, is because percentage increases are primarily a function of price, and the average crawler tractor price is the highest. These increases could contribute to the overall increases in the Wholesale Price Index as displayed in Table 7-25.

TABLE 7-25

Percent Contributions of Noise Abatement Costs
to the Wholesale Price Index (All Comodities)

MACHINE CLASS	WEIGHT IN WHOLESALE PRICE INDEX	LEVEL LEAD TIME	LEVEL I	LEVEL II				LEVEL III
			2 YRS	3 YRS	4 YRS	5 YRS	6 YRS	6 YRS
All Loaders	.079		.012	.018	.011	.0010	.0098	.0048
Crawler Tractor	.142		.018	.0016	.0016	.0021	.0014	.0060
Utility Tractors	.080		.0046	.0043	.0041	.0038	.0034	.0184

Impacts on Suppliers

Two quite distinct impacts will affect the suppliers of the wheel and crawler tractor industry. Certain present component suppliers may increase or decrease their sales depending on their ability to reduce the noise emission of their own product and thereby contribute to the reduction in overall machine noise. Other suppliers, those specializing in the manufacture of sound damping and sound absorbant materials and other products required for abatement, will experience an increase in sales.

Impact on Present Component Suppliers. The impacts on the sales of present component suppliers will be most significant in two supplier areas — engines and mufflers.

Engine Suppliers. Engines have characteristic noise levels just as do the machines they are placed in. There exists a significant variation in noise levels of different types of engines as well as of the same type engine from different suppliers. Consequently, engine manufacturers can be expected to be at a competitive disadvantage, if they produce diesel engines which are characterized, in general, as being noisier than their competition.

Conversely, some manufacturers appear to be in the forefront of quiet engine development. They have already developed add-on kits for their engines that can reduce noise by 3 dB(A). These kits may not be applicable to wheel and crawler tractors due to space constraints; however loader and tractor manufacturers may be able to circumvent costly R&D costs with the purchase of already quieted engines.

Muffler Suppliers. While most muffler suppliers are likely to begin development of more efficient mufflers, four present manufacturers have developed a favorable reputation for their muffler research programs. These manufacturers may reap a double gain, by selling more efficient mufflers to wheel and crawler tractor manufacturers to reduce exhaust noise, and conducting exhaust noise reduction progams for capital-short manufacturers who sub-contract this portion of their R&D effort.

Other Noise Abatement Suppliers. An across-the-board increase in the sales of suppliers of materials and equipment necessary for abatement can be expected, although its magnitude will not be of major consequence. Increases in sales by producers of the following items are anticipated:

1. quiet fan and cooling system components
2. sound damping component
3. sound absorbant material
4. protective film for foams
5. noise measurement equipment
6. fine suspension equipment

Here again, suppliers may also be given the opportunity to perform portions of the R&D effort required for abatement, including noise testing for smaller firms. These R&D efforts will further boost the sales of firms with relevant experience.

Impact on Foreign Trade

Regulatory Levels I and II will not greatly affect foreign trade. There is likely to be a small decrease in exports along with an offsetting decrease in imports.

Because the noise abatement technology studied here is essentially retrofit, machines for export can be produced without noise abatement add-ons, resulting, therefore, in minimal price increases in foreign markets. However, Level III noise regulations might prompt a major design change in advance of customarily scheduled changes, and the R&D expenses will be noticeable even in export versions which contain only add-ons, thereby putting upward pressure on export prices. The foreign trade implications would then be more adverse from the domestic manufacturers' viewpoint.

Noise regulations are more likely to affect imports. The majority of importers have weak market positions in the United States and may not be able to justify a noise abatement program for their products. Accordingly, they may cease to compete in the United States. But major importers with strong market potential are not likely to be swayed by regulations and may fill in most of the market gap left by their weaker competitors. It is concluded, therefore, that the aggregate total of imports should decline only slightly.

Employment and Regional Impacts

Regulating the noise emissions of wheel and crawler tractors will likely have negligible overall effect on employment. The existing R&D personnel in the major firms or in the suppliers of research to the smaller firms can readily handle the R&D requirement for abatement. There will be a modest increase in manufacturing labor to install the abatement equipment. However, this increase may be offset by a decline in regular production personnel due to the decrease in demand for regulated equipment. Geographical impacts will be outside the Midwest. Although the large construction loader and tractor manufacturers are located in the Midwest, they are not likely to be seriously affected. The important effects are more likely to be found in the cities where the small firms are located. The possible layoffs or shutdowns of these smaller firms will not play a major role in their region's economy. The increases in employment and income where suppliers of abatement equipment are located is also of limited magnitude with respect to any region.

Effect on Gross National Product (GNP)

Noise abatement regulations are not likely to directly affect the current dollar GNP. The estimate of the price elasticity of demand for impacted equipment is -1 as discussed previously. Therefore, marginal price increases may be offset by equal percentage decreases in demand.

The net result would show GNP unchanged as expressed in current dollars. If the machines sold are valued at 1972 price levels, and if the add-on abatement equipment is valued at its cost deflated to 1972 level,[19] a drop in real GNP due to fewer units being sold is expected. However, an increase in real GNP due to the production and sales of the new equipment and equipment modification is also expected. These effects are sufficiently offsetting so that the net change in real GNP will be negligible with regard to the equipment manufacturing sector.

SUMMARY OF COST AND ECONOMIC DATA FOR REGULATORY SCHEDULES

A computer model was used to evaluate alternate regulatory schedules both for health and welfare benefits and for costs and economic impacts. As a result of this analysis, twenty four schedules were finally selected for detailed analysis. Table 7-27 summarizes the pertinent cost and economic data associated with each of these options.

---

19 1972 is the base year now used by most government agencies for expressing constant dollar levels.

Table 7-26
Summary of Costs for Regulatory Schedule

Regulatory Schedule	Machine Types	Level/Effective Date 1980	1981	1982	1983	1984	Average Price Increase (%)	Average O&M Increase (%)	Change In Sales (%)	Change In Profits (%)	Potential No. of Plant Closings
1	CT_S		77	77	77	74	5.68	4.06	- 1.26	- 0.44	0
	CT_L		83	83	83	80	2.28	3.13	- 2.80	- 0.03	0
	WL_S		79	79	79	76	5.41	3.45	- 6.77	- 0.30	3.5
	WL_L		84	84	84	80	2.64	3.19	- 3.25	- 0.08	0
	WT		74	74	74	70	-18.06	4.05	-25.89	- 4.87	-0
	Combined						6.21	3.81	-13.30	- 0.85	3.5
2	CT_S					74	5.31	3.77	- 7.26	- 0.44	0
	CT_L					80	2.09	2.85	- 2.80	- 0.03	0
	WL_S					76	5.03	3.19	- 6.77	- 0.31	3.0
	WL_L					80	2.39	2.90	- 3.25	- 0.09	0
	WT					70	16.97	3.75	-23.89	- 4.74	0
	Combined						5.80	3.53	-13.30	- 0.84	3.0
3	CT_S		77	77	77	74	5.68	4.06	- 7.26	- 0.44	0
	CT_L		83	83	83	80	2.28	-3.13	- 2.80	- 0.03	0
	WL_S		79	79	79	76	5.41	3.45	- 6.77	- 0.30	3.5
	WL_L		84	84	84	80	2.61	3.19	- 3.25	- 0.08	.0
	WT	77	77	77	77	74	6.20	1.43	- 7.29	- 0.68	0
	Combined						4.72	2.77	- 6.80	- 0.38	3.5
4	CT_S		77	77	77	74	5.68	4.06	- 7.26	- 0.44	0
	CT_L			83	83	83	1.06	1.48	- 1.28	- 0.01	0
	WL_S		79	79	79	76	5.41	3.45	- 6.77	- 0.30	3.5
	WL_L			84	84	84	2.61	1.52	- 1.48	- 0.01	0
	WT		74	74	74	70	18.06	4.05	-23.89	- 4.87	0
	Combined						5.95	3.58	-13.16	- 0.84	3.5

* CT_S - Crawler Tractor 20 - 199 hp WL_S - Wheel Loader 20-249 hp

CT_L - " " 200 - 450 hp WL_S - " " 250 - 500 hp

WT - Wheel Tractors

Table 7-26
(Continued)

Regulatory Schedule	Machine Types	Level/Effective Dates 1980	1981	1982	1983	1984	Average Price Increase (%)	Average O&M Increase (%)	Change In Sales (%)	Change In Profits (%)	Potential No. of Plant Closings
5	CT_S					74	5.31	3.77	- 7.26	-0.44	0
	CT_L					83	0.85	1.16	- 1.14	0.00	0
	WL_S					76	5.03	3.19	- 6.77	-0.31	3.0
	WL_L					84	0.98	1.19	- 1.33	-0.02	0
	WT					70	16.97	3.75	-23.87	-4.74	0
				Combined			5.41	3.29	-13.15	-0.82	3.0
6	CT_S		77	77	77	74	5.68	4.06	- 7.26	-0.44	0
	CT_L			83	83	83	7.06	1.48	- 1.28	-0.01	0
	WL_S		79	79	79	76	5.41	3.45	- 6.77	-0.30	3.5
	WL_L			84	84	84	1.23	1.52	- 1.48	-0.01	0
	WT	77	77	77	77	74	6.20	1.43	- 7.29	-0.68	0
				Combined			3.54	2.53	- 6.66	-0.31	3.5
7	CT_S					74	5.31	3.77	- 7.26	-0.44	0
	CT_L			83	83	83	1.06	1.48	- 1.28	-0.01	0
	WL_S					76	5.03	3.19	- 6.77	-0.31	3.0
	WL_L			84	84	84	1.23	1.52	- 1.48	-0.02	0
	WT					74	5.18	1.14	- 7.29	-0.58	0
				Combined			4.00	2.29	- 6.66	-0.50	3.0
8	CT_S					74	5.31	3.77	- 7.26	-0.44	0
	CT_L					83	0.85	1.16	- 1.14	0.00	0
	WL_S					76	5.03	3.19	- 6.77	-0.31	3.0
	WL_L					84	0.98	1.19	- 1.33	-0.02	0
	WT					74	5.18	1.14	- 7.29	-0.58	0
				Combined			3.93	2.25	- 6.65	-0.30	3.0

Table 7-26
(Continued)

Regulatory Schedule	Machine Types	Level/Effective Dates 1980	1981	1982	1983	1984	Average Price Increase (%)	Average O&M Increase ($)	Change In Sales (%)	Change In Profits (%)	Potential No. of Plant Closings
9	CT_S	80	80	80	80	77	8.01	1.47	-2.35	-0.23	0
	CT_L			83	83	83	1.06	1.48	-1.28	-0.01	0
	WL_S	82	82	82	82	79	2.08	1.33	-2.31	-0.19	1.5
	WL_L			84	84	84	1.23	1.52	-1.48	-0.01	0
	WT		74	74	74	70	18.06	4.05	-23.89	4.87	0
				Combined			3.80	2.48	-10.69	-0.74	1.5
10	CT_S					77	1.73	1.22	-2.35	-0.05	0
	CT_L			83	83	83	1.06	1.45	-1.28	-0.01	0
	WL_S					79	1.73	1.09	-2.31	-0.02	1.5
	WL_L			84	84	84	1.23	1.52	-1.48	-0.01	0
	WT					70	16.97	3.75	-23.89	-4.74	0
				Combined			3.47	2.24	-10.69	-0.62	1.5
11	CT_S					77	1.73	1.22	-2.35	-0.05	0
	CT_L					83	0.85	1.16	-1.14	0.00	0
	WL_S					79	1.73	1.09	-2.31	-0.02	1.5
	WL_L					84	0.98	1.19	-1.33	-0.02	0
	WT					70	16.97	3.75	-23.89	-4.74	0
				Combined			3.40	2.20	-10.67	-0.62	1.5
12	CT_S	80	80	80	80	77	2.07	1.47	-2.35	-0.23	0
	CT_L			83	83	83	1.06	1.48	-1.28	-0.01	0
	WL_S	82	82	82	82	79	2.08	1.33	-2.31	-0.19	1.5
	WL_L			84	84	84	1.23	1.52	-1.48	-0.01	0
	WT	77	77	77	77	74	6.20	1.43	-7.29	-0.68	0
				Combined			2.31	1.43	-4.19	-0.21	1.5

Table 7-26
(Continued)

