NBSIR 75-965

AN EVALUATION AND ASSESSMENT OF EXISTING DATA AND PROCEDURES FOR THE MEASUREMENT OF NOISE FROM DOZERS AND LOADERS

Applied Acoustics Section
Institute for Basic Standards
National Bureau of Standards
Washington, D. C. 20234

October 1975

Final Report

Prepared for
U.S. Environmental Protection Agency
Washington, D. C. 20460

U.S. DEPARTMENT OF COMMERCE, Rogers C.B. Morton, ***Secretary***
James A. Baker, III, ***Under Secretary***
Dr. Betsy Ancker-Johnson, ***Assistant Secretary for Science and Technology***

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Acting Director***

Table of Contents

EPA is charged with taking strong comprehensive action to protect public health and welfare from increasing noise. Accordingly, the Agency initially identified medium and heavy trucks and portable air compressors as major noise sources and promulgated noise emission regulations covering these products. Additional products have recently been identified as major noise sources, including wheeled and tracked dozers and loaders. For the purposes of this report, dozers and loaders can be defined as any construction or industrial product which performs the dozing (pushing or pulling) operation and any construction or industrial machine which has a front end loading bucket, respectively.

As was the case for medium and heavy trucks, the dozer and loader noise of interest can be categorized mainly as the noise produced by the tractor power plant. For dozers and loaders, this includes noise from the cooling fan, engine, exhaust and intake. Other noises of interest arise from drive train systems, hydraulic components and relief valves, and, in the case of tracked vehicles, the track itself. The noise from the power plant increases as the engine speed (and power) increases. Maximum power plant noise usually occurs when the engine is delivering maximum power at its maximum operating speed. The percentage of time a dozer or loader spends at maximum noise conditions depends upon the work cycle, i.e., the material being moved, the distance that the material is being moved, and to some extent, the manner in which the dozer or loader is operated.

This report reviews existing noise measurement procedures which can be applied to dozers and loaders with regard to their usefulness in the regulation of dozer and loader noise as well as the availability, extent and applicability of existing data. On the basis of this review, the following probable or potential measurement difficulties have been identified that could hinder the promulgation and/or enforcement of future EPA regulations to control the noise emissions from dozers and loaders.

A NEED TO IDENTIFY AND CLASSIFY CONSTRUCTION EQUIPMENT COVERED. When mandatory regulations are applied, industry and EPA must precisely decide which equipment is covered by the regulation and which is not. Exact definitions specifying which equipment is to be classified as a dozer or loader must be prepared. This may include equipment labeled by the manufacturer as either industrial equipment or construction equipment. Categorization of equipment according to horsepower, size, or other parameters also must be accomplished.

A NEED TO SPECIFY THE DEGREE OF ASSEMBLAGE OF THE MACHINE TO BE TESTED. Many machines are not fully assembled at the main manufacturing facility. Some of these machines are shipped to the dealer or other facility where attachments such as dozer blades or loader buckets, etc., are installed on the base machine. It may not be practical to require testing on the fully completed machine (including attachments).

It is highly probable that testing could be performed on the base machine without attachments and meaningful results obtained; however, data are necessary to support this assumption. The degree of assemblage of the base machine required for testing must be specified.

A NEED TO ACCOUNT FOR HEAT RADIATION FROM THE ENGINE. Under certain conditions heat radiation from the engine compartment can cause measurement problems during stationary tests. Hot air surrounding the equipment can cause measurement inconsistencies due to changes in the noise generation mechanisms and noise radiation to the surrounding environment. This phenomena should be investigated.

A NEED TO ACCOUNT FOR ENVIRONMENTAL/SITE EFFECTS. There is a need for the various environmental and test site effects on noise generation, radiation and/or propagation to be systematically investigated and correction factors developed so that measurements made under any conditions may be corrected to a single standard set of conditions. If correction factors are not feasible then there is a need for a site calibration procedure or definition of limiting test conditions.

A NEED FOR SIMPLER TEST PROCEDURE. There exists a need to develop a test procedure that is simpler to perform than those specified in current standards and is less dependent on weather and test site variables. Correlation should be established between the results obtained utilizing such a test and human response to dozer and loader noise.

A NEED TO BETTER SPECIFY TRANSIENT RESPONSE OF INSTRUMENTATION. There exists a need to evaluate the response of existing instrumentation to actual transient signals, e.g., as would occur in a typical work cycle, in order to establish the relationships among the various precision instruments, to supply data to strengthen existing standards, and to establish a data base so that the technical community, manufacturers, lawmakers and enforcement agencies will have a common basis for comparison of results obtained using supposedly comparable equipment.

AN ALMOST NON-EXISTENT DATA BASE. Very limited data exist in the public domain on the noise levels associated with dozer and loader operations. Data which do exist are proprietary in nature and were gathered mainly as engineering tools to facilitate the development of product lines by the manufacturer.

A LACK OF TYPICAL USAGE DATA. In order to develop an appropriate, reliable and repeatable test procedure, it is necessary to consider the range of possible dozer and loader operational modes and the noise emission associated with each mode. What is needed is definition of the percentage of time which a dozer or loader typically spends at different operational modes during a work cycle. Such data could serve as the basis for logical decisions on whether a multi-modal test procedure or simply a few selected modes of operation should be specified as part of the test procedure. Such typical usage data do not presently exist for dozers and loaders.

In summary, it is doubtful that the data in the open literature are extensive enough to provide EPA with the information needed for a comprehensive analysis of the economic costs and technical feasibility associated with a given regulation. Furthermore, there are practically no data available upon which to base an evaluation of alternative dozer and loader noise measurement procedures or to establish correlations between the noise associated with various operational modes and the noise measured utilizing various test procedures.

Thus, it appears that EPA will have to generate a rather extensive physical data base and investigate alternative measurement procedures prior to formulation of the Notice of Proposed Rule Making.

An Evaluation and Assessment of Existing Data and Procedures for the Measurement of Noise From Dozers and Loaders

This report reviews (1) existing construction equipment noise measurement procedures with regard to their usefulness in the regulation of noise from dozers and loaders and (2) the availability, extent and applicability of existing data. On the basis of this review, probable or potential measurement-related difficulties are identified that could hinder the promulgation and/or enforcement of future EPA regulations to control the noise emission from dozers and loaders.

Key Words: Acoustics (sound); dozer; loader; measurement methodology; noise emission standard; noise measurement.

1. Introduction and Scope

The National Bureau of Standards (NBS), under the sponsorship of the Office of Noise Abatement and Control (ONAC), U. S. Environmental Protection Agency, has attempted to identify probable or potential measurement difficulties that could hinder the promulgation and/or enforcement of future noise regulations to control the noise emissions from dozers and loaders. A search of the open literature in conjunction with numerous industrial and private sector contacts established the basis for discussion of:

1. The basic characteristics of dozer and loader design and construction.

2. The effect of dozer and loader noise and the parties affected.

3. The major component noise sources for dozers and loaders.

4. The normal or typical modes of operation characteristic of dozers and loaders.

5. The usefulness of existing measurement procedures for use in regulation of the noise from dozers and loaders, considering the viewpoint of EPA, manufacturers and enforcement personnel.

6. The availability, extent and applicability of existing data that could be utilized by EPA in their efforts to promulgate noise emission regulations for dozers and loaders.

This report is limited to those factors related to the measurement of dozer and loader noise. EPA/ONAC will independently investigate the technical feasibility and economic implications of dozer and loader noise regulation.

2. Dozer and Loader Description and Design

2.1. Classification and Identification

Classification and identification of construction equipment is very complicated. Classifications which now exist are broad in nature, include both small and large equipment, and do not properly identify the equipment being classified. Agreement must be reached by EPA and industry as to how equipment is to be classified.

What is a dozer, for instance? EPA views a dozer as a product which performs the dozing (pushing or pulling) operation. In reports by Patterson[1][1/] and A. T. Kearney, Inc.[2], the term "traction vehicle" is coined to signify "any engine powered tractor used to push or pull loads at construction sites." Industry does not recognize the term "traction vehicle", and a "dozer" is not viewed as being the end product vehicle. A dozer is simply a major component or attachment to a crawler (tracked) or wheeled tractor which performs the dozing operation. The industry viewpoint is based on the fact that some 20% of all crawler or wheeled tractors perform other pushing or pulling operations which never require a dozer attachment and thus are not equipped with one. SAE[3] defines a tractor as "a self-propelled machine used to exert a push or pull force through a mounted attachment or drawbar to move objects or material. Tractors include both crawler tractors and wheel tractors." Another SAE standard[4] refers to a dozer as being the blade attachment only.

Loaders, as viewed by EPA, include tractors with front loading attachments as well as machines with integrally mounted front loading buckets. According to SAE[3], a loader is "a self-propelled machine with an integral front-mounted bucket supporting structure and linkage that loads material into the bucket through forward motion of the machine and lifts, transports, and discharges material. Not included are tractors with front-end loader attachments." Other SAE standards[5,6] which describe nomenclature and definitions of front end loaders only describe components and define the operations which pertain to the bucket and its supporting mechanisms.

In different geographic locations, different names are used for the same equipment. For instance, a loader is called a "high lift" in Wisconsin, yet may be called a "power shovel" in other areas. Many loaders also are equipped with backhoe attachments and are then referred to as "excavators".

There are literally thousands of categories and combinations which may exist. A base machine -- a tractor -- is built and certain attachments are added. Some attachments are installed at the dealer's facility, some are added by the purchaser. Some attachments, though specifically designed for a particular machine and approved for use by the base machine manufacturer, are made by specialty manufacturers. Frequently the application of a particular base machine is not even known when it is manufactured or sold.

When mandatory regulations are applied, it must be clear precisely which equipment is covered by the regulation and which is not. Classifications should not only identify the equipment but should categorize

---

[1/] Numbers in brackets indicate the literature references at the end of this report.

equipment according to horsepower, use, or other parameters.

For the purposes of this report, the viewpoint of EPA will be followed when describing dozers or loaders. A dozer is the product which performs the dozing (pushing or pulling) operation. A loader is any machine with a front end loading bucket whether integrally mounted or installed as an attachment.

2.2. Categorization of Equipment

Equipment is sometimes categorized as either "industrial" or "construction". The definition between the two categories is obscure even to the equipment manufacturers, the choice of category being primarily a marketing decision. In general, industrial equipment is lightweight and is more utilitarian in nature than construction equipment. Some industrial equipment is essentially farm tractors to which attachments can be added. This equipment, in addition to being used on farms, might be used by homebuilders, utility companies, or landscapers to pick up or push loose material, or do rough grading and other light work. Most industrial plants would have some equipment of this size available to do a variety of jobs. Small tracked vehicles of approximately 60 hp or under might also be included in this category.