Regulatory Schedule	Machine Types	1980	1981	1982	1983	1984	Average Price Increase (%)	Average O&M Increase (%)	Change In Sales (%)	Change In Profits (%)	Potential No. of Plant Closings
		Level/Effective Date									
13	CT_S					77	1.73	1.22	-2.35	-0.05	0
	CT_L			83	83	83	1.06	1.18	-1.28	-0.01	0
	WL_S					79	1.73	1.09	-2.31	-0.02	1.5
	WL_L			84	84	84	1.23	1.52	-1.48	-0.01	0
	WT					74	5.18	1.14	-7.29	-0.58	0
				Combined			1.98	1.20	-4.19	-0.10	1.5
14	CT_S					77	1.73	1.22	-2.35	-0.05	0
	CT_L					83	0.85	1.16	-1.14	0.00	0
	WL_S					79	1.73	1.09	-2.31	-0.02	1.5
	WL_L					84	0.98	1.19	-1.33	-0.02	0
	WT					74	5.18	1.14	-7.29	-0.58	0
				Combined			1.92	1.16	-4.18	-0.10	1.5
15	CT_S	80	80	80	80	80	1.77	1.16	-2.93	-0.96	0
	CT_L					80	2.09	2.85	-2.80	-0.03	0
	WL_S	82	82	82	82	82	1.81	1.17	-2.94	-0.93	0
	WL_L					80	2.39	2.90	-3.25	-0.09	0
	WT	77	77	77	77	77	5.37	1.25	-6.11	-0.43	0
				Combined			2.18	1.44	-4.18	-0.62	0
16	CT_S	80	80	80	80	80	1.77	1.16	-2.93	-0.96	0
	CT_L	86	86	86	86	86	0.64	0.90	-0.70	0.00	0
	WL_S	82	82	82	82	82	1.81	1.17	-2.94	-0.93	0
	WL_L	86	86	86	86	86	0.91	1.13	-0.96	0.02	0
	WT	77	77	77	77	77	5.37	1.25	-6.11	-0.43	0
				Combined			1.93	1.17	-3.99	-0.60	0

Table 7-26
(Continued)

Regulatory Schedule	Machine Types	Level/Effective Date 1980	1981	1982	1983	1984	Average Price Increase (%)	Average O&M Increase (%)	Change In Sales (%)	Change In Profits (%)	Potential No. of Plant Closings
17	CT_S		77	77	77	74	5.68	4.06	- 7.26	-0.44	0
	CT_L					80	2.09	2.85	- 2.80	-0.03	0
	WL_S		79	79	79	76	5.41	3.45	- 6.77	-0.30	3.5
	WL_L					80	2.39	2.90	- 3.25	-0.09	0
	WT		74	74	74	70	18.06	4.05	-23.89	-4.87	0
				Combined			6.15	3.77	-13.30	-0.85	3.5
18	CT_S		77	77	77	74	5.68	4.06	- 7.26	-0.44	0
	CT_L		83	83	83	80	2.28	3.13	- 2.80	-0.03	0
	WL_S					76	5.03	3.19	- 6.77	-0.31	3.0
	WL_L					80	2.39	2.90	- 3.25	-0.09	0
	WT					70	16.97	3.75	-23.89	-4.74	0
				Combined			5.96	3.63	-13.30	-0.84	3.0
19	CT_S		77	77	77	74	5.68	4.06	-7.26	-0.44	0
	CT_L	86	86	86	86	83	0.98	1.36	-1.14	0.00	0
	WL_S		79	79	79	76	5.41	3.45	-6.77	-0.31	3.5
	WL_L	86	86	86	86	84	1.16	1.44	-1.33	-0.01	0
	WT					74	5.18	1.14	-7.29	-0.58	0
				Combined			4.19	2.41	-6.65	-0.30	3.5
20	CT_S			77	77	77	2.17	1.55	-2.64	-0.07	0
	CT_L			83	83	83	1.06	1.48	-1.28	-0.01	0
	WL_S			79	79	79	2.18	1.39	-2.62	-0.04	2.5
	WL_L			84	84	84	1.23	1.52	-1.48	-0.01	0
	WT			74	74	74	6.48	1.47	-8.16	-0.78	0
				Combined			2.41	1.48	-4.68	-0.13	2.5

Table 7-26
(Continued)

Regulatory Schedule	Machine Types	Level/Effective Date 1980	1981	1982	1983	1984	Average Price Increase (%)	Average O&M Increase (%)	Change In Sales (%)	Change In Profits (%)	Potential No. of Plant Closings
21	CT_S					77	1.73	1.22	- 2.35	-0.05	0
	CT_L					83	0.85	1.16	- 1.14	0.00	0
	NL_S					79	1.73	1.09	- 2.31	-0.02	1.5
	WL_L					84	0.98	1.19	- 1.33	-0.02	0
	WT	77	77	77	77	74	6.20	1.43	- 7.29	-0.68	0
				Combined			2.05	1.29	- 4.18	-0.11	1.5
22	CT_S		77	77	77	74	5.68	4.06	- 7.26	-0.44	0
	CT_L					80	2.09	2.85	- 2.80	-0.03	0
	WL_S		79	79	79	76	5.41	3.45	- 6.77	-0.30	3.5
	WL_L					80	2.39	2.90	- 3.25	-0.09	0
	WT					70	16.97	3.75	-25.89	-4.74	0
				Combined			6.01	3.66	-15.30	-0.84	3.5
23	CT_S		77	77	77	74	5.68	4.06	- 7.26	-0.44	0
	CT_L		83	83	83	80	2.28	3.13	- 2.80	-0.03	0
	WL_S		79	79	79	76	5.41	3.45	- 6.77	-0.30	3.5
	WL_L		84	84	84	80	2.61	3.19	- 3.25	-0.08	0
	WT		74	74	74	74	7.19	1.65	- 8.59	-0.70	0
				Combined			4.84	2.86	- 7.31	-0.35	3.5
24	CT_S			77	77	74	5.55	3.95	- 7.2[illegible]	-0.43	0
	CT_L			83	83	80	2.21	3.03	- 2.8[illegible]	-0.03	0
	WL_S			79	79	76	5.28	3.35	- 6.77	-0.30	3.2
	WL_L			84	84	80	2.53	3.09	- 3.25	-0.08	0
	WT			74	74	74	6.48	1.47	- 8.16	-0.78	0
				Combined			4.66	2.73	- 7.14	-0.34	3.2

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 wheel and crawler tractors with the regulation 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 this regulation is advisable to ensure that the Administrator is provided with the accurate test data necessary to determine whether the machines distributed in commerce by manufacturers are in compliance with this regulations. Accordingly, the regulation provides that EPA Enforcement Officers may be present to observe any testing required by this regulations In addition, Enforcement Officers under previously promulgated regulations [40 CFR Part 204 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 this regulation 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 Acoustical Assurance Period (AAP) and is capable of applying the technology to the manufacturing process. The first 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 his equipment) or to require that a manufacutrer supply him with products for testing at EPA's Noise Enforcement Facility 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 204.105-3 of the regulation and any additional parameters tha a manufacturer or the Administrator may select. The basic parameters for configuration identification include the exhaust system, air induction system, cooling system, engine displacement, machine attachments, special application enclosures and power to ground transfer method (wheel or track type.)

A manufacturer shall verify production products prior to sale by one of two methods: The first method will involve testing any early production product (intended for sale) of each configuration. Production verification testing of all configurations produced by a manufacturer may not be required where a manfacturer can establish that the sound levels of some configurations at the end of their defined AAP (based on tests or on engineering judgement) are consistentlyhigher than that of other configurations. In such a case, that product which emits the highest noise level at the end of the defined AAP 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 engine and fuel type, engige manufacturer, engine horsepower, and engine configuration. Again, the manufacturer may designate additional categories based on additional parametesr 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 AAP 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 AAP 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 AAP must be clearly identified.

This proposed regulation also provides that the Administrator may test products at a manufacturer's facility using either his own 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 204.104 and discussed in Chapter 3, pages 26-28 of this document for conducting the tests required by this subpart. Procedures that are available to the manufacturer subsequent to disqualification are delineated in this 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 he tests on the first day that he is able. This procedure will minimize disruptions to manufacturing facilities. The manufacturer may request an additional 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 proposes to add a new configuration to his 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 regulation as being relevant to the Administrator's decision are illustrative and not exclusive. The manufacturer can submit all data and information that he believes will enable the Administrator to make a reasoned decision. It must be again emphasized that the manufacturer must request the use of previous data. If he fails to do so, then he must production verify all categories and configurations for each subsequent year.

The manufacturer need not verify configurations at any particular point in a year. The only requirement is that he verify a configuration prior to distribution in commerce. The inherent flexibility in the scheme of categorization will in many instances allow a manufacturer to either verify a configuration that he may not produce until late in a year based on representation or else wait until actual production of that configuration to verify it.

If a manufacturer fails to properly verify a configuration and that 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 with 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 AAP 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 wheel and crawler tractors and the inspection criteria are the noise emission standards.

Testing is initiated by a test request which will be issued to the manufacturer by the Assistant Aministrator 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 that 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 to a minimum and will 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 decision of the Administrator not to issue a test request to a manufacturer is the evidence that a manufacturer offers to demonstrate that his products comply with the applicable standards. If a manufacturer can provide evidence that his products are meeting the noise emission standards 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 wheel and crawler tractors 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 plan offers the advantage of keeping the number of products tested to a minimum when a 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 acceptance quality level (AQL). As applied to wheel and crawler tractor 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 percent 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 regulations establish 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 is tested and rejected, then the Administrator may require 100 percent testing of the wheel and crawler tractors 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 204.107-1(d) pertains to batches which consist of three or less machines. The subsection requires that each machine in that batch be tested and comply with the noise emission standard minus the 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 machines 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 two (2) products 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 wheel and crawler tractors which were not designed, built, and equipped so as to comply with the noise emission standard at the time of sale and during the AAP 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 Section 204.4(f) provides for cease to distribute orders for substantial infractions of regulations 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 wheel and crawler tractors subject to it shall be labeled to provide notice that the product complies to the noise emission standards. 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 an actual date of manufacture has been used so as to avoid disruption of marketing and distribution patterns.

APPLICABILITY OF PREVIOUSLY PROMULGATED REGULATIONS

Manufacturers who will be subject to this regulation must also comply with the general provisions of 40 CFR Part 204 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 wheel and crawler tractors subject to these regulations so that the products comply with the standard during the AAP 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 meet the Acoustial Assurance Period of these regulations. However, this regulation requires 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 AAP. The manufacturer must determine an SLDF for each of his product configurations.

To ensure that the products will meet the noise standards throughout the AAP, 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 wheel and crawler tractors 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 AAP must still meet the standard on the day of sale; so an SLDF of 0 must be used for than configuratrion.

As stated above, the Agency is not requiring durability testing as a matter of course, however, should it be necessary, section 13(a) of the Noise Control Act authorizes EPA to require the manufacturer to run such tests on selected wheel and crawler tractors.

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 a log book to record maintenance and repairs performed.

Sectiom 9

EXISTING LOCAL, STATE, AND FOREIGN REGULATIONS

According to Section 6 of the Noise Control Act of 1972, the proposed Federal regulation for wheel and crawler tractors will preempt new product standards for tractors at the local and state level unless those standards are indentical to the Federal standard. Local and state governments are not prohibited from "establishing or enforcing controls on environmental noise through licensing, regulations or restrictions of the use, operation or movement of any products" or from establishing or enforcing new product noise standards for types of construction equipment not regulated by the Federal Government.

EPA reviewed available literature and conducted a survey to determine the nmber of existing regulations that are applicable to construction equipment in general and wheel and crawler tractors in particular and that may be affected by federally imposed regulations.

Very few laws, regulations or ordinances were found that mention wheel and crawler tractors specifically [38]. Most of the legislation regulating this noise source does so by limiting emission levels allowed from "xonstruction equipment" or construction sites", rather than from each of the specific types of such equipment. Some of the legislation setting limits on "xonstuction equipment" includes wheel and crawler tractors as an example of such equipment, but most regulation of wheel and crawler tractor noise is presently accomplished indirectly by limiting construction site noise or construction equiepment noise.

LOCAL ORDINANCES REGULATING WHEEL AND CRAWLER TRACTOR NOISE LEVELS

Most of the regulatory activity governing construction equipment or site noise is occurring on the local level. This is true in foreign countries as well as in the United States.

Local governments controlled loader and dozer or construction noise in many different ways. Table 9-1 indicates the different types of standards used.

The most predominant method of construction noise control was through use of a "zone-type standard." This method generally involved allowing different maximum noise levels for different areas of the local community. Thirty-eight of the 50 ordinances studied had some type of zone standard that applied to construction noise.

Many different areas or land uses were mentioned in the ordinances, but the three most common were residential areas, commercial areas, and industrial areas. A wide variety of dBA allowable levels was also encountered, but the most common levels were 51-55 dBA in residential areas, 61-65 dBA for commercial areas, and 71-75 dBA for industrial areas. Measurement was typically to be at or on the land use receiving the sound; some ordinances required measurement at the site property boundary or a certain distance therefrom.

Table 9-1
Types of Performance Standards Found in Local Ordinances that Applied to Construction Noise or Construction Equipment

Ordinance Contains:	Population Groups						
	>500K	Counties & 200K-500K	100K-200K	50K-100K	25K-50K	To 25K	Total
Zone Type Standards Only	4	4	5	2	1	3	19
Zone & Use Standards					1	3	4
Zone & Sale Standards			1				1
Zone & Ambient Standards		1	2	1	2	1	7
Zone, Use & Ambient Standards	1	2	1				4
Sale Standard Only	1		1		2		4
Sale & Use Standard	1						1
Use Standard Only	3	1			2	1	7
Use & Ambient Standard			2				2
Ambient Standard Only					1		1

Six ordinances were studied which made it unlawful to sell, or offer for sale in the city, equipment which exceeded specified dBA levels. Table 9-2 shows the cities with sale - type standards and specified levels. All of these ordinances require construction equipment to meet a level of 80 dBA as measured a 50' from the equipment by 1980 (one of these would require 80 dBA by 1976).

Fifteen ordinances had some type of "use" standard in that use of construction equipment was prohibited where the equipment exceeded a specified level at a specified distance, or use was prohibited where total construction site noise exceeded a specified level. Nine of these fifteen ordinances set levels which applied to individual pieces of equipment. The levels allows ranged from a high of 91 dBA measured at 50' to 75 dBA measured at 50'. Table 9-3 presents the nine ordinances and the levels specified.

Six ordinances set levels that applied to total constuction site noise. The levels allowed ranged between 90 dBA at 50' from the site boundary to 75 dBA at the same distance. Table 9-4 presents the levels specified in each of these six ordinances.

Fifteen ordinances used an ambient-type standard, in that no construction noise was allowed that exceeded ambient levels by a specified amount. This type of ordinance generally specified that no more than 5 dBA over the ambient was permissible. Many of the ambient-type standards applied only to night construction work with a different level or no level applicable to day work.

Fourteen ordinances allowed duration adjustments to the specified sound levels which in effect increased allowable levels. The

Table 9-2
Table of Sale Standards Showing Maximum dBA Levels for New Construction Equipment*

Manufactured After	Chicago Illinois	Kansas City Missouri (Proposed)	Grand Rapids Michigan	Salt Lake City Utah	Prairie Village Kansas	Urbana Illinois
1972	94	94				
1973	88	88	88	94		
1974				88		
1975	86	86	86	86	86	86
1976						
1977						
1978						
1979						
1980	80		80	80	80	80

*Measured at 50 feet

Table 9-3
Table of Use Levels Per Piece of Equipment

	Farmington Conn	Chino** CA	Pasadena CA	Minneapolis Minn	San Jose CA	San Diego CA	San Francisco CA	Gladstone Mo	Los Angeles CA
Level	80 dBA	83 dBA or 85 dBA	85 dBA	80 dBA	81 dBA	75 dBA	80 dBA	90 dBA	75 dBA
Measurement	@ 50' from equipment or at receiving property line whichever is shorter	83 dBA @ 25' from equipment or 80 dBA outside site boundary line	@ 100' from equipment	@ property line? (Site property line or receiving property not specified)	@ 50' from equipment	? receiving property line (receiving residential property only)	@ 100' from equipment	@ 50' from equipment	@ 50' from equipment
Approximated Comparisons to 50' measurements	80 dBA @ 50'	77 dBA @ 50'	81 dBA @ 50'	?	81 dBA @ 50'	?	86 dBA @ 50'	90 dBA @ 50'	75 dBA @ 50'

*Proposed

**Chino and Palo Alto use a combined standard in that equipment can be used if it meets either the 83 dBA @25 ft for an individual piece of equipment or total site noise does not exceed 80 dBA outside the site boundary.

Table 9-4
Table of Use Standard Limiting Total Construction Site Noise

City	Toledo, Ohio	Anaheim, California	Anchorage, Alaska*	Park Ridge, Illinois	W. Palm Beach, Florida	Lake Park, Florida
Level	90 dBA	60 dBA (Night level only)	80 dBA	87 dBA "C" Scale	75 dBA	75 dBA
Measurement	At site boundary or 50' therefrom if operating at boundary	At any point on site property line	(Not specified)	at 75' from source	at 75' from site	at 75' from site

*Proposed

duration adjustments generally allowed an increase for noises occurring less than a certain portion of an hour or day. The amount of dBA increase allowed and the time durations specified varied widely.

Eight ordinances contained a minimum duration for measurement of the sound levels coming from a suspected source. The duration of measurement ranged from 12 hours to 5 minutes.

Ten ordinances provided for a -5 dBA adjustment to allowable levels for impulsive noises.

Thirty-five ordinances allowed an exemption from the performance standards for "emergency work." Emergency work was usually defined as work necessary after a public calamity or work necessary to protect against an imminent calamity. Thirty-one of the ordinances contained an emergency definition similar to the above. Fifteen of these 31 also exempted work necessary to restore utility service, and three also gave an exemption for roadway repair.

Thirty ordinances had specific provisions allowing variances from the performance standards. Very few of these gave specific information on what showing or procedure was required for a variance, but eight ordinances required a showing of "undue hardship", and four would allow a variance on a showing that it was "impracticable" to comply.

Twelve ordinances used octave band measurements, either in addition to or in lieu of "A" scale measurement. Thirty-eight relied exclusively on "A" weighted measurements.

Forty ordinances contained specific time limits on construction work. Generally, these ordinances prohibited use of construction equipment or construction work between a specified hour in the night and a specified hour the following morning. The times used varied a great deal, but the most often mentioned times were between 10:00 p.m. and 7:00 a.m.

Of the 40 ordinances containing time limits, 11 had more restrictive time limits for weekends, Sundays, or holidays, in that work during those days was prohibited or allowed for less hours. Three ordinances disallowed any use of "heavy equipment" (including pavement breakers) at any time without a permit.

Sixteen ordinances had a provision which allowed night work, regardless of time restriction, where the noise created did not cause a noise disturbance across residential boundaries. Thirty-seven ordinances specifically exempt emergency work from their time restrictions, and 25 specifically provide for variances to the time limits.

Most of the local ordinances did not provide specific authorities and duties for the agency enforcing or administering the ordinance. Information gathered from local ordinances was analyzed by population groups to determine if any significant differences could be detected that related to the size of the city. The only notable difference in the ordinances that appeared to be a function of size was that the larger cities (500,000 or over) gave more specific authorities and duties in their ordinances than did smaller cities.

Twenty-five ordinances studied include local government construction activity in construction noise subject to the ordinance. Five ordinances also require that any city contract contain a provision requiring contractor compliance with the ordinance.

Thirty-five ordinances contained some type of nuisance provision in addition to performance standards, which made it unlawful to create "unreasonable" noise levels.

Eight ordinances contained provisions that made it unlawful to use construction equipment that was not adequately muffled or without other noise reduction equipment or to tamper with equipment in a manner that caused increased noise levels.

Eleven ordinances contained definitions of construction equipment or work.

STATE LAWS AND REGULATIONS GOVERNING WHEEL AND CRAWLER TRACTOR NOISE LEVELS

Five states were found to have laws and regulations that set limits on construction noise.

Colorado sets the following levels for all construction activity:

80 dBA measured at 25' from the site 7 am- 7 pm

75 dBA measured at 25' from the site 7 pm - 7 am

Maryland sets the following levels for construction sites:

90 dBA measured at any receiving property	7 am - 10 pm
50 dBA measured at residential receiving property	10 pm - 7 am
62 dBA measured at commercial receiving property	10 pm - 7 am
75 dBA measured at industrial receiving property	10 pm - 7 am

New Jersey sets the following levels for commercial operations.

65 dBA measured at receiving residential property 7 am - 10 pm

50 dBA measured at receiving residential property 10 pm - 7 am

65 dBA measured at receiving commercial/industrial

property anytime

New York sets levels for construction site noise measured at 400'. These levels are shown in Table 9-5.

Table 9-5. New York State Construction Site Noise Emission Levels

For Construction Activity Occurring In	dBA (present levels	dBA (approx. levels after 1978)
Residential Districts		
day: 7am-7pm	70	64
night: 7pm-7am	55	49
Commercial Districts		
during normal business hours	75	69
during non-business hours	80	74
Industrial Districts any time	80	74

Washington sets the following levels for construction noise:

45 dBA for receiving residential property if the site is located in a residential district 10pm - 7am

47 dBA for receiving residential property if the site is located in a commercial district 10pm - 7am

50 dBA for receiving residential property if the site is located in an industrial district 10pm - 7am.

All states except New Jersey allow duration adjustment to the above levels that increase the allowable level for short durations.

Coloraddo and Maryland reduce allowable levels by 5 dBA for implusive noises. Nedw Jersey states that any impulsive noise is excessive if it exceeds 80 dBA (presumably at receiving land). New York allows no impulsive noise over 120 dBA (presumably measured at 400').

Washington is the only state that preempts local control of construction noise levels. Wasington mandates local ordinances that are consistent with state regulations, unless the local government can show special circumstances requiring different levels.

Maryland, New Jersey and Washington give a specific exemption for emergency work. Only Washington and Maryland specifically provide for variances to the standards. Washington, New Jersey and Maryland subject state construction activities to the state law.

FOREIGHN REGULATIONS

France, West Germany and Japan are the only foreign nations which have noise emission standards currently in force that affect new wheel and crawler tractors. France end Japan require only a stationary rated speed or high-idle test, while Germany requires stationary, drive-by and work cycle tests. France has a single regulation which covers all construction equipment powered by internal conbustion engines. It applies to all machines manufactured after May 1, 1973. The noise levels required by the French regulation are shown in Table 9-6,

Table 9-6

FRENCH CONSTRUCTION EQUIPMENT NOISE REGULATION

Sound Level @ 7 meters	Net Flywheel Horsepower Range	Effective Date
80 dBA	less than 200	January 1, 1977
83	200 - 300	January 1, 1977
87	300 - 500	January 1, 1977
90	greater than 500	January 1, 1977

In addition, to the standards listed in Table 5-1 for new machines, the use of older machines in France is restricted if their sound levels are greater than 83 dBA at 7 meters.

The German law requires 2 or 3 tests for each machine, depending on the machine type. Sound levels prescribed by the German law are shown in Table 9-7. In addition, total construction site noise is limited according to the type of surrounding property.

Japan has set a single standard of 75 dBA at 30 meters (approximately 81 dBA at 15 meters) for all construction equipment. However the various regions within Japan can implement use restrictions or other means to reduce construction noise.

Vienna, Austria has set a construction noise standard of 100 dBA at 1 meter (approximately 78 dBA at 14 meters) and Canton and Bern, Switzerland have set a standard of 85 dBA at 7 meters (approximately 78 dBA at 15 meters).

Other approaches to construction noise control used in foreign countries include (1) voluntary standards of recommended practice, (2) requirements set in construction contracts, (3) general nuisance laws and (4) zone type standards. The general nuisance and zone type standards are the most widely used methods for regulating construction site noise.