Construction equipment can run the gamut in size from 20 hp machines up to 2000 hp or more. Differences in acoustic spectral characteristics may exist depending on the horsepower and size of the machine due to different noise sources being predominant.

2.3. Industry Structure

An extensive survey of current data on the dozer and loader population in the United States and recent year dozer and loader sales information was not made. Data compiled in 1974 by A. T. Kearney, Inc.[2] for "traction vehicles" is reported to give an indication of the industry structure. The data reported are for vehicles commonly referred to as crawler or wheeled dozers.

Manufacturers of "traction vehicles" obtain raw materials and components used in the manufacturing process from interdivisional transfers, component suppliers and raw material suppliers. Construction equipment dealers are the primary channel of distribution either through sale or lease to the primary end user. Estimated percentages of units shipped to the primary end users for the period 1968-1972 are given in Table 1.

The method of distribution is predominantly by independent authorized dealers with some factory branches and factory owned dealerships. Units can also be distributed direct to the end user. Approximately 30% of "traction vehicles" are obtained through rental or rental/purchase agreements.

Manufacturers in the construction industry are basically large and

Table 1

Estimated percentage range of total traction vehicle unit shipments by end use market, 1968-1972[2].

End Use Market	Percentage of Units Shipped (Range)
Construction Industry	52 - 57%
Forestry Industry	13 - 19
Mining Industry	4 - 8
Industrial Users	5 - 10
Government Agencies	10 - 15
Other Users	1 - 6
Total	100%

Table 2

Estimated sales of divisions or subsidiaries whose product lines include manufacture of traction vehicles[2].

Manufacturer	Estimated Sales ($ Millions)
Allis-Chalmers*	$ 198.0
J. I. Case	426.9
Caterpillar Tractor	2,537.2
Clark Equipment	296.1
Deere & Company	306.2
International Harvester	411.9
Komatsu Manufacturing Company	13.0
Massey-Ferguson, Incorporated	172.2
M-R-S Manufacturing Company	5.0
V-Con Division of Marion Power Shovel	.8
Terex (Division of General Motors)	N/A

*Allis-Chalmers has divested their interests in construction equipment - now known as Fiat-Allis.

diversified. They generally produce other product lines such as farm, industrial or transportation equipment. There are relatively few manufacturers of construction equipment due to the capitol intensive nature of the industry.

"Traction vehicles" are manufactured by divisions or subsidiaries of major corporations which are among the largest in the United States. Manufacturing facilities are highly concentrated in the central United States. Exports of traction vehicles account for 30% to 45% of shipments of total units while imports have historically been a minor factor. Eleven manufacturers of crawlers and/or wheeled dozers are identified by Kearney as being currently active in the domestic market. Of these, nine are domestic manufacturers, one manufacturer is a domestic company which imports most of its units from foreign subsidiaries, and one manufacturer is strictly an importer. Table 2 gives an estimate of sales for these eleven manufacturers.

Manufacturers do not necessarily produce both crawlers and wheeled dozers nor necessarily offer both large and small equipment. Tables 3 and 4 show the market segment of crawlers and wheeled dozers which are offered by each manufacturer.

If loaders were included in the above tabulations of data, many more manufacturers would be included. Lists of manufacturers of both dozers and loaders compiled by General Motors Corporation[7] are reproduced as Tables 5 and 6. No breakdown of sales data presently exists in the public domain for loaders.

2.4. Design Characteristics

Engine horsepower and noise emissions are related. As size, weight and horsepower of dozers and loaders are increased, noise emissions increase also. The size of the construction site, more or less, dictates the size of the equipment used on the site. Larger construction sites can more efficiently use larger construction equipment. Equipment that would be used in vast remote areas, such as construction sites for dams and open-pit mines, would be impractical in smaller areas, such as sites in urban-residential areas near homes, schools, hospitals and other businesses. Construction operations in urban-rural areas, such as roadway building and factory site preparation, typically would use larger equipment than is used in urban-residential areas but smaller equipment than is used in rural areas.

An assessment of spectator noise levels for dozers and loaders should thus be based on the societal impact of the noise emissions from a particular dozer or loader, i.e., the cost/benefit ratio of noise control measures. Equipment used in remote areas should not have as stringent a noise regulation as equipment used in urban residential areas. A logical breakdown suggested by a major construction machine manufacturer[8] categorizes dozers and loaders with respect to engine horsepower since

Table 3

Crawlers offered by manufacturer by horsepower range[2].

Manufacturer	Horsepower Range 20-89	29-199	200-299	300 and Over
Allis-Chalmers*	X	X	X	X
J. I. Case	X	X		
Caterpillar Tractor	X	X	X	X
Deere and Company	X			
International Harvester	X	X	X	
Komatsu Manufacturing		X	X	X
Massey-Ferguson	X			
Terex			X	X

*Fiat-Allis

Table 4

Wheel dozers offered by manufacturer by horsepower range[2].

Manufacturer	Horsepower Range 20-89	90-199	200-299	300 and Over
Caterpillar Tractor		X		X
Clark Equipment			X	X
International Harvester			X	X
M-R-S Manufacturing		X	X	X
V-Con Division of Marion Power Shovel				X

Table 5. Manufacturers distributing loaders and dozers in the U.S.[7].

Parent Firm	Division or Subsidiary (Trade Name in Parentheses)	Wheel Loaders* (4-wheel Drive)	Wheel Dozers** (Rubber-tired)	Tracked Loaders (Crawler loaders)	Tracked Dozers (Crawler tractors)
Allis-Chalmers Corp.	Industrial Tractor Division	X			
Tenneco Corp.	J. I. Case Co.	X		X	X
Catepillar Tractor Co.	U.S. Commercial Div.	X I	X	X I	X I
Clark Equipment Co.	Construction Equipment Div. (Michigan)	X	X		
Paccar	Dart Truck Co.	X			
Deere & Co.	Industrial Equipment Div.	X		X	X
Eaton Corp.	Construction Equipment Div. (Yale, formerly Trojan)	X			
Ford Motor Co.	Tractor Operations	X			
Fiat-Allis, Inc.	(Fiat-Allis)	X		X I	X I
International Harvester	Pay Line Div. (Hough)	X		X I	X I
Komatsu Ltd.	Komatsu America Corp.			X I	X I
Marathon Manu. Co.	Marathon-LeTourneau Co., (Longview Div. (LeTourneau))	X			
Massey-Ferguson Ltd.	(Massey-Ferguson and Massey-Ferguson-Handmag)	X I	X I	X I	X I
Owatonna Mfg. Co.	(Owatonna) (Mustang)	X			
General Motors Corp.	Terex Div.	X			X
Taylor Machine Words		X			
Marion Power Shovel	V-Con Div.		X		
JCB Ltd.	JCB Excavators, Inc.	X I		X I	

Letter "I" indicates that one or more models are manufactured outside U.S. and imported for sale.

* Wheel loaders are non-skid-steer, with bucket 1 cu.yd. or larger.

** Wheel dozers listed are rubber-tired only, excluding sanitary landfill compactor.

Table 6. Manufacturers distributing wheel loaders in the U. S.[7].

Parent Firm	Division or Subsidiary (Trade Name in Parenthesis)	Four-Wheel Drive under 1 cu.yd. Articulated	Two-Wheel Drive Any size	Tractor-Loader Back-hoe (2 or 4 whl dr)	Skid-Steer (4-wheel drive)
Allis-Chalmers Corp.	Industrial Tractor Div.		X	X	
Aximuth Engr. Co.		X			
Tenneco Corp.	J.I. Case Co.		X	X	X
Tenneco Corp.	Davis Div. of J.I. Case	X			
Davis Welding & Mfg.Co.					X
Deere & Co.	Industrial Equipment Div.		X	X	X
Dynamic Ind.		X			
Erickson Corp.					X
Ford Motor Co.	Tractor Operations		X	X	X
Gehl Co.	(Hydraskat)				X
Bucyrus-Erie	Hy-Dynamic Div. (Dyno Hoe)			X	
Hydra-Mac Inc.					X
International Harvester	Pay Line Div.		X	X	X
Long Mfg. N.C. Inc.			X	X	
Massey-Ferguson Ltd.			X	X	X
Clark Equipment Co.	Melroe Div. (Bobcat)				X
Hy-Matic Corp.		X			X
JCB Ltd.	JCB Excavators Inc.			X	
Sperry Rand Corp.	Sperry New Holland Div.				X
Owatonna Mfg. Co.	(Owatonna) (Mustang)	X			X
Koehring Co.	Parsons Div.			X	
TCI Inc.			X		
TECO Crab Inc.		X			
Thomas Equipment Ltd.					X
Versatile Power Corp.	(BRONCO)	X			
Waldon Inc.		X			
White Motor Corp.	Construction Equipment Div.	X	X	X	X
Pettibone Corp.				X	
Digmore Equipment & Engrg.		X			

horsepower bears some relationship to the area of use and also the noise emitted. The suggested classifications and typical usage areas are:

1. 20 thru 150 hp - urban-residential areas

2. 151 thru 300 hp - urban-rural areas

3. 301 thru 600 hp - rural areas

4. 601 hp and up - remote areas.

3. Effects of Noise and Parties Affected

Noise from construction equipment is the major cause of spectator noise on a construction site. The persons who potentially are adversely affected by the noise from construction equipment, including dozers and loaders, include the operator[2/] of the equipment or other workmen on the construction site, passers by, and persons living or working near the construction site. Construction noise can interfere with speech communication, lead to distraction or other kinds of task interference, and potentially contribute to the risk of hearing damage and other possible physiological effects.

4. Major Noise Sources

It is important to identify the major sources of noise in dozers and loaders and the effect of normal operation on the noise levels associated with each of these sources. Experience[1] has shown that the noise levels generated by dozers and loaders depend more on horsepower than anything else.

4.1. Engine Related Noise Sources

Since both construction equipment and heavy duty trucks are powered by diesel engines, many of the major engine-related noise contributors for construction equipment are the same as for heavy duty trucks. The primary difference lies in the location of the major noise components and the shielding provided by the body. Basically the three major engine related noise sources in the dynamic test mode[1] are, in order of predominance:

1. Fan Noise - is the result of air flow past the fan blades which results in rotational (associated with pressure differences across the fan blades) and turbulent noise (associated with the eddy flows and vortices shed at the blade edges). Such noise is related to fan tip speed and to air distribution, which is governed by the fan configuration and environment. It should be noted that fan and radiator size is limited by visibility requirements of the operator.

2. Engine (Mechanical) Noise - is primarily produced by the combustion process which produces rapid changes in pressure in the

2/ Operator noise exposure is covered by OSHA regulations and therefore, is not included in the scope of this report.

cylinder which in turn results in excited mechanical vibration in the engine structure. Some of this vibrational energy is subsequently radiated to the atmosphere as acoustic energy.