Table 9-7

GERMAN LOADER AND DOZER NOISE REGULATIONS

GERMANY: TRACKED LOADERS

Test Mode	Up to 110 KW (Up to 148 hp SAE)	111 KW up (149 hp SAE up)
Sound levels effective June 1, 1973		
Machine stationary @ 7 meters	86	89
Work cycle	87	90
Sound levels effective January 1, 1977		
Machine stationary	81	84
Work cycle	83	86

GERMANY: TRACKED DOZERS

Test Mode	Up to 110 KW (Up to 148 hp SAE)	111 KW up (149 hp SAE up)
Sound levels effective June 1, 1973		
Machine stationary @ 7 meters	87	90
Machine drive-by @ 10 meters from center	90	92
Work cycle @ 10 meters from center	87	90

Table 9-7

GERMAN LOADER AND DOZER NOISE REGULATIONS

GERMANY: TRACKED LOADERS

Test Mode	Up to 110 KW (Up to 148 hp SAE)	111 KW up (149 hp SAE up)
Sound levels effective January 1, 1977		
Machine stationary	82	85
Machine drive-by	87	89
Work cycle	82	85

GERMANY: WHEELED LOADERS

Sound levels effective September 1, 1972		
Machine stationary @ 7 meters	87	90
Machine drive-by @ 10 meters from center	90	93
Work cycle @ 10 meters from center	86	90
	(Up to 150 hp SAE)	(151 hp SAE up)
Sound levels effective January 1, 1976		
Machine stationary	82	85
Machine drive-by	85	88
Work cycle	81	85

Germany - for construction noise

60 dBA measured at receiving (primarily) residential property 6am-10pm

70 dBA measured at receiving commercial property 6am-10pm

MODEL ORDINANCE

The model ordinance presented herein incorporates alternative provisions and wording selections to facilitate choice among the aspects of any actual ordinance which will reflect the needs and desires of State and local governments. The model should also be considered as part of a total community noise control ordinance rather than as a separate and distinct piece of legislation. Therefore, the provisions given herein are only those most relevant to construction noise control.

The model is directed at either wheel and crawler tractors specifically, or wheel and crawler tractors as one type of construction equipment, or one source of construction noise.

A. Definitions

(1) Ambient sound level is defined as:

The sound pressure level of the all encompassing noise associated with a given environment, being usually a composite of sounds from many sources. For the purposes of this ordinance, ambient sound level is the level (obtained or obtained 90 percent of time) when the noise level is averaged over a (10-minute) (15-minute) (1-hour) period (without inclusion of isolated identifiable sources). Measurements of ambient levels shall be taken at the approximate time and place at which a comparison is to be made.

(2) Construction work is defined as:

The on site erection; fabrication; installation; alteration; demolition or removal of any structure, facility, highway, sewer, public utility; or all related activities including, but not restricted to clearing of land, earthmoving, blasting, landscaping and tree trimming.

(3) Construction equipment is defined as:

Any device designed and intended for use in construction work including, but not limited to, any air compressor, pile driver, manual tool, bulldozer, loader, pavement breaker, steam shovel, derrick, crane, steam or electric hoist.

(4) Emergency work is defined as:

Work made necessary to restore public property to a safe condition following a public calamity or work required to protect persons or property from imminent danger.

Work required by public or private utilities when restoring utility service.

Work required to restore safe conditions in public streets.

(5) Person is defined as:

Any individual, association, partnership or corporation and includes any officer, employee, department, agency, or instrumentally of the United States, a state or political subdivision of that state.

B. Authorities (and Duties) of Administrative Agency

For the purpose of enforcing this ordinance and to promote noise abatement from (construction equipment and construction work) wheel and crawler tractors, the Agency shall have the following authorities (and duties):

(1) The authority to coordinate the efforts of other local agencies including, but not limited to, (building permit department, planning department, zoning department, health department, purchasing department, utilities department) and combine functions where appropriate for the better enforcement of and to promote the policy of this ordinance.

(2) The authority to review all projects (subject to review by other local agencies) which may result in construction noise of any type prior to approval of such projects and to require from applicants noise impact statements including all data required by the administrative agency.

(3) The authority to deny approval of such projects reviewed in (2) where such projects present an imminent threat to health and welfare which cannot be reasonably abated, otherwise to condition approval of the projects on specified sound abatement measures to be taken by the applicant.

(4) The authority to make regulations dealing with the

a. Measurement of (construction equipment), (wheel and crawler tractors) noise levels or other noise level measurements.

b. Noise impact statement requirements.

(5) The authority to, upon presentation of proper credentials, enter and inspect any private property or place, and inspect any report or records at any reasonable time when granted permission by the owner. When permission is refused or cannot be obtained, a search warrant may be obtained from a court of competent jurisdiction upon showing of probable cause to believe that a violation of this ordinance may exist. Such inspection may include administration of any necessary tests.

(6) The authority to:

(a) If the administrative agency has reasonable cause to believe that any device is in violation of this code, the administrative agency may order the owner of the device to conduct such tests as are necessary, in the opinion of the administrative agency or, to determine whether the device or its operation is in violation of this code and to submit the test results to the administrative agency within ten (10) days after the tests are completed.

(b) Such tests shall be conducted in a manner approved by the administrative agency. If any part of the test is conducted at a place other than the site where the device is located, that part of the test shall be certified by a laboratory acceptable to the administrator agency. The administrative agency may require that the entire test results shall be reviewed and certified by a professional engineer.

(c) The owner shall notify the administrative agency of the time and place of a test at least seven (7) days before the commencement of such test. Reasonable facilities shall be made available for the administrative agency to witness the test.

(d) If in the opinion of the administrator, tests by the administration are necessary, the administrative agency may order the owner to provide such access to the device as the administrative agency may reasonably request, to provide a power source suitable to the points of testing, and to provide allied facilities, exclusive of sound level meter. These provisions shall be made at the expense of the owner of the device. The owner shall be furnished with copies of the analytical results of the data collected.

(7) The authority to:

(a) Require the written registration of (construction equipment) (wheel and crawler tractors). A period of 60 days shall be allowed for the filing of such registration. However, in cases of emergency, the administrative agency may designate a shorter period of time.

(b) Registration shall be made on forms furnished by the administrative agency. The forms may require information concerning the device covered by the registration, the sound level caused by the device or any additional information required by the administrative agency for the purpose of enforcing this code. The registrant shall maintain the registration in current status by notifying the administration of any change in any item of information furnished in compliance with this subsection within a reasonable time, not exceeding thirty days after the change is made.

(c) Registration shall be made by the owner of the device. If a registrant is a partnership or group other than a corporation, the registration shall be made by one individual who is a member of the group. If the registrant is a corporation, the registration shall be made by an officer of the corporation.

(8) The authority to:

(a) Develop and recommend for promulgation (to the appropriate authority) provisions regulating the use and operation of any product, including the specification of maximum allowable sound emission levels of such product.

(b) Develop and recommend for promulgation (to the appropriate authority) provisions prohibiting the sale of products which do not meet specified sound emisson levels, where the sound level of the product is not regulated by the United States Environmental Protection Agency under section 6 of the Noise Control Act of 1972.

(9) The authority to investigate complaints of violations of this chapter and to make inspections and observations of environmental conditions and to institute necessary pro-

ceedings to prosecute violations of this ordinance.

(10) The authority to delegate authorities and duties under this ordinance.

C. Local Contracts and Purchases

As used in this section, the term "contract" shall mean any written agreement or legal instrument whereby the local government is committed to expend, or does expend, public funds in consideration for work, labor, services, equipment or any combination of the foregoing, except that the term "contract" shall not include:

Contracts for financial or other assistance entered into by the local government with any Federal, State or other local governmental entity or agency.

Contracts, resolutions, indentures, declarations of trust, or other legal instruments for life authorizing or relating to (a) the purchase of insurance, (b) the authorization, issuance, award and sale of bonds, (c) certificates of indebtedness, notes or other fiscal obligations of the local government, or documents consisting thereof.

(1) No contract shall be awarded or entered into by the local government unless such contract contains provisions requiring that:

Devices and activities which will be operated, conducted, purchased or constructed pursuant to the contract and which are subject to the provisions of this Code will be operated, conducted, or constructed without causing a violation of this Article, and that should such a violation occur it shall constitute a breach of contract.

A further provision shall provide for liquidated damages for such breach with the amount of damages to be decided by the local contract officer and the other party to the contract. The administrative agency of this act, may, pursuant to local contracts, recommend to (require of) the local purchasing agent or other local departments, specifications to be followed in the operation of devices or in construction activities that will reduce noise levels produced by such devices or activities.

(2) The administrative agency [(may) (shall)] [(require) (recommend)] to local departments purchasing equipment for use by the local government, that any product which has been certified by the administrative agency of the United States Environmental Protection Agency pursuant to section 15 of the Noise Control Act as a low noise emission product, and which he determines is suitable for use as a substitute, shall be procured by the city/county and used in preference to any other product, provided that such certified product is reasonably available and has a procurement cost which is not more than (125) percentum of the least expensive type of product for which it is certified as a substitute.

D. Prohibited Acts

It is a violation of this ordinance for any person:

(1) To operate or allow operation of (construction equipment) (wheel and crawler tractors) without the exhaust muffling equipment or other sound attenuation devices, such as insulation or shrouds, which are part of the above equipment when sold as new equipment;

(2) To operate or allow operation of (construction equipment) (wheel and crawler tractors) without permits as required by this ordinance;

(3) To operate or allow operation of (construction equipment) (wheel and crawler tractors) without sound attenuation devices required by the (administrative agency) (enforcement officer) or to operate or allow operation in a manner not consistent with instructions given by the (administrative agency) (enforcement officer) after such devices or methods of operation have been required in lieu of a citation or as a condition of project approval;

(4) To tamper with or modify any (construction equipment) (wheel and crawler tractors) in a manner which causes increased sound levels from the above equipment.

E. Time Limitations on (Construction Work) (Operation of Wheel and Crawler Tractors)

It is a violation of this ordinance for any person:

(1) To operate or allow the operation of any (construction equipment) (wheel and crawler tractors) between the hours of xPM and xAM on weekdays (including Saturday and Sunday).

NOTE: The night hours specified by local ordinances are 14 as a maximum number of hours and 7 as a minimum. The times ranged from 6PM to 8AM with the times of 10PM to 7AM most often mentioned.

(2) To operate or allow the operation of any (construction equipment) (wheel and crawler tractors) at (any time) (between the hours of xPM and xAM) (on Federal holidays).

(3) The time restrictions in (1) and (2) above apply only where the noise levels created by such equipment will cause a noise disturbance as measured at or across the property line of (any) (residential) (residential or commercial) property. For the purposes of this subsection a noise disturbance shall mean any noise which causes an increase of "N" dBA over ambient levels.

NOTE: This is typically stated in local ordinances as 5 dBA over ambient.

(4) Emergency work shall be exempt from the time limitations stated in (1) and (2) above (for a period of "N" hours and after "N" hours, emergency work may only be continued with the (written) authorization of the (administrative agency) (enforcement officer).

(5) Variances (permits) allowing operation during the times specified in (1) and (2) above may be obtained upon a proper showing, as specified in section G of this ordinance.

F. Performance Standards

Discussion

Zone-type standards regulating noise from construction equipment as found in the ordinances are often too prohibitive. Zone standards reflect desires for the most quiet where people live, less quiet where they shop and the least amount of quiet in industrial areas. Construction equipment is a movable noise source and will locate temporarily in any zone of a local area. It is not the typical stationary industrial plant (or other stationary source) which zone standards are primarily designed to control. It is unrealistic to expect a contractor to have the equipment for the silent operations that are often required for residential areas. In short, because of the mobility of construction equipment and the fact that it cannot generally meet many of the levels specified for many zones, it should be exempted from zone-type standards, and this is what many local ordinances have done.

One standard should be applied to construction equipment use. This standard should be allowed to vary or be flexible where a situation might indicate allowance of more or less noise, but one standard should be basic to local ordinances no matter what zone the equipment use is in.

The same arguments preclude ambient-based standards in that ambient levels also vary according to location.

A more realistic standard for construction equipment could either be one that prohibits sale of equipment not meeting specified levels, one that prohibits use of a particular type of equipment that does not meet specified standards or one that prohibits use of equipment indirectly, through prohibition of total construction-site levels in excess of an acoustical standard.

Sale standards do not by themselves prevent excess noise; they do not control noise caused by degradation of equipment, and they are subject to preemption by federal laws. For these reasons they should not be the sole basis of a performance standard.

The remaining two types of standards are presented as (1) and (2) below, as alternate provisions with arguments for each stated below the sections. Another alternate provision (3) combines elements of (1) and (2).

(1) It is a violation of this ordinance for any persons to use, operate, or allow use or operation of any (construction equipment) (wheel and crawler tractors) that exceeds (x dBA) when measured at 7 meters from such equipment. Measurement procedures shall (be in accordance with) (take into consideration) relevant SAE measurement procedures.