3. Exhaust Noise - is created when high pressure exhaust gases, released through the engine exhaust valves, excite oscillations in the exhaust system which are radiated to the atmosphere at the tail pipe, through the pipe surfaces and through the muffler shell. This noise is a function of engine type; engine timing; valve duration time; intake system type; muffler type, size and location; pipe diameter; pipe bends; dual or single system; etc.

Other engine related noise sources[1] include:

4. Air-Intake Noise - is created by the opening and closing of the intake valve which causes the volume of air in the system to pulsate. Associated noise levels are dependent upon whether the engine is gasoline or diesel, turbocharged or naturally aspirated, 2-cycle or 4-cycle, the number of cylinders, the engine displacement, engine rpm, engine load, etc.

5. Transmission Noise - arises from the meshing of gear teeth in transmission systems and may be apparent under load, no load, or reverse load conditions. The noise may be aggravated by resonance of the gearbox casing or by structure-borne components that excite large body surfaces that act as efficient radiators.

Some examples of engine noise control techniques are given in references 9 thru 18. The method of control for these sources is much the same as for diesel trucks with one major exception -- cooling fan noise. Diesel trucks, because of their high speed operating mode, depend mostly on ram air through the radiator for cooling, with a fan as a back-up. Construction equipment, on the other hand, operates in a stationary or relatively slow moving mode and must depend more on the fan for forced air cooling. While much can be done to shroud the engine and fan of a diesel truck, the greater cooling efficiencies needed for construction equipment prevent use of some of these treatments.

As machinery size increases, engine and cooling system noise of construction equipment becomes more difficult to control. Empirically, engine and cooling fan noise increase with increasing engine horsepower at the rate of approximately 3 and 6 dB per doubling of engine horsepower, respectively, in the horsepower range of 200 hp.

A larger engine rejects more waste heat and requires a larger radiator and air flow. For larger engines the optimum radiator and fan size for noise control and cooling requirements cannot be used due to size limitations. The radiator frontal area cannot be proportionately increased with engine size since it would then reduce operator visibility. Pressure losses increase with engine horsepower and the advantage of increased fan diameter with power is not fully realized.

Engine noises tend to radiate from (or excite) thin sheet metal parts such as the oil pan or valve covers. Methods of reducing engine noise include structural modifications to the engine block, changing thickness or shape of components and panels, or decoupling components from the exciting forces.

Exhaust noise of muffled engines is low in comparison with the other noise sources and until the other sources are reduced, improved mufflers would have a negligible effect. If exhaust noise is a problem due to a poor muffler, improved mufflers offer a relatively inexpensive solution but again there are size limitations based on operator visibility. Space in the engine compartment is limited and the main muffler must therefore be externally mounted.

4.2. Other Noise Sources

For tracked vehicles, track noise can be a major noise source, especially during operation of the vehicle in the high speed reverse mode. There is disagreement between industrial and other knowledgable personnel concerning the percentage of time that the high speed reverse mode is used during a normal work cycle. Industrial experts claim that high speed reverse operation is an atypical operating mode while those outside the industry estimate that the high speed reverse mode is used 30-40% of the time.

Track noise is caused by metal-to-metal contact which produces vibrations throughout the track. Utilizing present state-of-the-art noise control technology, not much can be done to reduce track noise without substantially increasing initial track costs and operating costs. One existing quiet track system uses rubber bushed pins which replace the standard straight steel pins. The familiar squeal caused by sliding motion at the pin-bushing interface is eliminated and impacts of the track chain on idlers and drive sprockets are isolated within each track chain section. In addition to the higher track cost, track life is reduced substantially. Outside of this rather impractical approach to track quieting, the technology to quiet track noise is lacking.

Additional sources of noise include hydraulic components as well as impulsive noises such as relief valve noise and banging buckets and blades -- the level of which depend much on operator skill.

5. Typical Work Cycles

The test procedures used today do not measure average noise levels of construction equipment but measure levels representative of the higher range of sound levels generated by the machinery under actual operating conditions.

Industry representatives claim that, due to the multitudinous jobs performed by dozers and loaders, no meaningful average noise levels exist and no typical work cycle can be established. Typical operation, it is claimed, varies according to the material being moved. Moving rock, for instance, creates more noise than moving a softer material such as dirt or sand. This added noise is not a result of the machine doing more work, however, but results from the interaction between the blade and material being moved. When measuring noise emissions, one is not interested in the noise generated by moving a particular material but is interested in the noise generated by the loading on the engine of the dozer or loader. It should be noted that engine loading does not depend on the type or consistency of the material being hauled or pushed. For most efficient operation, the engine loading should be at or near its maximum. Typical operating procedures, which require doing the greatest amount of work in the shortest possible time, thus call for maintenance of maximum or near maximum engine loading. For example, to obtain the most efficient operation of a dozer, the blade is lowered into whatever material is present until a torque converter stall condition (maximum load) is reached. The material is then moved. Less hard-packed dirt would be pushed than sand in a typical operation, but loading of the engine for either operation would be the same. The noise emitted due to engine loading would also be the same.

Typical work cycles are being considered for operator noise level measurement standards by the SAE Construction Noise Subcommittee. There seems to be no reason why, then, that a typical work cycle cannot be established for spectator noise regulations, provided the noise generated as a result of the machine's interaction with the material being moved does not predominate.

6. Existing Measurement Procedures

The test procedures contained in six existing documents could be utilized to measure noise emissions from wheeled and tracked dozers and loaders. They are:

1. SAE Recommended Practice J88a, Exterior Sound Level Measurement Procedure for Powered Mobile Construction Machinery.[19]

2. French Decree No. 69-380, Limitation of the Sound Level of Airborne Noise Emitted by Internal Combustion Engines in Certain Construction Equipment.[20]

3. German Regulation, Noise Limits for Track Type Tractors[21] (currently being revised).

4. German Regulation, Noise Limits for Wheel Loaders[22] (currently being revised).

5. ISO Draft Proposal for Acoustics - Determination of Airborne Noise Emitted by Earth Moving Machinery to the Surroundings - Survey

Method.[23]

6. ASA Standard 3-1975, Test-Site Measurement of Noise Emitted by Engine Powered Equipment[24].

Of these six documents, only the American Standards, SAE J88a and ASA 3-1975, and the French Decree are in their final form. With the exception of ASA STD.3-1975 (permission to reprint this standard was not granted by ASA), complete texts of these standards are reproduced in Appendix A. To better facilitate a discussion of these measurement procedures table 7 has been developed which outlines the pertinent sections of each of the test methods. This table serves as the basis for comparison among the six procedures.

The SAE recommended practice is intended to measure noise emissions which are repeatable and representative of the higher range of sound levels generated by the machinery under actual field operating conditions. These levels do not necessarily represent the average sound level over a typical use cycle. The standard consists of a series of stationary and moving tests which are designed to assure that all possible noise producing elements of the machine are measured.

The stationary tests include measurements at a distance of 50 feet (15.2 m) from the machine on all four sides for the following no load test conditions:

1. Wide open throttle

2. Low idle-maximum governed speed-low idle

3. Wide open throttle including activation of the appropriate hydraulic dircuits and other drive systems.

Fan and mechanical noise emissions are measured during the wide open throttle test; the low idle-maximum governed speed-low idle loads the engine such that engine noise, airborne and structureborne noise, and exhaust noise emissions can be measured, and the wide open throttle test which includes activation of various drive systems allows one to measure hydraulic and hydrostatic noise emissions.

The dynamic tests are designed to check gear train and track noise emissions by driving the machinery through a measurement zone at wide open throttle in an intermediate gear for an unloaded, empty unit. Measurements are made for the right and left side of the vehicle at a distance of 50 feet (15.2 m).

The ASA standard specifies measurement methods for determining the maximum noise emitted by a variety of engine powered equipment. For construction and industrial equipment the test procedures are very similar to SAE J88a test procedures with the most notable exception being the

Table 7. Comparison of existing and proposed measurement procedures for determining the exterior noise of dozers and loaders.

Standard	SAE J88a	ASA STD 3-1975	French Decree 69-380	German Regulation	ISO Draft ISO/TC 43/SC1 (Secretariat-190) 260
Vehicles Covered	Powered mobile c n-struction equipment of 20 rated bhp and over	Motor vehicles, public conveyances, construction and industrial machinery, residential and recreational vehicles powered by engines operating on petroleum-based fuels, coal, steam, electricity, or other source of energy	All construction equipment equipped with internal combustion engines other than automotive vehicles	track type tractors and wheel type loaders	earth moving machinery
Instrumentation	1) Type 1 sound level meter meeting requirements of ANSI S1.4-1971[1/] 2) Alternative measurement system meeting requirements of SAE J184[2/]	sound level meter meeting requirements of ANSI S1.4-1971[1/] Type 1 for certification, Type 2 for enforcement or survey	sound level meter meeting requirements of French national standard S 31 009[3/]	sound level meter meeting requirements of ANSI S1.4-1971[1/] Type 1 and IEC 179[4/]	sound level meter meeting requirements of IEC 179[4/] and appropriate octave filters meeting requirements of IEC 225[5/]
Test Site	Flat open space free of obstructions within 100 ft (30.4 m) of either microphone or machinery	open space of uniform grade not exceeding 2 % average and free of reflecting surfaces other than ground plane within 30 m (100 ft) from either microphone or machinery	open area free of obstructions within 25 m of equipment under test	flat open space free of obstructions within 30 m from machine being tested	flat open space free of obstructions within 30 m from machine being tested
Measurement Area Surface	hard packed earth[6/] smooth concrete or smooth sealed asphalt or similar material	flat concrete, asphalt or similar hard material, hard packed earth or ground[6/]	concrete or impervious asphalt	track type tractor -- packed, moist, sandy loom soil wheel type loader -- concrete, asphalt or hard packed earth	hard packed earth[7/] asphalt, concrete, or similar hard surface
Testing Modes	moving and stationary	moving and stationary	stationary	moving, stationary, work cycle	moving and stationary
Length of Vehicle Path	66 ft (20 m)	30 m (100 ft)		20 meters	20 meters
Microphone Location (Moving Tests)	50 ft (15.2 m) from major side surface parallel to machine path, each side, and 4 ft (1.2 m) above ground plane	15 m (50 ft) from vehicle centerline each side and 1.2 m (4 ft) above ground plane		10 meters on both sides of centerline of machine path, and 1.2 meters above surface on which machine is located	7 meters from each sides of reference parallelepiped of vehicle and 1.5 meters above ground level
Microphone Location (Work Cycle)				track type tractor -- 10 meters on both sides of centerline of machine path, and 1.2 meters above surface on which machine is located wheel type loader -- 10 to 20 meters on both sides of centerline of machine path depending on length of machine, and 1.2 meters above surface on which machine is located.	
Vehicle Operation (Moving Tests)	forward intermediate gear ratio at no load at full governor control setting	(for vehicles capable of speeds over 25 km/hr (15 mph) full throttle acceleration mode and closed throttle deceleration mode covering at least upper one-third of engine speed range		track type tractor -- highest speed reverse at full open governor control. Also work cycle test mode. wheel type loader -- forward gear so governor control fully open max. speed less than 15	maximum governor setting in forward intermediate gear at no load. If vehicle designed to operate in forward-reverse shuttle mode. both forward and reverse used.