NOTE: Construction industry representatives have spoken against this standard because it often does not reflect the primary health and welfare considerations in that 7 meters (approximately 25'), or any such standard distance from the equipment, may be far removed from persons not engaged in the construction work.

On the other hand, this does promote lower levels where equipment is used in public places, such as downtown areas or roadways.

(2) It is a violation of this ordinance for any person to use or operate or allow the use or operation of construction equipment so that the noise level (at the construction site boundary) (at 7 meters from the consruction site boundary) exceeds (x dBA) (x Leq).

NOTE: This type of standard considers the impacted area, but leaves ambiguity where the equipment is not in use at a defined site with known boundaries (such as a public roadway).

(a) Leq (Equivalent A-Weighted Sound Level) is defined to to mean the constant sound level that in a given situation and time period, conveys the same sound energy as the actual time varying A-weighted sound. For the purpose of the above provision, a time period (equivalent to the allowed period for daily operation) (of 1 hour) (etc.) shall be used.

(3) Combines (1) and (2) above.

It is a violation of this ordinance for any person to use or operate, or allow the use or operation of any (construction equipment) (wheel and crawler tractors) that does not meet at least one of the following standards.

(a) No (construction equipment) (wheel and crawler tractors) shall exceed (N dBA) when measured at 7 meters from such equipment, or

(b) No (construction equipment) (wheel and crawler tractors) shall exceed (x dBA) when measured at the construction site boundary.

Paragraphs (4), (5) and (6) would be included as paragraphs (2), (3) and (4) with either (1), (2), or (3) above.

(4) On (weekends (Sundays) (and Federal holidays) the above allowed levels shall be reduced by x dBA.

(5) Emergency work or equipment used in emergency work is exempt from compliance with the levels stated above, for a period of x hours, after which time (written) approval of continued work must be obtained from the administrator.

(6) Permits (variances) from the above sound levels shall be allowed in accordance with section G of this ordinance.

G. <u>Variances (Permits)</u>

(1) Any person may apply for a permit for relief from any noise restrictions designated in this ordinance. Applications for a permit for relief from the noise restrictions designated in this ordinance on the basis of undue hardship may be made to the administrative agency or his authorized representative. Any permit granted by the administrative agency or his authorized representative shall contain all conditions upon which said permit has been granted and shall specify a reasonable time for which the permit shall be effective. The relief requested may be granted upon good and sufficient showing:

(a) That additional time is necessary for the applicant to alter or modify his activity or operation to comply with this ordinance, or

(b) The activity, operation or noise source will be of temporary duration, and cannot be done in a manner that would comply with sections of this chapter, or

(c) That no other reasonable alternative is available to the applicant, and

(d) Reasonable conditions or requirements may be prescribed when deemed necessary to minimize adverse effects upon the community, the surrounding neighborhood, or the public.

(Alternate Variance Provision 1)

(1) Any person may apply for a permit for relief from any noise restriction in this ordinance. If the applicant can show to the administrative agency or his designee that a diligent investigation of available noise abatement techniques indicates that immediate compliance with the requirements of this chapter would be impractical or unreasonable, a permit to allow exception from the provisions contained in all or a portion of this chapter may be issued, with appropriate conditions to minimize the public detriment caused by such exceptions. Any such permit shall be of as short duration as possible, up to six months, but renewable upon a showing of good cause, and shall be conditioned by a schedule for compliance and details of methods therefor, in appropriate cases. Any persons aggrieved with the decision of the administrative agency or his designee may appeal to the city council.

(Alternate Variance Provision 2)

(1) Any person may apply for a permit for relief from any noise restriction in this ordinance. The administrative agency is authorized to grant permits for relief from any provision of this Ordinance, upon a showing of good cause, subject to such limitations as to area, noise levels, time limits, and other terms and conditions as it determines are appropriate to protect the public health, safety and welfare from the noise

emanating therefrom.

(2) A permit may be issued authorizing noises prohibited by this ordinance as follows:

(a) Application for permit. Applications for permits shall be in writing and shall contain the following information:

1. The name, address and telephone number of the applicant.

2. A general description of the equipment, apparatus, or other sound source to be utilized, and the area in which it will be utilized.

3. An estimate of the maximum sound level which will be generated by the equipment, apparatus, or sound source to be utilized and the basis for such estimate.

4. The inclusive dates between which the sound will be generated.

5. Facts showing that the public interest will be served by the issuance of such permit or that extreme hardship will accrue to the applicant if such permit does not issue.

(b) Criteria. Applications shall be filed with the administrative agency who shall approve or disapprove same within five working days. The criteria which shall be considered by the administrative agency in determining whether the requested permit shall issue will include, but not be limited to, the following:

1. The level of the noise for which a permit is sought.

2. The ambient noise level in the vicinity where the sound source will be utilized.

3. The proximity of the noise to residential sleeping facilities.

4. The nature and zoning of the area within which the noise will emanate.

5. The density of the inhabitation of the area within which the noise will emanate.

6. The time of the day or night the noise will occur.

7. The duration of the noise.

8. Whether the noise will be recurrent, intermittent or constant.

(c) Issuance of Permit. The Administrative Officer shall issue the requested permit unless he finds, considering the aforementioned criteria, that the public interest will suffer thereby and that such public detriment exceeds the hardship to be suffered by the applicant if the permit is not issued. In the event the Administrative Officer disapproves the application, he shall return same to the applicant with a statement of the reasons for such action. In approving a permit hereunder, the Administrative Officer may impose such conditions as he deems necessary to protect the public interest.

(d) Revocation or Suspension. Any permit issued hereunder shall be revocable and may be revoked by the Administrative Officer when a fact is found to exist which would have been a ground for refusal to approve same or when there has been a violation of any of the terms or conditions thereof.

(e) Appeal. Any person aggrieved by any action of the Administrative Officer denying, revoking, or imposing any condition on a permit may appeal such decision to the commission by filing a written appeal within ten days of such action with the secretary thereof. When a proper appeal has been filed, the decision of the Administrative Officer shall be set aside and a hearing shall be set before the commission, noticed and held, all in accordance with the rules of said commission. The commission may continue the hearing from time to time and shall render its decision within three days after the close thereof. The commission may:

1. Direct the issuance of the permit;
2. Delete, alter, or impose any term or condition on the permit reasonably calculated to alleviate any dereliction or protect the public interest; or
3. Uphond the denial of the permit.

(f) Appeal to Council. Any person aggrieved by any action of the commission upholding the denial, revocation, or imposition of conditions on a permit may appeal such decision to the Council by filing a written appeal within ten days of such action with the Clerk. When a proper appeal has been filed, the decision of the commission shall be set aside and a public hearing shall be set before the Council. The hearing shall be formal, except that the formal rules of evidence shall not apply. The Council may continue the hearing from time to time and shall render its decision within three days after the close thereof.

H. Enforcement Provisions

(1) Any person who violates any provision of this ordinance shall be subject to a civil penalty of not less than (x$) nor more than (y$) for each offense, or injunctive relief to restrain from continuing the violation or threat of violation, or both injunctive relief and civil penalty. Upon application for injunctive relief and a finding that a person is violating or threatening to violate any provision of this ordinance, the appropriate court shall grant injunctive relief to restrain the violation.

(2) Any person who willfully or knowingly violates any provision of this ordinance shall be fined for each offense a sum of not less than (x$) nor more than (y$), imprisoned for a period not to exceed 'N' days, or both.

(3) Each day of violation of any provision of this ordinance shall constitute a separate offense.

(4) In lieu of issuing a notice of violation, the administrative agency may issue an order requiring abatement of a sound source alleged to be in violation, within a reasonable time period, and according to guidelines the administrative agency may prescribe.

(5) An abatement order shall not be issued for any violation, when the administrative agency has reason to believe that it will not be feasible to comply with an abatement order.

(6) The administrative agency may order an immediate halt to any sound that exposes any person to continuous sound or to impulsive sound levels in excess of those levels recognized as hazardous to health or welfare.

Within three days following issuance of such an order, the administrative agency shall apply to the local court for an injunction to replace the order.

(7) No order pursuant to subsection (6) shall be issued if the only persons exposed to sound levels in excess of those listed in the ordinance are exposed as a result of trespass, invitation upon private property by the person causing or permitting the sound, or employment by a contractor of the person causing or permitting the sound.

(8) Any person subject to an order issued pursuant to subsection (6) shall comply with such order until the sound is brought into compliance with the order as determined by the administrative agency or a judicial order has superceded the administrative agency's order.

(9) Any person other than persons responsible for enforcement of this ordinance may commence a civil action on his own behalf (a) against any person who is alleged to be in violation of any provision of this ordinance, or (b) against the administrative agency where there is alleged a failure of the administrative agency to perform any act under this ordinance that is not discretionary. The local court shall have jurisdiction without regard to the amount in controversy to grant such relief as it deems necessary.

(10) No action may be commenced:

(a) under subsection (9)(a)

(i) prior to thirty days after the plaintiff has given notice of the alleged violation to the department of such violation, or

(ii) if the administrative agency has commenced and is diligently prosecuting an action against the alleged violator with respect to such violation, but in such action any affected person may intervene as a matter of right, or

(b) under subsection (9)(b), prior to thirty days after the plaintiff has given notice to the administrative agency that he will commence such action. Notice under this subsection shall be given in a manner prescribed by the administrative agency.

(11) In any action under this section the administrative agency, if not a party, may intervene as a matter of right.

(12) The court in issuing any final order in any action brought pursuant to subsection (9) may at its discretion award cost of litigation to any party.

(13) No provision of this ordinance shall be construed to impair any common law or statutory cause of action or legal remedy therefrom of any person for injury or damage rising from any violation of this ordinance or from other law.

(14) Severability. If any provision of this ordinance is held to be unconstitutional or otherwise invalid by any court of competent jurisdiction, the remaining provisions of the ordinance shall not be invalidated.

(15) Effective Date. This law shall take effect immediately.

Appendix A

DOCKET ANALYSIS

(Reserved)

Appendix B

DEVELOPMENT OF REGULATORY STUDY LEVELS

Appendix B

DEVELOPMENT OF REGULATORY STUDY LEVELS

As discussed in Section 6 - Noise Control Technology, two candidate study levels for each machine type/classification were considered. Level II corresponds to commonly used (retrofit) technology levels achievable without major redesign of the machines and consistent with lower levels currently in production, as determined in Section 3 - Baseline Noise Emission Levels. Level II should be feasible for manufacturers of wheel and crawler tractors to implement within a 3 to 6 year time frame across an assemblage of models. Level III corresponds to levels believed to be readily achievable in production in 6 to 8 years based upon the use of existing techniques for quieting individual noise sources and the synthesis of engineering and empirical evidence. Achievement of these levels in a cost-efficient manner without degrading performance and maintenance factors requires redesign of the machine. These two boundary levels (Level II and Level III), as shown in Table B-1, have been plotted on each of the parametric curves illustrated in Figures B-1 through B-4.

In addition, depending upon the shape of the respective curve, another point (Level I) was selected typically corresponding to a noise emission level midway between current average levels and the Level II. These three levels generally bound the range of potential benefits achievable from imposition of a noise emission standard and therefore have been assessed for cost and economic impacts. In developing "not to exceed"

TABLE B-1

DESIGN LEVELS FOR HEALTH/WELFARE, COST AND ECONOMIC IMPACT ANALYSIS
(LEVELS II AND III)

MACHINE TYPE/ HORSEPOWER	CURRENT LEVEL	LEVEL II REDUCTION FROM CURRENT LEVEL	LEVEL II	LEVEL III REDUCTION FROM CURRENT LEVEL	LEVEL III
Crawler Dozer					
20-89	79.5	5.5	74	8.5	71
90-199	80.0	5.0	75	8.0	72
200-259	84.0	4.0	80	7.0	77
260-450	84.0	3.0	81	6.0	78
Crawler Loader					
20-89	79.5	5.5	74	8.5	71
90-275+	80.0	5.0	75	8.0	72
Wheel Loader					
20-134	81.5	5.5	76	8.5	73
135-241	81.5	4.5	77	7.5	74
242-348	84.0	3.0	81	7.0	77
349-500	84.0	2.0	82	6.0	78
Utility Tractor					
20-90+	77.0	5.0	72	9.0	68

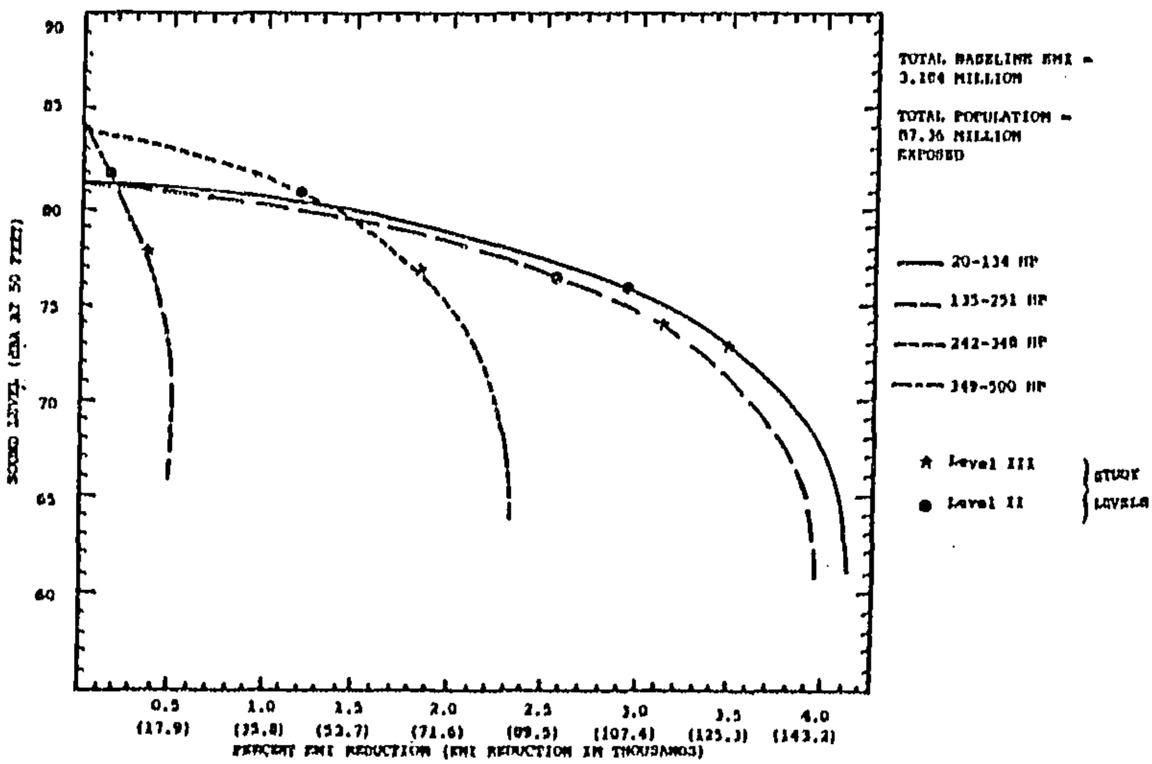


Figure B-1 Population Impact Reduction vs. Noise Emission Level for Wheeled Loaders by Horsepower Class (with Ambient)

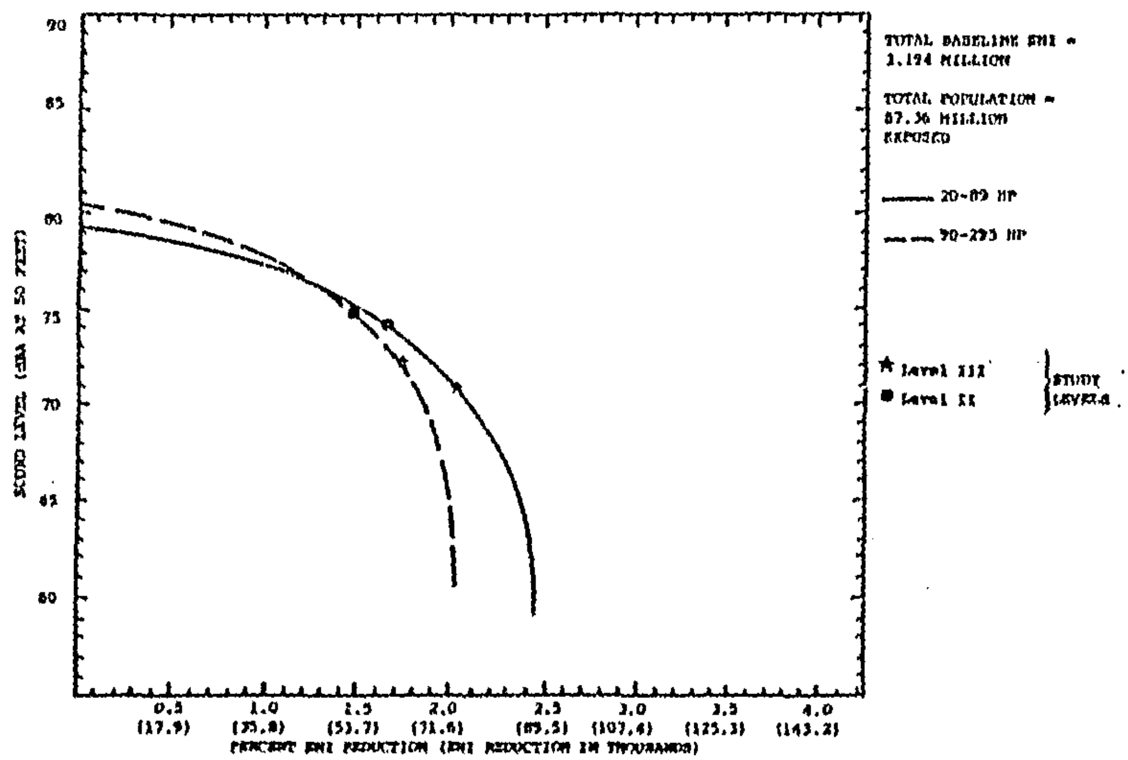


Figure B-2 Population Impact Reduction vs. Noise Emission Level for Crawler Loaders by Horsepower Class (With Ambient)

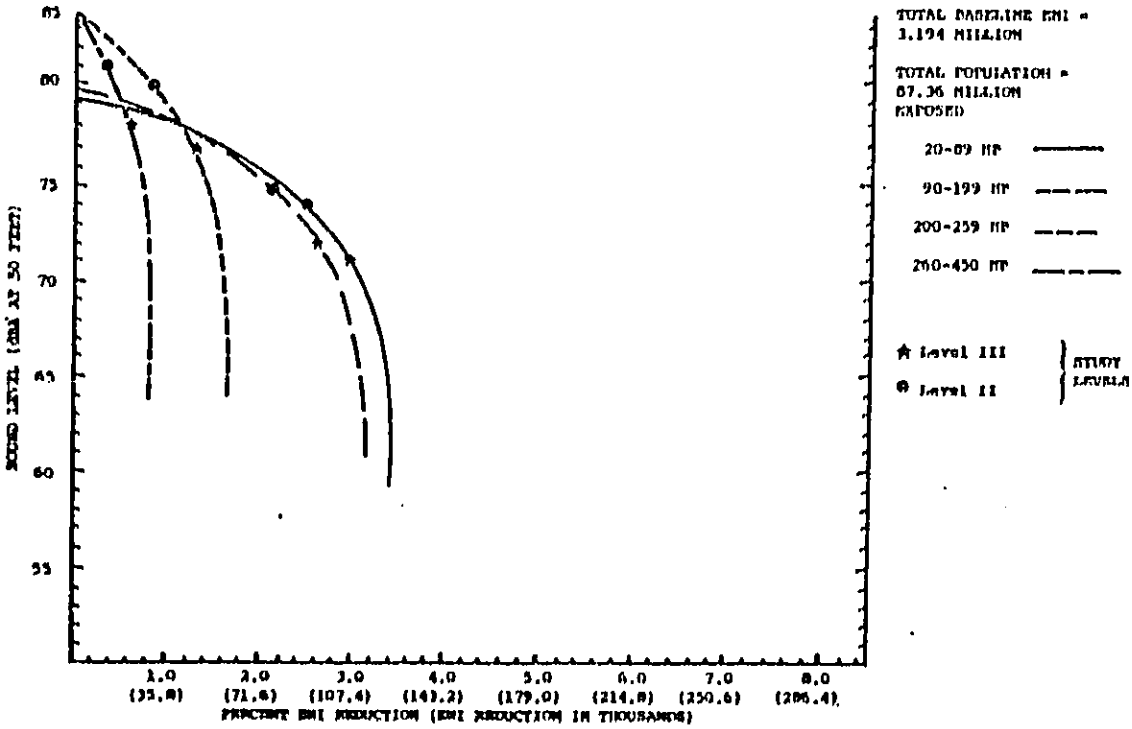


Figure B-3 Population Impact Reduction vs. Noise Emission Level for Crawler Dozers by Horsepower Class (With Ambient)

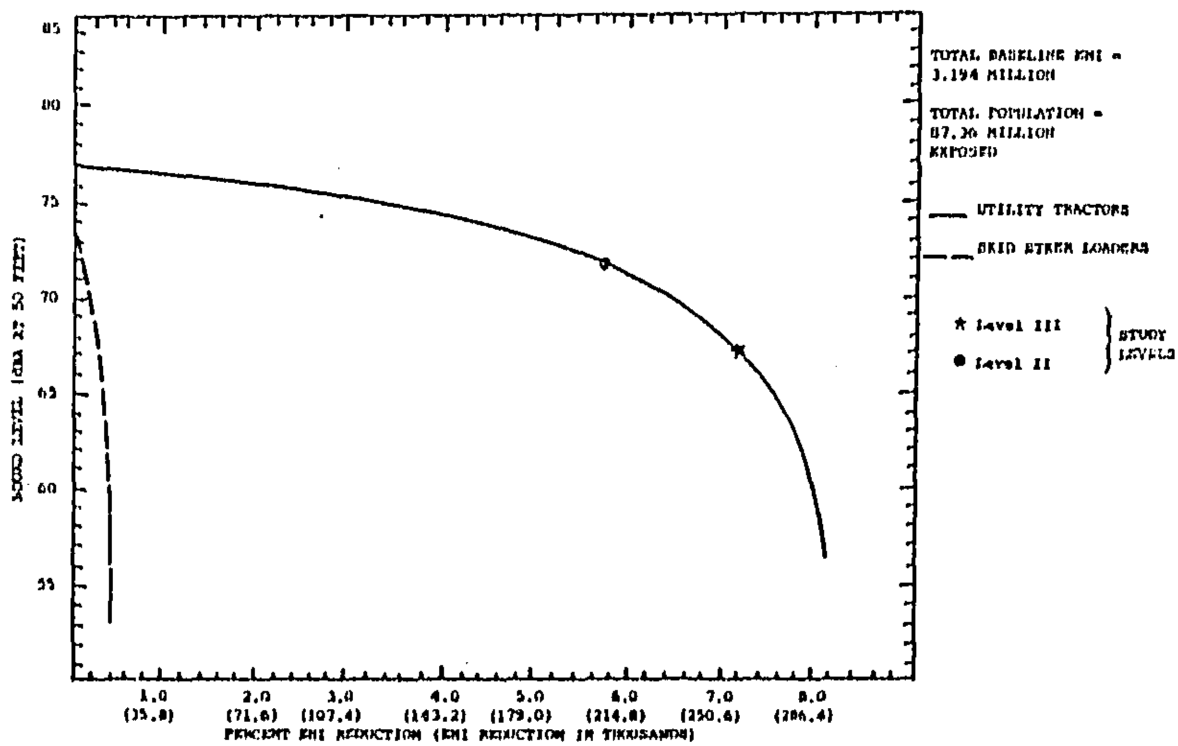


Figure B-4 Population Impact Reduction vs. Noise Emission Level for Utility tractors and Skid Steer Loaders (With Ambient) regulatory study levels, these design levels were adjusted upward by 2 dBA to account for production and test variability. The 2 dBA was selected based upon an analysis of the variability of machine noise emission data. A summary of "not to exceed" regulatory study levels for each machine type and initial classification category is provided in Table B-2.

TABLE B-2

STUDY LEVELS (dBA) AND LEAD TIMES FOR EACH

MACHINE TYPE AND INITIAL CLASSIFICATION CATEGORY

Machine Type	Classification (HP)	Study Level* Level I	Level II	Level III
Crawler Dozer	20- 89	79	76	73
	90-199	80	77	74
	200-259	84	82	79
	260-450 Limit	86	83	80
Crawler Loader	20- 89	79	76	73
	90-2[illegible]+	80	77	74
Wheel Loader	20-134	81	78	75
	135-241	82	79	76
	242-348	85	83	79
	349-500 Limit	86	84	80
Utility Tractor	20- 90+	77	74	70

*"Not to exceed" levels determined by a High-Idle Stationary test at 15 meters utilizing a four-side arithmetic average of measurements.