Table 7 (continued)

Standard	SAE J88a	ASA STD 3-1975	French Decree 69-380	German Regulation	ISO Draft ISO/TC 43/SC1 (Secretariat-190) 260
				km/hr (9.8 mph) with bucket filled with sand. Also work cycle test mode.	
Vehicle Reference Point (Moving Tests)	unspecified	front of vehicle		leading and trailing edges of machine in test zone	when some part of machine is within measurement length
Microphone Location (Stationary Tests)	50 ft (15.2 m) normal to center of major surfaces of machine and 4 ft (1.2 m) above ground plane	15 m (50 ft) from centerline of vehicle path in direction giving greatest sound level and 1.2 m (4 ft) above ground plane, also 15 m (50 ft) above ground plane above vehicle centerline if suspected that appreciable energy radiated upward from equipment	7 meters from engine casing or part of equipment that take its place, and 1.5 meters above ground	8 positions around machine, 7 meters from sides and corners of imaginary box over machine including bulldozer blade and 1.2 meters above surface on which machine is located	6 positions around machine, 7 meters from sides of imaginary box over machine on centerline. 4 positions at 1.5 meters above surface 2 positions on sides at 7 meters above surface
Vehicle Operation (Stationary Tests)	no load in neutral maximum governed speed, low idle-maximum governed speed-low idle, hydraulic circuits activated	(for vehicles having a maximum speed less than 25 km/hr (15 mph) and equipment used inside factories or other industrial applications, and auxiliary equipment) rated engine speed no load maximum power and other combinations of load and speed or operating modes which would produce greater sound, if practicable; full throttle no load, idle to engine rated speed	no load, governor or speed control set to give maximum full-load speed	high idle speed at full open governor position	cycle from low idle to maximum governed speed at no load, maximum governed speed, hydraulic circuits activated while at maximum governed speed
Quantity Measured	Maximum A-weighted sound level, slow response	Maximum A-weighted sound level, fast response	Maximum A-weighted sound level, slow response	Maximum A-weighted sound level, fast response	Maximum A-weighted sound level, slow response
Reported Value	For cycling and moving tests, average of two values within 2 dB of each other for noisiest microphone position. (For stable tests only one reading)	Moving tests: sound level for noisier side and noisier mode of operation. Stationary tests: maximum level obtained.	highest level recorded	stationary mode-arithmetical average, drive-by mode - arithmetical average of 4 readings (2 each side), Work cycle-arithmetical average hoth readings	for each mode, each location, calculated mean, and A-weighted sound power level, background level if correction applied.

1. American Standard Specification for Sound Level Meters, ANSI-S1.4-1971, (American National Standards Institute, New York, New York), 1971.

2. SAE Recommended Practice Qualifying a Sound Data Acquisition System - SAE J184 (Society of Automotive Engineers, Warrendale, Pa.), 1970.

3. Acoustique, Sonometres de Precision, Objet de la Norme, French National Standard S 31 009, (available from American National Standard Institute, New York, New York) September 1968.

4. International Electrotechnical Commission Recommendations for Precision Sound Level Meters, Publication 179 (available from American National Standards Institute, New York, New York), 1973.

5. International Electrotechnical Commission Recommendations for Octave, Half-Octave, and Third-Octave Band Filters intended for the Analysis of Sounds and Vibrations, Publication 225 (available from American National Standards Institute, New York, New York), 1966.

6. For moving tests of all steel wheel, steel drum or track type machines.

7. For moving tests of all steel wheel and track vehicles, optional for rubber tired vehicles.

specified microphone location for stationary tests. In the ASA document, preliminary measurements are made to locate that position 15 meters (50 feet) from the vehicle where the sound level is maximum. Sound level measurements are made at this position. Further comparison can be made by reviewing the respective entries in Table 7.

The French Decree specifies measurement of noise emission at a distance of 7 meters (25 ft.) from the engine casing on four sides, while the machinery is operating at wide open throttle. As stated before, this test allows measurement of the noise emissions from the fan and mechanical systems. No tests are specified in the French Decree for measuring exhaust, gear train, track, hydraulics or hydrostatic noise emissions. For large equipment the 7 meter (25 ft.) distance from the engine casing can dictate a measurement location which is impractical, i.e., a location within the bounds of the machinery.

The two German regulations establish a machine work cycle test mode where the machinery performs its main function of carrying (a loader) or pushing soil (a dozer) in addition to stationary and moving tests similar to the wide open throttle and drive-by tests of the SAE standard. The work cycle described in these regulations, however, doesn't appear to approximate typical work cycles.

The ISO draft proposal specifies essentially the same series of stationary and moving tests as the SAE document. Measurements are taken at four locations, each 7 meters (25 ft) from the machinery surface (only side locations for moving tests). The mean A-weighted sound level is determined for both stationary and moving tests. As an option, the A-weighted sound power level may also be determined for the stationary test mode.

In addition to the previously discussed measurement procedures, there exists an ISO draft proposal entitled "Determination of Airborne Noise Emitted by Civil Engineering Equipment for Outdoor Use"[25]. This is a generic standard[3/] developed by the European Economic Community (EEC) and follows the International trend of specifying the estimation of sound power level for all stationary tests. Another nearly identical generic standard has been developed by ISO -- ISO/DIS 3744 - Acoustics - Determination of Sound Power Levels of Noise Sources - Engineering Methods for Free Field Conditions Over a Reflecting Plane[26]. The relationship between these two generic standards (draft) and their relationship to yet-to-be-developed test codes is not clear at this time.

[3/] A generic standard specifies procedures for the measurement and/or determination of the acoustic quantity to be measured regardless of the noise source. Such a standard requires the generation of test codes for specific noise sources which specify the operating and/or mounting conditions of the noise source and the microphone array.

7. Data Base and Correlations

A review of the literature and discussions with knowledgeable industry personnel reveal a limited data base in the public domain[1,2]. Engineering data have been collected by manufacturers of construction equipment, but it is mostly proprietary in nature. Many manufacturers utilize SAE J88a test procedures in part of their program to gather engineering data of noise emissions from construction machinery. SAE J88a appears to be a good engineering tool for the manufacturer but no data base yet exists to assure that test procedures suggested in SAE J88a and other (foreign) standards are appropriate for regulatory purposes.

It appears doubtful that proprietary data which have been obtained by the construction industry are sufficiently extensive to provide EPA with even a substantial fraction of the information needed for a comprehensive analysis of the economic costs and technical feasibility associated with a given regulation. Furthermore, it is evident that there are practically no data available upon which to base an evaluation of alternative dozer and loader noise measurement procedures or to establish correlations between the noise associated with various operational modes and the noise measured utilizing various test procedures.

Thus, it appears that EPA will have to generate a rather extensive physical data base and investigate alternative measurement procedures prior to formulation of the Notice of Proposed Rule Making.

8. Overview of Dozer and Loader Noise Measurement Difficulties

The information discussed in Sections 2 through 7 of this report serves as the basis for an overview of dozer and loader noise measurement problems. Utilizing that information with the discussions of this section, potential noise measurement problems that could hinder the promulgation and/or enforcement of future noise regulations to control noise emissions from dozers and loaders are identified.

Prior to the establishment of an appropriate measurement procedure that can be utilized for determining the exterior noise of dozers and loaders, certain informational requirements must be satisfied. These include: (1) a product classification scheme based on where the equipment is used, (2) a product classification and identification scheme indicating which specific pieces of equipment are to be covered, (3) typical work cycle data including the effects of operation and environment on noise levels, and (4) the societal impact of dozer and loader noise on people and the nature of this impact. Such data allow one to select, with confidence, the acoustical quantity to be measured, the operational mode of the vehicle, and the locations for microphones which need to be specified in the regulation. Test site specifications and instrumentation requirements also hinge on the availability of this fundamental information.

8.1. Probable or Potential Measurement Difficulties

The measurement problems which exist in the determination of noise emissions from wheeled and tracked dozers and loaders are extensive and varied. They range from procedural problems -- measurement difficulties, availability of test machinery, costs associated with testing -- to availability of test space.

8.1.a. Representative Noise Regulations

Perhaps the most serious problem is the lack of a data base on typical work cycles with which to facilitate the establishment of proper test procedures. All of the test procedures which exist today appear to be good engineering tools for the manufacturer but unless validated their application to enforcement of noise regulations should be questioned. They all measure noise emissions which represent the higher range of sound levels generated by the machinery under actual field operating conditions. These levels do not necessarily represent the average sound level of the machinery over a field-use cycle.

A philosophy must be developed regarding the quantity to be measured and the rationale behind this philosophy must satisfy the intent of the Noise Control Act of 1972. For instance, if average noise levels are selected, a typical work cycle must be developed. Selection of a typical work cycle will be difficult due to the varied uses of identical equipment. Once measurement procedures are established, a substantial data base is needed.

8.2. Classification

Some of the factors associated with establishment of dozer and loader classes based on engine horsepower have been discussed in Section 2. The main purpose for dozer and loader classification in conjunction with noise regulations is to set different noise limits on different categories of dozers and loaders either because of the potential societal noise impact of a particular class of dozers and loaders or because of economic cost and technological feasibility of noise control as applied to the various classes of dozers and loaders.

At present, reasonable divisions of dozer and loader classes based on use can be made by classification according to horsepower; however, the resultant noise level characteristics of each class over the range of normal operation are not presently known.

8.3. Machines to be Tested

Particular problems in testing may arise due to the nature of the products and the way they are sold. Testing may be difficult for many machines which require final assembly at a facility other than the main manufacturing plant -- such as a dealer's or customer's facility. Reasons for final assembly at other facilities are many and varied -- (1) multi-plant facilities may exist in which all parts are shipped directly to the dealer for final assembly (2) attachments to the base machine may be designed and constructed by an independent manufacturer and installed by the dealer or customer (3) back ordered items may be delivered to the construction site and installed, and (4) some machines may just be too large to be transported by truck or rail when fully assembled. Economic considerations lead to many foreign made machines being shipped unassembled.