Appendic C

Individual Options

Appendix C

INDIVIDUAL OPTIONS

Before arriving at a regulatory schedule, 18 possible regulatory options were first developed for each machine type and horsepower classification (Table C-1). These 18 individual options could be combined to create nearly two million (18^5) combined options. Of these combined options, 24 were studied in detail before selecting the final regulatory schedule.

Table C-1
Regulatory Options for Each Equipment Classification

Options for Crawler Tractors < 200 HP

	1980	1981	1982	1983	1984
1	No Reg	77	77	77	77
2	No Reg	77	77	77	74
3	No Reg	No Reg	77	77	77
4	No Reg	No Reg	77	77	74
5	No Reg	No Reg	No Reg	77	77
6	No Reg	No Reg	No Reg	77	74
7	No Reg	No Reg	No Reg	No Reg	77
8	No Reg	No Reg	No Reg	No Reg	74
9	No Reg	No Reg	No Reg	No Reg	No Reg
10	80	77	77	77	77
11	80	77	77	77	74
12	80	80	77	77	77
13	80	80	77	77	74
14	80	80	80	77	77
15	80	80	80	77	74
16	80	80	80	80	77
17	80	80	80	80	74
18	80	80	80	80	80

Options for Crawler Tractors 200 HP - 450 HP

	1980	1981	1982	1983	1984
1	No Reg	83	83	83	83
2	No Reg	83	83	83	80
3	No Reg	No Reg	83	83	83
4	No Reg	No Reg	83	83	80
5	No Reg	No Reg	No Reg	83	83
6	No Reg	No Reg	No Reg	83	80
7	No Reg	No Reg	No Reg	No Reg	83
8	No Reg	No Reg	No Reg	No Reg	80
9	No Reg	No Reg	No Reg	No Reg	No Reg
10	86	83	83	83	83
11	86	83	83	83	80
12	86	86	83	83	83
13	86	86	83	83	80
14	86	86	86	83	83
15	86	86	86	83	80
16	86	86	86	86	83
17	86	86	86	86	80
18	86	86	86	86	86

Table C-1
Continued

Options for Wheel Loaders < 250 HP

	1980	1981	1982	1983	1984
1	No Reg	79	79	79	79
2	No Reg	79	79	79	76
3	No Reg	No Reg	79	79	79
4	No Reg	No Reg	79	79	76
5	No Reg	No Reg	No Reg	79	79
6	No Reg	No Reg	No Reg	79	76
7	No Reg	No Reg	No Reg	No Reg	79
8	No Reg	No Reg	No Reg	No Reg	76
9	No Reg	No Reg	No Reg	No Reg	No Reg
10	82	79	79	79	79
11	82	79	79	79	76
12	82	82	79	79	79
13	82	82	79	79	76
14	82	82	82	79	79
15	82	82	82	79	76
16	82	82	82	82	79
17	82	82	82	82	76
18	82	82	82	82	82

Options for Wheel Loaders 250 HP - 500 HP

	1980	1981	1982	1983	1984
1	No Reg	84	84	84	84
2	No Reg	84	84	84	80
3	No Reg	No Reg	84	84	84
4	No Reg	No Reg	84	84	80
5	No Reg	No Reg	No Reg	84	84
6	No Reg	No Reg	No Reg	84	80
7	No Reg	No Reg	No Reg	No Reg	84
8	No Reg	No Reg	No Reg	No Reg	80
9	No Reg	No Reg	No Reg	No Reg	No Reg
10	86	84	84	84	84
11	86	84	84	84	80
12	86	86	84	84	84
13	86	86	84	84	80
14	86	86	86	84	84
15	86	86	86	84	80
16	86	86	86	86	84
17	86	86	86	86	80
18	86	86	86	86	86

Table C-1
Continued

Options for Wheel Tractors

	1980	1981	1982	1983	1984
1	No Reg	74	74	74	74
2	No Reg	74	74	74	70
3	No Reg	No Reg	74	74	74
4	No Reg	No Reg	74	74	70
5	No Reg	No Reg	No Reg	74	74
6	No Reg	No Reg	No Reg	74	70
7	No Reg	No Reg	No Reg	No Reg	74
8	No Reg	No Reg	No Reg	No Reg	70
9	No Reg	No Reg	No Reg	No Reg	No Reg
10	77	74	74	74	74
11	77	74	74	74	70
12	77	77	74	74	74
13	77	77	74	74	70
14	77	77	77	74	74
15	77	77	77	74	70
16	77	77	77	74	74
17	77	77	77	77	70
18	77	77	77	77	77

Appendix D

BACKGROUND INFORMATION

Appendix D

BACKGROUND INFORMATION

In order to obtain the most accurate data available for use in the development of the proposed regulation, EPA's Office of Noise Abatement and Control has gathered information from many sources. EPA has contracted with three consulting firms to provide support in developing the necessary data for setting the proposed noise emission levels for wheel and crawler tractors. Science Applications Inc., noise control consultants, provided support for the technology analysis and development of a test methodology. Support for the economic analysis was provided by Energy Resources Company, Inc., of Cambridge, Massachusetts. Dames and Moore, consultants in the environment and applied earth sciences, provided support for the preparation of the Environmental Impact Statement. EPA also utilized the information gathering services of Informatics, Inc. Additionally, in conjunction with EPA, the Army Mobility Equipment Research and Development Command (MERDCOM) has conducted an independent field test program to measure the sound levels of wheel and crawler tractors.

EPA personnel and contractor personnel have contacted manufacturers, distributors and users of impacted equipment in an effort to construct a complete picture of the industry. In addition to correspondence and telephone contact, many visits were made to manufacturers to collect, discuss, and exchange information. Information was also sought from trade associations, industry, and state and local officials concerned with noise control. A list of contacts is presented in Tables D-1 through D-7.

Table D-1

Manufacturers of Construction Wheel and Crawler Tractors and Contacts

Allis - Chalmers, P.O.Box 521, Topeka, KS 66601

Alvin Acker
John Logan
Gene Nicely
Gerald Nixon

ATP

Loyd Molby

J.I. Case, 700 State Street, Racine, WI 53404

Carl Batton
John Crowley

Caterpillar Tractor Co., Peoria, IL 61629

Lester Bergsten
Lester Byrd
John McNally
G.H. Ritterbusch

Clark Equipment Co., 324 E. Dewey Street, Buchanan, MI 49107

Edward Donahue
Robert Hand
Daniel Kello

Deere & Co., John Deere Rd., Moline, IL 61265

James F. Arndt

Digmor Equipment & Engineering Co., Inc.
1435 West Park Avenue, Redlands, CA 92373

Lawrence Miller

Dynamic Industries Inc.

Oliver Gordy

Table D-1 (cont'd)

Eaton Coporation, 1 Trojan Circle, Batavia, NY 14020

J. C. Sprague
George Corby
Michael J. McCormick

Fiat-Allis, 300 S. 6th Street, Springfield, IL 62705

J.B. Codlin

Ford Motor Co., The Ameri n Road, Dearborn, MI 48121

John U. Damian
George Randall

General Motors Corp., Terex Division, Hudson, Ohio 44236

Keith Cherne
E. Ratering

International - Harvester, 10400 W. North Avenue
Melrose Park, IL 60160

J. R. Prosek
J. C. Laegeler
J. W. Zurek

Hy-Matic Corp., 1635 Pittman Ave., Sparks, Nevada 89431

John Stone
Edward Wakeman

Massey Ferguson Limited, 12601 Southfield Rd., P. O. Box 322, Detroit, MI 48232

Robert Bushong

Owatonna Mfg. Co., Inc. P.O. Box 547, Owatonna, MN 55060

David Blinne

Table D-1 (cont'd)

Taylor Machine Works Inc., P.O.Box 150, Louisville, MS 39339

J.I. Monk

TCI Power Products Inc., Benson, MN 56215

William Lugum
Calvin Schwalbe

Waldon Inc.

Willard Bartell
Melvin Carnelson
Vernon Schmidt

Table D-2

Other Equipment Manufacturers and Contacts

Athey Products Corp., P.O. Box 669, Raleigh, N.C. 37602
Larry Lloyd

AVCO Corp., 1275 King Street, Greenwich, Conn. 06831
William D. Sheeley

Beacon Machinery, Inc.
Marrietta Griskell

Bucyrus-Erie Co., 1100 Milwaukee Ave., Milwaukee, WI 531172

Burrows Equipment Co.
James Tratta

Charles Machine Works, Inc., 1959 W. Ditch Witch Rd.
Perry, OK 73077
G. Stangl
Gene Goley
J.D. Grim

Dart Truck Company, Box 321, Kansas City, MO 64141
Larry James

EIMCO Mining Machinery, P.O.BOX 1211, Salt Lake City, Utah
Rolf Knopp

Erickson Corp., Clear Run Rd., P. O. Box 527, Dubois, Pa. 15801
Mr. Spickett

Gehle Co., 143 Water Street, West Bend, WI 53095
John Leverenz

Gladden- Hass
Mr. Gladden

Hydra Mac, Inc., Box N, Thief River Falls, MN 56701
Bruce W. Steiger

Hyster Co., Lloyd Bldg., Portland, OR 97232

J.C.B. Excavators, Inc., P.O. Box 207, White March, MD. 21162
Jeffery Boswell
D. McKeever

Table D-2 (cont'd)

Koehring Co., Lorain Division, P.O. Box 4294, 409 Signal Mountain Rd., Chattanooga, TN 37405
William Heysen

Koehring Co., Parsons Division, 200 N. 8th Ave, E. Newton, Iowa 50208
Florence Rorbaugh

Komatsu American Corp., 555 California St., San Francisco, CA 94104
Y. Miyajiri

Koyker Mfg. Co., Hull; Iowa 51239
Cliff Gort

Lodal Inc., East Blvd, Kingford, MI 49801

Loed Corp., 738 S. 10th Ave, Warsaw, WI 54401
Gerry Peterson

Long Mfg. N.C. Inc., 1907 N. Main St., Tarboro, NC 27886
Max Saunders

Lull Engineering Co., 3045 Hwy 13, St. Paul, MN 55111

Marathon Le Torneau Mfg., 600 Jefferson, Longview, TX 75657
Bart McCoy

Marion Power Shovel Co., Inc., 7336 Airfrieght Lane, Dallas TX 75235
B. Trenary

Midmart
Richard Kayler

MRS Mfg. Co., P.O. Box 199, Flora, MS 39071
W.O. Ray

Oaks Mfg. Co., Oaks, ND 58474
John Tuoma

Pettibone Corp., 4710 W. Division St., Chicago, IL 60651
Robert Blomquist

Table D-2 (cont'd)

Raygo-Wagner Inc., 9401 85th N., Minneapolis, MN 55440
William Bushlem

Rexnord, Inc., 777 E. Wisconsin Ave., Milwaukee, WI 53202
Glen Johnson

Sanford Day Co., Inc.
Jean Hancock

Sian Equipment Co.
John Swart

Sperry-New Holland, Franklin & Robers St., New Holland, PA 17557
R.E.Wallin

Steigler Tractor Inc., 3101 First Ave., North, P.O.Box 6006, Fargo,ND 58102
John Walko

Thomas Equipment Ltd.
Brian Crandlemire

Track Machinery Corp.
James Adamczak

Utah International, 550 California St., San Francisco, CA 94104
Ilmar Lusis

Vermeer Mfg. Co., Box 200, Pella, Iowa 50217
John VanderWert

Versatile Mfg., 1260 Clarence Ave., Winnipeg, Man., Canada
Mr. Blamer

Wabco Construction Corporation & Mining Equipment, 2300 N.E. Adams St., Peoria, IL 61639
J.A. McCann