Thus, testing at the manufacturer's facility may require expensive assembly and disassembly for large vehicles, and may be impossible or impractical for other unassembled machines. Testing at foreign manufacturing facilities may present audit and control difficulties.

Testing cannot easily be performed on stockpiled vehicles until sale is eminent. Many stored vehicles, for which no immediate sale is assured, are not equipped with tires, blades, buckets, or other attachments. Since tires are quite expensive and deterioration would prevent sale of a tire, special mounts are used to support the machine while in storage. Blades, buckets and other attachments are not installed since their inclusion or not is the decision of the eventual customer.

It should be possible for testing to be performed on the base machine without attachments (but with tires) and meaningful results obtained; however, data are necessary to support this assumption. In general, the effect of an attachment is to slightly shield noise being generated from behind the attachment. With an attachment raised, this shielding would not occur so it is questionable whether more meaningful results would be obtained when the attachment is present. Hydraulic noise emission testing may be hampered, however, if the hydraulic drive equipment is part of the attachment. In some cases, hydraulic drive units are attached to the base machine even though the attachment is not installed. These units could be operated for noise emission testing. The question of whether meaningful data could be obtained with this sort of testing should be explored.

Even testing a base machine (tractor without attachments) for compliance with a regulation may be difficult. Seemingly identical machines may have different components due to geographic availability; especially where foreign counterparts of American machines are manufactured by the same company. These components may change the noise characteristics of the machine. In addition, though basic models may exist for 6-8 years, evolutionary changes are continually being made. After 6 years or so the same machine might be completely different even though it will bear the same model number. Continual monitoring of changes would be necessary to assess the effect on noise emissions.

8.4. Test Site

Test site considerations have both practical and measurement implications. Approximately 1.5 acres of land is needed for an outdoor test site if moving tests are required. If not presently owned, the purchase of this land can be quite costly, especially if the manufacturing facility is in an urban area. Because of transportation problems associated with large equipment, it is desirable to have on-site testing facilities.

In urban areas, manufacturing plants are typically property line-to-property line facilities, that is, no land is available for expansion let alone for noise testing sites. Other industrial activities generally surround the facility, sometimes presenting uncontrollable noise sources which can severely disrupt attempts at testing for noise emissions.

In rural areas land may be available at present but, due to the changing environmental scene, what is rural today may be urban tomorrow. Freeways or other industrial plants may emerge causing the same problems that now exist in urban areas. The manufacturing plants own expansion plans may even have to be altered to facilitate an outdoor area for moving tests.

Exclusive of land, one manufacturer estimates that expenditures of (for paving, measuring equipment, etc.) from $100k - 200k would be needed to develop a test site to comply with SAE J88a requirements. A stationary test requirement would not only cut down costs of site construction and equipment tremendously but more importantly would reduce the necessary land area as well.

A paved surface is presently favored for machine testing. Potentially a paved surface would yield more reproducible results than would be possible over a dirt surface. Testing over paved surfaces typically give higher sound level readings than dirt due to the reflective characteristics of the harder surface but to what extent correlation exists between tests conducted on dirt and tests conducted on paved surfaces is not known at present. The major problems associated with testing over a dirt surface occur due to the everchanging surface conditions caused by previous test vehicle traffic (especially with tracked vehicles) or environmental conditions such as rain or drought which can vary surface conditions. Test results are thus less likely to be reproducible.

In addition, dirt surface testing results in expensive clean-up procedures for tracked vehicles. Before a tracked vehicle can be sold it is necessary to remove all of the dirt and mud which has been compacted between the track and track guides during the noise tests. This job typically takes from three to eight hours per machine. The clean-up job must be thorough since the track area must then be repainted.

There is a great need to explore a variety of proposed test plans -- paved versus dirt, stationary versus moving, etc. -- in order to evaluate the good and bad features of each. One must also consider the future testing needs of the manufacturer. Regulations for other types of construction equipment will undoubtedly emerge. To avoid unnecessary expense to the manufacturer, the testing facility should be large enough to accommodate, and be compatible with, the testing needs of other construction equipment such as scrapers and haulers.

8.5. Quantity Measured

The EPA "levels document" utilizes the equivalent A-weighted sound level as the appropriate quantity to use in characterizing noise exposure. Thus, it would be desirable if the quantity (or quantities) measured in a regulation on a specific noise source, e.g., a dozer or loader could be easily and directly related to the contribution which the source makes to the equivalent A-weighted sound level for typical listeners.

It seems evident that a comprehensive experimental program is needed to guide and justify the development of the measurement procedure -- whether maximum sound levels for several operational modes or an average sound level based on a typical use cycle. The presence of discrete pure tones and/or impulsive component noises typical of dozers and loaders should be examined to aid in determining if these noises should be accounted for.

8.6. Acoustic Environment

There appears to be general agreement that the noise emission from motor vehicles should be measured in a free field over a reflecting plane. If a 50 foot (15.2 m) measurement distance is utilized, a rather large open area is needed plus a roadway of sufficient length to accomodate the specified operational mode(s) of the vehicle.

Although considerable uniformity of testing has been achieved by the SAE and ISO in defining standard noise measurement procedures, there remains a small but important variation between noise measurements made at different sites, or at different times at the same site. Experience to date with measurement of motor vehicle noise at 25 to 50 foot (7.6 to 15.2 m) distances, for typical microphone heights, indicates that the levels measured are sensitive to the characteristics of the surrounding ambient (air temperature, humidity, atmospheric pressure), to the characteristics of the reflecting plane (acoustic impedance, flatness), to temperature gradients above the plane (which depend on present and past air temperatures, sunlight, and wind velocities as well as the emittance and absorptance of the reflecting plane), and to atmospheric inhomogeneities (wind velocity and local turbulance). All of these factors influence the generation of noise by the propulsion system and associated auxiliary equipment, the radiation from the source into the surrounding atmosphere and/or the propagation from the immediate vicinity of the vehicle to the measurement location.

Since these factors influence reliable measurements of many of the sources which EPA is, or will be, regulating, there is a need for the various environmental and site effects to be systematically investigated so that: (1) noise measurements taken at a given site can be corrected to standard environmental conditions, (2) noise measurements taken at different sites under the same environmental conditions can be correlated and therefore (3) noise measurements taken at different sites under any environmental conditions can be correlated. If correction factors are not feasible then there is a need for a site calibration procedure and/or definition of limiting test conditions.

8.6.a. Constructive and Destructive Interference Effects

When stationary mode measurements are performed with fixed source and receiver heights, constructive and/or destructive interference between the direct and reflected signals from the machine noise sources can result in an increase/or reduction of the signal sound level at the location of the receiver, respectively. With a source of large physical size and a wide spectrum of emitted noise the effects of these ground reflections are not as serious as with a small source and a pure tone.

8.6.b. Heat Radiation

Though no data exist in the literature, temperature effects caused by heat radiation from the engine can cause measurement problems during stationary tests. A bubble of hot air can surround the equipment if conditions are right. Wind can shape this bubble in different ways thus causing measurement inconsistencies due to changes in the noise generation mechanisms and noise radiation to the surrounding environment.

8.6.c. Cooling Fan Wind Generation

Another measurement problem can be caused by the cooling fan of the equipment. When measurements are made with a radiator directing the air flow from the cooling fan toward the microphone, air movement can reach high velocities, even at a distance of 50 feet. A study should be made to determine if the velocity of this fan-generated wind is sufficient to hamper the measurement being made.

These are just some of the factors which should be addressed. In general, these are factors over which one has little or no control.

8.7. Instrumentation

The instrumentation section of the regulation should require equipment meeting the Type 1 requirements of American National Standard Specifications for Sound Level Meters, S1.4-1971[27]. In addition, pertinent sections of American National Standard Methods for the Measurement of Sound Pressure Levels, S1.13-1971[28] should be incorporated. For instruments for which standards do not exist, or where existing standards are not sufficient, the regulation should include specific criteria for evaluating the performance of such devices. For example, a critical deficiency in existing standards is that the response of instrumentation to transient signals is not well defined.

It is important to clearly state in the regulation the allowable tolerances for frequency response, environmental effects, harmonic distortion, etc., which the instruments are required to meet. These specifications should be applied not only to specific components of the system but to the overall system as well. Regardless of the instrumentation configuration, the overall system measurement error should not be degraded below that allowed for measurements made directly with a sound level meter.

In addition, overall system calibration should be required at frequent stipulated intervals. The fact that each component of a system appears satisfactory does not ensure that the system performance will be acceptable.

8.8. Current Versus Alternative Test Procedures

8.8.a. Current Test Procedures

The SAE J88a test procedures (which are the only procedures presently utilized in the United States) require a minimum of 34 readings as shown in Table 8. The implementation time for these stationary and moving tests can be reduced somewhat if space and instrumentation is available to place microphones on all four sides and take simultaneous measurements. Though manpower and/or instrumentation requirements are increased substantially testing time could be reduced to a minimum of 10 tests[29].

The low idle-maximum governed speed-low idle test included in SAE J88a is designed to provide a simple stationary test. This test procedure was added to SAE J88a in the hopes that future data obtained from this test would substantiate data that has already been validated for diesel trucks. For trucks, this procedure has been shown to be a repeatable, meaningful, stationary test.

Industry claims that the stationary test modes specified in SAE J88a do not give representative data. They claim that the wide open throttle and low idle-maximum governed speed-low idle test modes may result in governor overshoots resulting in abnormally high engine and fan speed conditions. Correspondingly higher noise emissions result which are not representative of actual use conditions.

A torque converter stall test mode -- which had been specified in previous test procedures but was eliminated from SAE J88a -- could be used to load the engine against the transmission torque converter and replace the wide open throttle and low idle-maximum governed speed-low idle test modes. The main disadvantage of the torque converter stall test mode is that it can not be used on machines with manual transmissions and thus can not be applied uniformly to all loaders and dozers -- a necessity for compliance testing.

With a stationary test, track noise (in the case of tracked vehicles) is of course, not measured. As discussed previously, the technology to quiet track noise is minimal at present. One wonders why, then, it is necessary to measure track noise. If a regulation is based on the maximum measured noise emitted from a machine then the most predominant noise for tracked vehicles would probably be track noise. Other noise emissions would be predominant during stationary modes or low speed operation (i.e., over 60% of the time for a typical operating cycle of a dozer or loader). These

Table 8

SAE J 88a TEST PROCEDURE

RECORD HIGHEST NOISE LEVEL

		NUMBER OF READINGS
STATIONARY 4 SIDES AT 50 FEET	W.O.T. 1 TEST READING EACH SIDE	4
	I.M.I. (IDLE-MAX-IDLE) 3 TEST READINGS EACH SIDE *	12
	ACTUATE HYDRAULICS AT W.O.T. 3 TEST READINGS EACH SIDE *	12
DYNAMIC PASSBY AT 50 FEET RIGHT & LEFT SIDE	W.O.T. IN INTERMEDIATE GEAR, NO LOAD, EMPTY UNIT 3 TEST READINGS EACH SIDE *	6
	TOTAL MINIMUM NUMBER OF READINGS	34

*AVERAGE THE TWO HIGHEST READINGS THAT ARE WITHIN 2 dBA other sources would essentially be unregulated since they would probably be lower than the minimum track noise that can be accomplished by present technology and there would be no incentive to quiet these other sources. It would appear to be more prudent to base a maximum permissible sound level regulation on noise emissions other than track noise until state-of-the-art track noise control is more prevalent and more practical -- noise emissions which could most likely be checked by a stationary test. The overall noise level of the dozer or loader would thus cause less societal impact since the noise level would be lower for 60 percent or more of the time at least.