White Motor Corporation., 100 Erieview Plaza, Cleveland, OH 44144

Construction Equipment Div.,
Gene Lockie
Harold Maclure

Farm Equipment Co.
Keath Lange

Table D-3

Trade Associations

American Road Builders Association	Don Hanson
Associated Equipment Distributors 615 W. 22nd street Oak Brooke, IL 60521	P. Herman
Associated General Contractors 1957 E Street, SW Washington,D.C. 20036	Art Schmul John Sirocca
Construction Specification Inst. Ste 300, 1150 17th Street N.W. Washington, D.C. 20036	J.A. Gascoigne
Construction Industry Manufacturers Association Marine Plaza, 1700 E. Wisconsin Ave. Milwaukee, WI 53202	H.T. Larmore William Miller J.J. Benson
Engine Manufacturers Association 111 E. Washer Drive Chicago, IL 60601	T. Young
Farm and Industrial Equipment Inst. 410 N. Michigan Ave Chicago, IL 60611	James Ebbinghaus Robert Hasegawa Gary Morgan Harvey Morgan, Jr. L.W. Randt
Society of Automotive Engineers 400 Commonwealth Drive Warrendale, PA 15096	William Toth Tom Northrop

Table D-4

PUBLISHERS & EDITORS CONTACTED

Construction Publishing Co.	Mary Pfeil
New England Construction	
Dunn and Donnelly	
Highway and Heavy Construction	Elwood Maschter
Magazine	Dee Piotrowski
McGraw-Hill	
Engineering News Record	John Seton
Economics Research	Bill Reinhardt

Table D-5

State and Local Officials

California

Jack Swing, Noise Specialist
Office of Noise Control
State Department of Health

Albert Optigan, Noise Pollution Specialist
Acoustics Division
Los Angeles Department of Environmental Quality

James Dukes, Noise Abatement and Control Administrator
Department of Public Works
San Diego Environmental Quality Department

Jack Ross, Assistant Mechanical Engineer
Department of Public Works
City and County of San Francisco

Colorado

Thomas Martin, Noise Abatement Officer
Colorado Springs Safety Department

Florida

Jessee Borthwick, Noise Control Program Manager
Florida Department of Environmental Regulations

Robert Jones, Director of Noise Programs
Hillsborough County, Environmental Protection Commission

Hawaii

Mr. Thema Anamidu, Environmental Health Specialist
Noise and Radiation Branch
State Department of Health

Illinois

John Moore, Manager
John Paulaskie, Noise Supervisor
Division of Noise Pollution Control
Illinois Environmental Protection Agency

Table D-5 (cont'd)

Maryland

Thomas Tower, Director, Noise Section
Bureau of Air Quality and Noise Control
Maryland Environmental Health Administration

Massachusetts

Donald Squires, Senior Engineer - Noise Control
Boston Air Pollution Control Commission

New Jersey

Edward DiPolvere, Supervisor of Noise Control
New Jersey Department of Environmental Protection

New York

Dr. Fred G. Hagg, Director, Noise Bureau
New York State Environmental Conservation Department

Henry Watkins, Assistant Director
New York City Bureau of Noise Abatement and Control

Mike Manleos, Chief, Noise Branch - Air Pollution Unit
Nassau County Department of Health

North Carolina

Johnnie Smith, Director, Division of Noise Control
N.C. Department of Health and Environmental Control

Oregon

John Hector, Chief, Noise Pollution Section
Oregon Department of Environmental Quality

Dr. Paul Herman, Acoustical Project Manager
Portland Bureau of Neighborhood Environment

Pennsylvania

Don Kerstetter
Bureau of Air Quality and Noise Control
Pennsylvania Department of Environmental Resources

Appendix E

INPUTS TO THE CONSTRUCTION SITE MODEL

Appendix E

INPUTS TO THE CONSTRUCTION SITE MODEL

Revised usage factors and other data have been developed for wheel and crawler tractors as input to the construction site model described in section 5. These new data have been used in Table 5-3 through 5-6 to update the data previously published [13]. A principal revision has been made to the usage factors which are based upon the hours of use at each construction site type for each machine type/classification category. The revised hours were developed from: (1) Census data relating to the estimated number of machines in existence and (2) manufacturers' information concerning the usage of the various equipment type/classification categories in the various construction site types; and (3) construction associations' estimates of annual hours of operation for various equipment types. Summaries of the estimates of the number of machines currently used in construction at each site type are shown in Table E-1. Additional estimates for annual hours of use for each machine type are shown in Table E-2.

TABLE E-1

Estimated Number of Machines in Construction By Site Type

Machine Type and Horsepower Class	Residential	Non-Residential	Industry Commercial	Public Works	Total In Construction	Total In Existence
Crawler Tractors						
(20-199)	39,019	32,409	4,602	7,347	83,380	111,595
(200-450)	1,590	5,726	517	536	8,369	20,588
Wheel Loaders						
(20-249)	15,266	11,596	6,446	8,101	41,410	65,934
(250-500)	3,688	2,370	751	126	6,935	14,652
Wheel Tractors	46,330	21,880	41,180	19,310	128,700	195,000

Table E-2

Estimated Average Annual Hours of Use of Each Machine in Construction Activity
(Average Yearly Use During Economic Life)

Machine Type/Classification		Annual Hours of Use
Crawler Tractor	(20-199)	1300
Crawler Tractor	(200-450)	1400
Wheel Loaders	(20-249)	1300
Wheel Loaders	(250-500)	1400
Wheel Tractors		1200

Additionally, Table E-3 provides a revised estimate of the annual number of construction sites of each type throughout the United States, obtained from Construction Review, Domestic and International Business Administration (DIBA), Department of Commerce, August/September, 1976 of the annual number of construction sites of each type throughout the United States. Based upon the Data provided in Table E-1 through E-3, an estimate of the annual hours of operation for each site type has been obtained as shown in Table E-4. Lastly, the data shown in Table E-4 has been used to compute the revised usage factors shown in Table 5-3 through 5-6 by first dividing the values shown in Table E-4 by the total hours each site exists, as indicated in Tables 5-3 through 5-6, and then by prorating this usage to each respective phase of construction such that the previously published [13] relative usage ratios are preserved.

TABLE E-3

Estimated Annual Number Of Construction Site Types

Construction Site Type	Annual Number Throughout United States
Resident and Domestic Housing	728,000
Non-Residential	87,100
Industrial/Commercial	235,500
Public Works	485,224

TABLE E-4

Estimated Annual Hours of Operation Per Site

Machine Type and Classification	Residential	Non-Residential	Industrial/ Commercial	Public Works
Crawler Tractor				
(20-199)	68.9	488.0	27.8	20.2
(20-450)	323	91.7	2.99	1.45
Wheel Loaders				
(20-249)	26.7	174.0	36.7	22.3
(250-500)	7.02	38.7	4.51	.02
Wheel Tractors	76.4	301.0	210.0	47.7

REFERENCES

REFERENCES

1. EPA, "Noise from Construction Equipment and Operations, Building Equipment and Home Appliances," Environmental Protection Agency NTID 300.1, December 1971.

2. Energy Resources Co., Inc. Economics Impact Analysis of Noise Abatement Regulation for Construction Tractors and Loaders, July 1976.

3. Society of Automotive Engineers, "Exterior Sound Level Measurement Procedure for Powered Mobile Construction Equipment", SAE J88a, June 1975, Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA. 15096

4. Society of Automotive Engineers, "Operator Sound Level Measurement Procedure for Powered Mobile Construction Machinery - Work Cycle Test", SAE Construction Noise Subcommittee, Draft No. 2, July 1, 1975.

5. Science Applications Inc., Technology Analysis, Loaders and Dozers, July 1976.

6. EPA, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety", U.S. Environmental Protection Agency, Washington, D.C. 20460. Report 550 + 9-74-004, March, 1974.

7. French Decree No. 69-380, Limitation of the Sound Level of Airborne Noise Emitted by Internal Combustion Engines in Certain Construction Equipment, Recueil des Textes Relatifs aux Bruits - No. 1383, Edition mise a jour au 15 Aout 1972, Journal Officiel de la Republique Francaise, 26 rue Desaix, 75732 Paris, CEDEX 15, France.

8. Quindry, T., "An Evaluation and Assessement of Existing Data and Preocedures for the Measurement of Noise from Loaders and Dozers," Applied Acoustics Section, Institute for Basic Standards, National Bureau of Standards, Washington, D.C.,October 1975.

9. Society of Automotive Engineers, "Exterior Sound Level Measurement Procedure for Powered Mobile Construction Equipment", SAE J88, April 1973, Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA. 15096.

10. "Sound Level Measurements at the Operator Station for Agricultural and Construction Equipment" SAE J919a, May 1966, Society of Automotive Engineers, 400 Common wealth Drive, Warrendale, PA. 15096.

11. EPA, "Portable Air Compressor Noise Emission Noise Standards", Environmental Protection Agency, Washington, D.C., December 31, 1975.

12. EPA, "Medium and Heavy Truck Noise Emission Standards", Environmental Protection Agency, Washington, D.C., April 13, 1976.

13. "Background Document for Portable Air Compressors," Environmental Protection Agency Report 550/9/76-004, December 1975.

14. EPA, "Population Distribution of the United States as a Function of Outdoor Noise Level," Environmental Protection Agency Report 550/9-74-009, June 1974.

15. EPA, "Public Health and Welfare Criteria for Noise," Environmental Protection Agency Report 550/9-73-002, July 1973.

16. Waters, P.E., "Commercial Road Vehicle Noise", Journal of Sound and Vibration, Vol. 35, No. 2, 1974; pp 155-222.

17. Bates, K.C., and Yoerger, R.R., "Shaping Sound Frequency Spectra of Axial Flow Fans", Society of Automotive Engineers, Paper 750775; September 1975.

18. Shrader, J.T. and Page, W.H., "Truck Noise IV-C, The Reduction of Cooling System Noise on Heavy Duty Diesel Trucks," Department of Transportation, Report No. DOT-TST-74-22, May 1974.

19. Harris, C.M., Handbook of Noise Control, McGraw-Hill Book Company Inc., New York, 1957.

20. Challen, B.J., "The Effects of Combustion System on Engine Noise", Society of Automotive Engineers SP-397, Paper 750798, August 1975.

21. Thein, G.E. and Fachback, H.A., "Design Concepts of Diesel Engines with Low Noise Emission" S.A.E. Paper 750838, August 1975.

22. Priede, T., "The Problems of Noise of Engines in Different Vehicle Groups", Society of Automotive Engineers SP-397, Paper 750795, August 1975.

23. Damkevala, R.J., et al., "Noise Control Handbook for Diesel Powered Vehicles", Department of Transportation, Report No. DOT-TSC-OST-74-5, April 1975.

24. Grover, E.C. and Anderton, D., "Noise and Vibrations in Transmissions", Paper No. 7, Second International Power Transmission Conference, 1969.

25. Grande, E., Brown, D., Sutherland, L. and Tedrick, R., "Small Turbine Engine Noise Reduction," Vol. II, Technical Report AFAPL-TR-73-79, December 1973.

26. Hopler, R.D. and Wehr, S.E. "Noise Reduction Program for U.S. Army Construction Equipment" S.A.E. Paper 740714, September 1974.

27. Kaye, M C., "Truck Noise III-A - Preliminary Noise Diagnosis of Freightliners Datum Truck-Tractor," Report No. DOT-TST-73-6, May 1973.

28. Patterson, W.H., and Freeze, T., "Traction Vehicles: Noise and Cost of Abatement; Bolt, Beranek and Newman, Inc. Report 25666; Submitted to U.S. Environmental Protection Agency, Washington, D.C., January 1974.

29. Damotte, E.E., "Final Report, Noise Level Study on Caterpillar D7F" Caterpillar File #E70-270, September 1972.

30. Kamperman, G.W., and Nicholson, M.A., "Noise Control Methodology for Army Construction and Materials Handling Equipment", Kamperman Associates Report, March 1975.

31. Hunt, R.E., Kirkland, K.C., and Reyle, S.P., "Truck Noise IVA Diesel Exhaust and Air Intake Noise," Dept. of Transportation, DOT Report DOT-TSC-S7-73-12, March 1974.

32. House Noise - Reduction Measurements for Use in Studies of Aircraft Flyover Noise," Society of Automotive Engineers, Inc., AIR 1081, October 1971.

33. Science Applications, Inc., "Summary of State, Local, Foreign and Federal Laws Dealing with Tracked and Wheeled Loaders and Tracked and Wheeled Bull Dozers", March 1976.

34. S.C. Wehr and R.J.Peppen, "Acoustical Testing Program for Loaders and Dozers", U.S. Army MERADCOM, Fort Belvoir, Virginia, 30 June 1976.

35. Contractors Equipment Manual, Associated General Contractors of America, 7th Ed., 1974.

U.S. GOVERNMENT PRINTING OFFICE 1976 — 720-337/61H