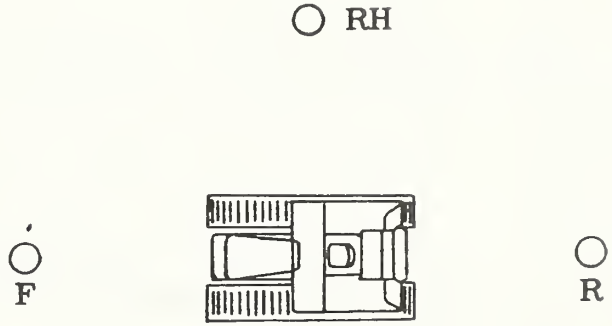
8.8.b. Alternative Test Procedures

The public interest probably could better be served by a simple less costly test than SAE J88a that could be effectively utilized to determine the noise potential of construction machines such as dozers and loaders. Such a test would hopefully better approximate the sound energy emitted under actual working conditions which constitutes a potential impact on the public rather than the single maximum value from SAE J88a which may not be representative of actual working conditions. A simpler test should be more appropriately applicable to a production compliance program.

A simpler test that includes only stationary testing would avoid the large expenses associated with land acquisition and test site preparation. A stationary test suggested by the construction industry[30] involves measuring the noise emissions from a machine while the engine is operating at rated RPM. Measurements made over a standard surface at locations 50 feet (15.2 m) from the right and left of the machine are suggested. Limited data, as shown in Table 9, shows that measurements for the right and left hand sides only will closely approximate the average of all four sides for the machines tested. In addition to reducing the number of measurement positions, the need for attachments, i.e., blades, buckets, etc., to be installed is eliminated. Other limited data[30] indicate that except for track noises, the stationary tests produce higher noise levels than passby tests. These data also show hydraulic noise levels that are consistantly lower than the noise from other components. Industry claims that a stationary test at engine rated rpm approximates actual use conditions better than the tests of SAE J88a. This claim should be verified through an extensive test program.

Though a great need exists for all weather availability of a test facility -- namely an indoor facility which would give a good correlation between experimental and actual use data, the sizes of equipment, in addition to dozers and loaders, which must be accomodated would require prohibitive cost outlays. It should be noted that if the estimation of sound power is deemed appropriate in the case of stationary tests, then the feasibility of utilizing close-in measurements should be evaluated in order to ease the test site requirements. The appropriateness of close-in measurements has been shown to be valid in the case of portable air compressors[31].

Table 9. A-weighted sound levels (dB) measured at a distance of 50 ft (15.2 m) for loaders and crawlers at wide open throttle[27].



	RH	LH	F	R	AVG. 4 READINGS	AVG. RH & LH ONLY
LOADERS:						
A	79.7	78.7	74.1	83.9	79.1	79.2
B	81.5	81.0	77.8	86.0	81.6	81.3
C	86.3	84.7	79.1	90.5	85.2	85.5
CRAWLERS:						
A	81.2	80	82-7	80.5	81.1	80.6
B	88.4	84.4	87.6	93.0	88.4	86.4
C	87.8	87.7	84.2	89.2	87.2	87.8
D	81.0	80.0	78.5	78.7	79.6	80.5
E	84.6	85.0	81.0	83.0	83.4	84.8

9. Appendix A. Existing Loader and Dozer Measurement Procedures[4/]

EXTERIOR SOUND LEVEL MEASUREMENT PROCEDURE FOR POWERED MOBILE CONSTRUCTION EQUIPMENT - SAE J88a SAE Recommended Practice

---

Report of Vehicle Sound Level Committee approved November 1972 and last revised June 1975.

1. SCOPE-This SAE Recommended Practice sets forth the instrumentation and procedure to be used in measuring exterior sound levels for powered mobile construction equipment of 20 rated bhp and over. It is not intended to cover operation of safety devices (such as backup alarms) air compressors, jack hammers, and machinery designed primarily for operation on highways or ily for operation on highways or within factories, aircraft, or recreational vehicles such as snowmobiles and boats. The sound levels obtained by using the test procedures set forth in this SAE Recommended Practice are repeatable and are representative of the higher range of sound levels generated by the machinery under actual field operating conditions, but do not necessarily represent the average sound level over a field use cycle.

2. INSTRUMENTATION

2.1 A sound level meter which meets the Type 1 or S1A requirements of the American National Standard Specification for Sound Level Meters, S1.4-1971.

2.2 As an alternative to making direct measurements using a sound level meter, a microphone or sound level meter may be used with a magnetic tape recorder and/or graphic level recorder or indicating instrument, providing the system meets the requirements of SAE Recommended Practice J184 QUALIFYING A SOUND DATA ACQUISITION SYSTEM.

2.3 An acoustical calibrator (see paragraph 4.2.4 – accuracy within ± 0.5dB).

2.4 A microphone windscreen shall be used that does not permit the effect on the microphone and frequency response to exceed ± 0.5 dB to 5kHz and ± 2.0dB to 12 kHz.

2.5 An anemometer or other device for measurement of ambient wind speed and direction (accuracy within ± 10%).

2.6 A power source rpm indicator (accuracy within ± 2%).

2.7 A thermometer for measurement of ambient temperature (accuracy within ± 1°).

2.8 A barometer for measuring atmospheric pressure (accuracy within ± 1%).

3.1 Test Site – The test area shall consist of a flat open space free of any large reflecting surfaces such as a signboard, building or hillside, located within 30m (100ft) of either the microphone or the machinery being measured (see Fig.1). It is recommended that measurements be made only when the wind speed is below 19 km/h (12 mph).

3.1.1 The minimum measurement area (see Fig. 1) shall consist of the triangle formed by the microphone location, points A & B, and the rectangle formed by points A, B, C & D. Both designated areas shall be smooth concrete or smooth and sealed sphalt or a similar hard and smooth surface. The rectangle formed by points C, D, E & F shall consist of hard-packed earth. The planes between the microphone location and line AB and planes encompassed by points A, B, C, F, E & D shall form a continuous, uniform plane. If a minimum measurement area test site is used, it will require reorientation of the machine for each major surface measurement during the stationary tests, and the moving test will have to be run in two opposite directions. The other option is to have a larger measurement area test site and relocate the microphone for the series of prescribed test conditions with the machine in one position for stationary tests and driving by in only one direction for the moving tests.

3.1.2 Because bystanders have an appreciable influence on the meter response when they are in the vicinity of the construction machinery or

---

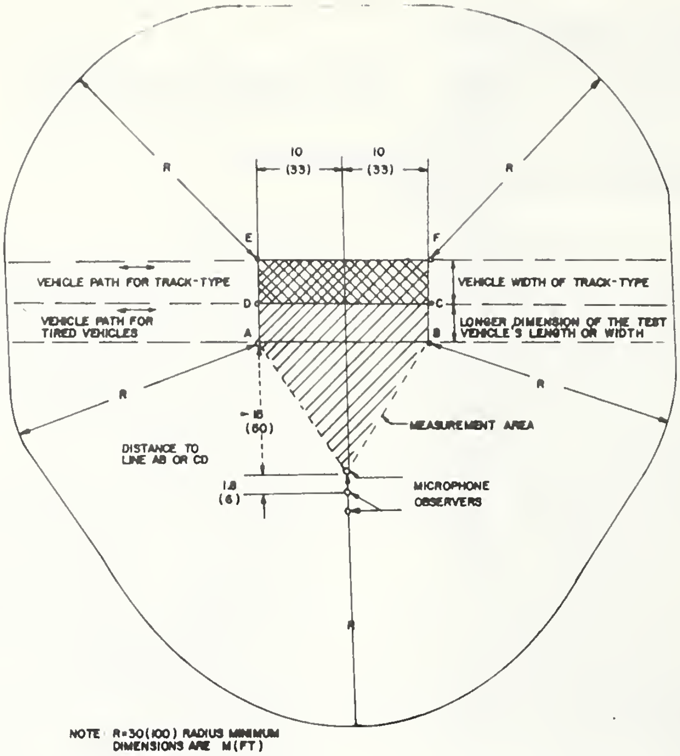


FIG. 1 - TEST SIT CONFIGURATION

microphone, not more than one person, other than the observer reading the meter, shall be within 17m (56 ft) of the construction machinery and 1.8m (6ft) of the measuring microphone, and that person shall be directly behind the observer who is reading the meter, on a line through the microphone and the observer (see Fig. 1).

3.1.3 The ambient sound level due to sources other than the construction machinery being measured (including wind effects) shall be at least 10 dB lower than the sound level of the machinery being measured. (see paragraph 3.3.3).

3.1.4 The surface between and under the construction machinery and microphone shall be smooth and free of acoustically absorptive material, such as snow or grass.

3.1.5 For all stationary tests the machinery shall be located on the hard surface area formed by points A,B,C&D in Fig 1.

3.1.6 Moving Tests

3.1.6.1 For moving tests of all rubber tired machines, the path of travel shall be across the area defined by points A, B, C & D in the directions shown in Fig. 1.

3.1.6.2 For moving tests of all steel wheel, steel drum or track-type of machines the path of travel shall be across the area defined by C, D, E & F in the direction shown in Fig. 1.

3.2 Tests Required

(a) For mobile construction machinery that is used primarily in a stationary mode, test per paragraphs 3.2.1.1, 3.2.1.2, and if applicable 3.2.1.3.

(b) For self-propelled construction machinery that is used primarily in a mobile mode, test per paragraphs 3.2.1.1, 3.2.1.2, 3.2.1.3, and 3.2.2. For construction machines which have an auxiliary power source, such as a truck mounted crane, the main engine and auxiliary engine shall be run separately during tests 3.2.1.1 and 3.2.1.2 with the other engine shut down. During test 3.2.1.3 only the auxiliary engine shall be run and only the main propulsion engine run during the test prescribed in 3.2.2. For combined construction machinery (such as small loader with backhoe) test per paragraphs 3.2.1.1, 3.2.1.2, 3.2.1.3 and 3.2.2.

3.2.1 Stationary Tests with Ground Propulsion Transmission Shift Selector in Neutral Position.

3.2.1.1 Operate all mobile construction machinery engines at no load with all component drive systems in neutral position and maximum governed speed (high idle at no load) at a stabilized condition.

3.2.1.2 Operate all mobile construction machinery engines at no load with all component drive systems in neutral position through the cycle "low idle-maximum governed speed (high idle at no load) low idle" as rapidly as possible, but allowing the engine to stabilize for at least 10 sec at maximum governed/ speed (high idle at no load) before it is permitted to return to low idle.

3.2.1.3 With the engine at the maximum governed speed (high idle at no load) in a stabilized condition, activate the appropriate hydraulic circuits, mechanical, electrical, hydrostatic, or torque converter drive systems to cycle the major components or component from the most retracted and/or lowered position to fully extended and/or maximum height position and then back to orginal position. This cycling should be done as fast as practical, taking into consideration all the pertinent safety factors/that can be accomplished without blowing relief valves. For safety reasons and undesirability of change of location of major noise source in relation to microphone, a major portion of the mobile machine, such as the tractor of a scraper unit, drum of a compactor, or the upper rotational structure of an excavator, shall not be moved or placed in a vibratory mode of operation during this stationary machine test.

3.2.2 *Constant speed moving Test* – Self-propelled construction machinery shall be operated in a forward intermediate gear ratio at no load at a location as specified in paragraphs 3.1.6.1 or 3.1.6.2. The power source shall be operated at full governor control setting. Intermediate is intended to mean second gear ratio for machines with three or four gear ratios, third gear ratio for machines with five or six gear ratios. fourth gear ratio for machines with seven or eight gear ratios, etc. (Gear ratio refers to overall gear reductions.) If there is a problem with the transmission shifting up or down in this phase of this test, one gear lower or higher may be used to eliminate the problem. Hydrostatic or electric drive machinery will be operated as near as possible to one-half its maximum ground speed. Machinery that has major noise-generating components which could be used at the above ground speed, such as on an elevating scraper or on a vibrating compactor, shall have these major components in operation during this moving test.

3.2.3 Construction machinery that has a major attachment that is normally used for the main operating function shall be equipped with this attachment. Examples of this are buckets on loaders and dozers on either wheel or track-type tractors. For all tests these attachments shall be in a minimum transport position of 0.15m (6 in) to 0.3 m (12 in) for dozers, scrapers, etc., and for loaders use carry position as specified by SAE Standard J732 SPECIFICATIONS DEFINITIONS-FRONT END LOADER.

3.3 MEASUREMENTS

3.3.1 The microphone shall be located at a height of 1.2m (4 ft) above the ground plane.

3.3.2 The sound level meter shall be set for slow response and the A-weighting network.

3.3.3 The ambient wind speed and direction, ambient temperature, atmospheric pressure, and ambient A-weighted sound level shall be measured and recorded at the height of 1.2m (4 ft) and within at least 3m (10 ft) of the one specified location of the microphone as shown in Fig. 1.

3.3.4 The stabilized maximum governed engine speed shall be measured and recorded.

3.3.5 The sound level meter needle movement shall be observed during each test sequence at the specified microphone location. The highest value observed, disregarding sounds of short duration that are out of character with the test on the machine, (example) impact sound such as bucket rack against stops, shall be recorded for each test sequence. For stabilized test conditions (3.2.1.1) a single reading shall be recorded for each measurement point. For cycling and moving test conditions (3.2.1.2, 3.2.1.3 and 3.2.2) a minimum of three readings shall be taken for each measuring point. If none of these readings are within 2 dB of each other, then additional readings shall be taken until there are two that are within 2 dB of each other. The reported value shall be the average of these two values that are within 2 dB of each other. If there are two pairs of readings that are within 2 dB of each other, report the average of the higher pair. The final reported result for each test mode shall be the highest reading for stabilized test conditions and the highest average for the cyclic or moving tests and must include the location of the microphone.

3.3.6 For stationary tests, record the sound level obtained at a distance of 15m (50 ft) normal to the centers of the four major surfaces of the equipment at the microphone height. Generally, four major surfaces refer to front, rear, and sides of an imaginary box that would just fit over the machine but does not include attachment items such as buckets, dozers, and booms (see Fig. 2). In the case of a crane or an ex-

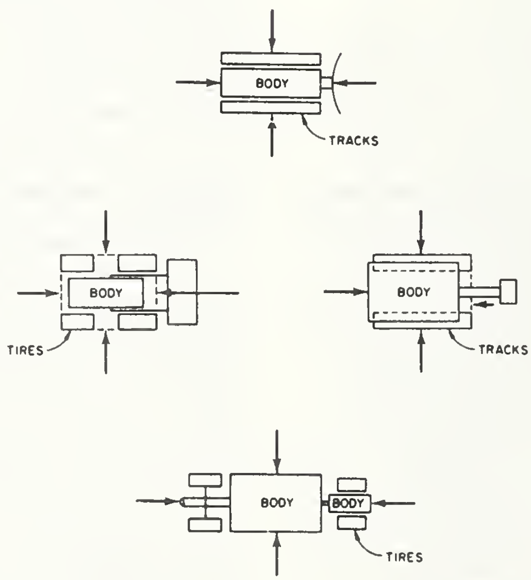


FIG. 2 - MAJOR SURFACE OUTLINES

cavator, the upper (revolving superstructure) fore-and-aft centerline should be in line with the lower fore-and-aft centerline. Operate the machine in a manner as specified in paragraphs 3.2.1.1, 3.2.1.2 and 3.2.1.3.

3.3.7 For moving tests, take measurements at a distance of 15m (50 ft) measured in a direction normal to a major side surface which is parallel to the machine path, as shown in Fig. 1. Operate the machine in a manner specified in paragraph 3.2.2.

3.3.8 The final reported sound level per this SAE Recommended Practice shall be the highest of the reported values obtained in paragraphs 3.3.6 and 3.3.7; the test report shall include the test mode, the machine operating conditions during the reported test mode, the stabilized maximum governed engine speed, the location of the microphone in relation to the construction machine, the surface description over which the machine operated and the sound level measurements were made.

4.1 It is recommended that persons technically trained and experienced in the current techniques of sound measurements select the instrumentation and conduct the tests.

4.2 Proper use of all test instrumentation is essential to obtain valid measurements. Operating manuals or other literature furnished by the instrument manufacturer should be referred to for both recommended operation of the instrument and precautions to be observed. Specific items to be considered are:

4.2.1 The type of microphone which shall be oriented with respect to the source so that the sound strikes the diaphragm at the angle for which the microphone was calibrated to have the flatest frequency response characteristic over the frequency range of interest.

4.2.2 The effects of ambient weather conditions on the performance of all instruments (for example: temperature, humidity, and barometric pressure). Instrumentation can be influenced by low temperature, and caution should be exercised.

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

4.2.4 Proper acoustical calibration procedure, to include the influence of extension cables, etc. Field acoustical calibration shall be made immediately before and after each test sequence of a piece of construction machinery.

5. REFERENCES

5.1 ANSI S1.1-1960 (R1971), Acoustical Terminology

5.2 ANSI S1.2-1962 (R1971), Physical Measurement of Sound

5.3 ANSI S1.4-1971, Specification for Sound Level Meters

5.4 ANSI S1.13-1971, Methods for the Measurement of Sound Pressure Levels

5.5 ISO R362, Measurement of Noise Emitted by Vehicles

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

5.7 SAE Standard J732c-Specification Definitions-Front End Loader

5.8 C.A.G.I. - PNEUROP Test Code for Measurement of Sound for Pneumatic Equipment

Applications for copies of ANSI and ISO documents should be addressed to:

American National Standards Institute, Inc.
1430 Broadway
New York, New York 10018

Official Journal of the French Republic

2 May 1972 Pages 4535-4536

LIMITATION OF THE SOUND LEVEL OF AIRBORNE NOISE EMITTED BY INTERNAL COMBUSTION ENGINES IN CERTAIN CONSTRUCTION EQUIPMENT

In view of the decree No. 69-380 of April 18, 1969 relative to the soundproofing of construction equipment;

And in view of the order of 25 October 1962 relative to the measurement of noise produced by automotive vehicles,

Now all proclaim:

Article 1 - All construction equipment equipped with internal combustion engines, other than automotive vehicles coming under the requirements of the order of October 25, 1962 mentioned above, if manufactured or imported more than one year following the effective date of this order, may be used on construction sites, whether public or not, only if they are equipped with devices to quiet the intake and exhaust of the engines.

The airborne noise produced by the engines of this equipment, measured as prescribed in the accompanying annex, shall not exceed 80 dB(A) at a distance of 7 meters. Derogations can be granted by the Minister for the Protection of Nature and the Environment, however, for a period of, at most, one year.

Article 2 - Construction equipment with internal combustion engines, manufactured or imported before the effective date of the requirements of the first paragraph of article 1 above, may be used at locations less than 50 meters from buildings used as dwellings, or for work, or reserved for any other human activity only if:

They are fitted with devices to quiet the intake and exhaust of the engines within two years after the effective date of the present order; and

They meet the requirements of the second paragraph of article 1 within five years after the effective date of the present order.

Article 3 - Interministerial orders can define, for different categories of construction equipment and operating conditions, the permissible *overall* sound levels; the sound levels fixed by article 1 above refer only to the noise of the internal combustion engines.

In this case, the measurements of noise produced by the engines alone, prescribed in article 4 will not be necessary.

Article 4 - Construction equipment such as described in article 1 will be certificated as to their sound output by the Minister for the Protection of Nature and the Environment.

This certification is to be based on measurements of the sound output carried out, according to the method prescribed in the accompanying annex, by laboratories approved for this purpose by the Minister for the Protection of Nature and the Environment.

The certification is made either by type or for individual items of equipment. For engines that can be adapted to various items of construction equipment without modification of their intake and exhaust silencers, the certification can be issued by type for the engine itself, rather for each item of construction equipment on which it is used.

Manufacturers and importers of construction equipment should address their requests for certification to approved laboratories, who will forward them, along with the measurement results, to the Minister for the Protection of Nature and the Environment.

Manufacturers and importers must furnish with the equipment a certificate of certification or an affidavit of conformity with a certificated model, according to a form given in the annex to this order.

Article 5 - Laboratories wishing to conduct sound output measurements in accordance with this order should request that they be approved for this purpose by the Minister for the Protection of Nature and the Environment, and should furnish detailed information on their facilities and measurement capabilities. Such approval will be pronounced, if it is given, by a decree of the Minister. It can be withdrawn at any time, upon notification of the interested laboratory on the same form, without previous notice or compensation.

Article 6 - The components of the equipment envisaged in article 1, and particularly the silencing devices and their protective covers, must be maintained in good condition or replaced if necessary, in order that the noise emitted by said equipment does not exceed the levels prescribed in article 1.

Article 7 - The present order will be published in the Official Journal of the French Republic. Signed on 11 April 1972, in Paris [by the ministers named at the beginning or their delegates].

ANNEX to the Order of 11 April 1972 relative to the limitation of the sound level of noises emitted by internal combustion engines of certain construction equipment.

RECOMMENDATIONS FOR DETERMINING THE AIRBORNE NOISE EMITTED BY INTERNAL COMBUSTION ENGINES OF CERTAIN CONSTRUCTION EQUIPMENT

The present Recommendation establishes the method for determining the airborne noise emitted by internal combustion engines of certain construction equipment. It also defines how to analyze the test data and how to present the results.

1. *Measurement Apparatus*

The measurements shall be made with a sound level meter and associated microphone meeting the requirements of French National Standard S 31 009. The measurements should be made with A-weighting and slow dynamic characteristic. The apparatus should be suitably calibrated.

2. *Environment for the Tests*

The equipment shall be set up in an open area. No large object, such as buildings or machines, should be located within 25 meters of the equipment under test; if this is impossible, their position should be described in the test report.

The equipment shall be placed on a hard reflecting surface, of concrete or impervious asphalt, whose diameter is such that the microphone positions, defined in paragraph 5 below, all lie within this surfaced area. The microphone should not be near any reflecting surface. The operators and the test equipment should be located at least 1 meter from both the microphone and the equipment under test. The measurements should be made with little or no wind.

3. *Background Noise Level*

The conditions for measuring the background noise and the corresponding corrections to be subsequently applied to the test data are prescribed by paragraph 6.3 of the French National Standard S 30 006 (June 1966).

4. *Operation of the Equipment Under Test*

The Equipment under test shall be brought up to temperature and operated in a stable regime.

The measurements should be made with no load, but with the governor or speed control set to give maximum full-load speed, as specified by the manufacturer.

5. *Location of the Measurement Positions*

Readings of the sound level should be made at four points around the engine, at a distance of 7 meters from the engine casing or the sides of the equipment that take its place, and at a height of 1.50 meters above the ground.

The four points should be situated on two perpendicular axes; if the engine axis is horizontal, one of the measurement axes should be parallel to it.

6. *Interpretation of the Results*

The value retained to characterize the noise of the engine should be the highest sound level recorded.

In case that value should be slightly higher than the maximum permissible value, a second measurement should be made at the location in question. If the result of the second measurement exceeds the value prescribed in article 1, the equipment will be deemed not to conform to the requirements of the present order.

7. *Presentation of Results*

The test report shall give the following information:

a. Description of the equipment and test conditions (Mark, model, serial number, principal dimensions and operating conditions of the engine, atmospheric conditions at the time of the test).

b. Sketch indicating the test area and showing the location of the measurement positions, as well as the direction and distance of any large objects within 25 meters of the engine under test.

c. Mark, model and serial number of the acoustical measuring equipment used, including the windscreen if necessary.

d. Background noise level.

e. A-weighted sound levels for the four measurement points.

AFFIDAVIT

of Conformity of construction equipment equipped with one or more internal combustion engines with a certificated model (Applies to the order of 11 April 1972)

The undersigned company (1) ______________________________ certifies that the construction equipment hereafter designated:

____

Mark: __________ Type: __________ Serial Number: ______________________

Type of engine in the equipment: ______________ Maximum effective sound level: ____________ conforms to the model tested for certification No. ______________________ dated ________________ in compliance with the requirements of the order of ________________________________ relative to the limitation of the sound level of noises emitted by internal combustion engines in certain construction equipment.

Signature __________________________________

Date ______________________________________

(1) The trade name and the main office address of the company should be given.

10. References

1. Patterson, W. N. and Freeze, T., Traction Vehicles: Noise and Cost of Abatement, (Bolt Beranek and Newman, Inc.) Report No. 2566b submitted to the Environmental Protection Agency, Washington, D. C., January 1974.

2. Anon., A study to determine the Economic Impact of Noise Emission Standards in the Construction Equipment Industry, (Traction Vehicle Report by A. T. Kearney, Inc.) submitted to the Environmental Protection Agency, Washington, D. C. August 1974.

3. Identification Terminology of Earthmoving Machines - SAE 1057b, SAE Standard (Society of Automotive Engineers, Warrendale, Pa.) June 1975.

4. SAE Standard J173, Specification Definitions - Dozers, (Society of Automotive Engineers, Warrendale, Pa.) May 1970.

5. SAE Standard J731c, Nomenclature - Loader (Front End) (Society of Automotive Engineers, Warrendale, Pa.) May 1968.

6. SAE Standard 732c, Specification Definitions - Front End Loader, (Society of Automotive Engineers, Warrendale, Pa.) October 1968.

7. Cherne, K. D., Senior Project Engineer, Vehicular Noise Control, (General Motors Corporation), Private Correspondence, August 22, 1975.

8. Anon., Spectator Sound Level Test Data, Proposed Equipment Classification, Proposed Spectator Sound Levels for Mobile Earthmoving Equipment, (Caterpillar Tractor Co.) Internal report submitted to the Environmental Protection Agency, Washington, D. C. October 1973.

9. Nagel, A. E., A Noise Control Study of Certain Construction Equipment Vehicles, (Mining Enforcement and Safety Administration, Pittsburgh, Pa.).

10. Giovanetto, J., Reducing Noise After the Fact, Automotive Engineering, Vol. 20, No. 9, September 1972.

11. Jenkins, S. H. and Kuebner, H. K., Lowering Diesel Noise Through Hardware Modifications, Automotive Engineering, Vol. 81, No. 6, June 1973.

12. Jenkins, S. H., Lalor, N., and Grover, E. C., Diesel Engine Noise Can be Reduced, Automotive Engineering, Vol 81, No. 1, January 1973.

13. Tiede, D. D., and Kabole, D. F., Quieting the Diesel with Structural Changes, Automotive Engineering, Vol. 80, No. 12, December 1972.

14. Stephenson, N. J., and Thomas, I. D. A., Reduction of Noise from Construction Machines with Particular Reference to Cooling Systems, Noise Control and Vibration Reduction, February, 1975.

15. Anon., Sound Reduction Application, 72-71 and 72-81 Loader, (Terex Division of General Motors, Hudson Ohio), Pub. 72SP20.

16. Anon., Sound Reduction Application, 72-21, 31, 41, 51 Loader (Terex Division of General Motors), Hudson, Ohio, Pub. 72SP19.

17. Anon., Sound Reduction Application, Crawlers, (Terex Division of General Motors), Hudson, Ohio, Pub. 72SP18.

18. Sanders, C. E., A Contractors Approach to Noise Control of Off-Road Vehicles, Noise Con 73 Proceedings, Institute of Noise Control Engineering, Washington, D. C., October 1973.

19. SAE Recommended Practice J88a, Exterior Sound Level Measurement Procedures for Powered Mobile Construction Machinery (Society of Automotive Engineers, Warrendale, Pa.) September 1974.

20. 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 au Bruit - No1383, Edition mise a jour au 15 aout 1972, Journal Officiel de la Republique Francoise, 26, rue Desaix, 75732 Paris, CEDEX 15, France.

21. German Regulation, Noise Limits for Track Type Tractors (currently being revised) (Tiefdau-Berufsgenossenshaft, 8 Munchen 60 Am-Knie 6, Germany).

22. German Regulation, Noise Limits for Wheel Loaders (currently being revised) (Tiefdau-Berufsgenossenshaft, 8 Munchen 60 Am-Knie 6, Germany).

23. ISO Draft Proposal for Acoustics - Determination of Airborne Noise Emitted by Earth Moving Machinery to the Surroundings - Survey Method, Draft Proposal ISO/TC43/SC 1 (Secretariat -190) 260, December 1974.

24. Acoustical Society of America Standard, Test-Site Measurement of Noise Emitted by Engine Powered Equipment, ASA STD 3-1975 (Acoustical Society of America, New York, New York) 1975.[5/]

25. International Organization for Standardization draft proposal, Acoustics - Determination of Airborne Noise Emitted by Civil Engineering Equipment for Outdoor Use, ISO/TC43/SC1 (Secretariat - 191) 261.

26. International Organization for Standardization draft international standard, Acoustics - Determination of Sound Power Levels of Noise Sources - Engineering Methods for Free Field Conditions Over a Reflecting Plane, ISO/DIS 3744.

[5/] ASA 3-1975 was submitted to the American National Standards Institute for approval for publication as ANSI S1.19 but was rejected in its present form.

27. American National Standard, Specifications for Sound Level Meters, ANSI S1.4-1971 (American National Standards Institute, New York, New York) 1971.

28. American National Standard, Methods for the Measurement of Sound Pressure Levels, ANSI - S1.13-1971 (American National Standards Institute, New York, New York) 1971.

29. Bergsten, L. D., Exterior Sound Level Measurement Procedure for Powered Mobile Construction Equipment, Noise Con 73 Proceedings, Institute of Noise Control Engineering, Washington, D. C., October 1973.

30. Cherne, K. D., Senior Project Engineer, Vehicular Noise Control, (General Motors Corporation), Private Correspondence, June 27, 1975.

31. Holmer, C. I., Procedures for Estimating Sound Power From Measurements of Sound Pressure: An Experimental Investigation with Application to Noise from Portable Air Compressors, NBSIR 75-652, EPA-550/8-76-001, National Bureau of Standards, Washington, D. C., November 1975.

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 75-965	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE An Evaluation and Assessment of Existing Data and Procedures for the Measurement of Noise from Dozers and Loaders			5. Publication Date Oct. 1975
			6. Performing Organization Code
7. AUTHOR(S) Thomas L. Quindry			8. Performing Organ. Report No. NBSIR 75-965
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			10. Project/Task/Work Unit No. 2000451
			11. Contract/Grant No.
12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)* U. S. Environmental Protection Agency Washington, D. C. 20460			13. Type of Report & Period Covered final
			14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report reviews existing construction equipment noise measurement procedures with regard to their usefulness in the regulation of noise from dozers and loaders as well as the availability, extent and applicability of existing data. On the basis of this review, probable or potential measurement difficulties are identified that could hinder the promulgation and/or enforcement of future EPA regulations to control the noise emission from dozers and loaders.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Acoustics (sound); dozer; loader; measurement methodology; noise emission standard, noise measurement.

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
[ ] Unlimited [X] For Official Distribution. Do Not Release to NTIS	UNCLASSIFIED	46
[ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13 [ ] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price