N-96-01
II-A-22

550/9-74-014

PORTABLE AIR COMPRESSOR NOISE CONTROL TECHNOLOGY AND COST INFORMATION

SEPTEMBER 1974

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

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PREPARED BY

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List of Unit Conversion Factors

To convert from	to	multiply by
cubic feet per minute (cfm)	cubic meters per minute (m^3/m)	.00283
meters (m)	feet (ft)	3.28
kilometers per hour (km/hr)	miles per hour (mi/hr)	0.62
pounds per square inch (psi)	kilograms per square centimeter (kg/cm^2)	0.07

Section 1
PROLOGUE

STATUTORY BASIS FOR ACTION

Through the Noise Control Act of 1972 (86 Stat. 1234), Congress established a national policy "to promote an environment for all Americans free from noise that jeopardizes their health and welfare." In pursuit of that policy, Congress stated in Section 2 of the Act "while primary responsibility for control of noise rests with State and local governments, Federal Action is essential to deal with major noise sources in commerce, control of which requires National uniformity of treatment." As part of this essential Federal action, subsection 5(b)(1) requires that the Administrator of the U. S. Environmental Protection Agency, after consultation with the appropriate Federal agencies, publish a report or series of reports "identifying products (or classes of products) which in his judgment are major sources of noise." Section 6 of the Act requires the Administrator to publish proposed regulations for each product identified as a major source of noise and for which in his judgment noise standards are feasible. Such products fall into various categories, of which construction equipment is one. Pursuant to Subsection 5(b)(1), the Administrator has published a report identifying portable air compressors as a major source of noise.

PREEMPTION

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

Section 6(e)(1) forbids state and local municipalities from controlling noise from products through laws or regulations that prohibit the sale (or offering for sale) of new products for which different Federal noise emission standards have already been promulgated. States and localities may augment the enforcement duties of the EPA by enacting a regulation identical to the Federal regulation, since such action on the state or local level would assist in accomplishing the purposes of the Act. Further, state and local areas may regulate noise emissions for all new products for which Federal regulations have become effective but that were manufactured before the effective date of the regulations.

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

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

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

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

- Quantitative limits on environmental noise received in specific land use zones, as in a quantitative noise ordinance.
- Nuisance laws amounting to operation or use restrictions.
- Regulations limiting the amount of environmental noise at the boundary of the construction site.
- Other similar regulations within the powers reserved to the states and localities by Section 6(e)(2).

In this manner, the local areas may balance the issues involved and can arrive at a satisfactory environmental noise regulation that protects the public health and welfare as much as deemed possible.

LABELING

The enforcement strategies outlined in Section II of this document will be accompanied by the requirement for labeling products distributed in commerce.

The label will provide notice to a buyer that a product is sold in conformity with applicable regulations. A label will also make the buyer and user aware that the air compressor possesses noise attentuation devices and that such items should not be removed or rendered inoperative. The label may also indicate the associated liability for such removal or tampering.

LOW NOISE EMISSION PRODUCTS (LNEP)

Section 15 of the Noise Control Act of 1972 established a process under which the Federal Government will give preference in its purchasing to products having noise emissions significantly lower than those required by the Federal noise source emissions standards promulgated pursuant to Section 6 of the Act. A new part 203 of Title 40 of the Code of Federal Regulations (40 CFR 203.1 through 203.8) was established in the Federal Register on February 21, 1974.

The Environmental Protection Agency will establish and issue the LNEP criteria for portable air compressors prior to promulgation of a regulation for same.

IMPORTS

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

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

Section 2

RATIONALE FOR REGULATION OF THE PORTABLE AIR COMPRESSOR

To develop an EPA criterion for identifying products as major sources of noise, first priority was given to those products that contribute most to overall community noise exposure. Community noise exposure is defined as that exposure experienced by the community as a whole as the result of the operation of a product or group of products, as opposed to that exposure experienced by the users of the product(s).

In this section, it is shown that while portable air compressors may not provide the highest sound level at construction sites, they do contribute significantly to community noise exposure, thus justifying their regulation. Air compressors rank with dump trucks and concrete trucks in producing the highest sound energy per day.

In terms of assesment, community noise exposure was evaluated in terms of the day/night equivalent sound level (L_{dn})[1] that was developed especially as a measure of community noise exposure. Since L_{dn} is an equivalent energy measure, it can be used to describe the noise in areas in which noise sources operate continuously or in which sources operate intermittently but are present enough of the time to emit a great deal of sound energy in a 24-hour period.

Studies have been made of the number of people exposed to various levels of community noise.[2,3] Table 2-1 summarizes the estimated number of people in residential areas subjected to urban traffic noise, aircraft noise, construction site noise, and freeway traffic noise at or above an outdoor L_{dn} of 60, 65, and 70 dB, respectively.

Since EPA has identified an outdoor L_{dn} of 55 dB[1] as the day/night equivalent sound level requisite* to protect the public from long-term adverse health and welfare effects in residential areas, Table 2-1 indicates that it will be necessary to quiet the major sources contributing to urban traffic noise, construction site noise, freeway traffic noise, and aircraft noise if this level is to be achieved.

Table 2-1

ESTIMATED NUMBER (In Millions) OF PEOPLE IN RESIDENTIAL AREAS SUBJECTED TO DIFFERENT KINDS AND LEVELS OF OUTDOOR NOISE

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

IDENTIFICATION OF MAJOR SOURCES

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

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

Aircraft are, pursuant to Section 3(3)(A), excluded as products under

*Without consideration of the cost and technology involved to achieve an L_{dn} of 55 dB.

Section 6 of the Act. Aircraft noise regulations will be proposed to the FAA as delineated in Section 7 of the Act. Medium and heavy duty trucks contribute the most sound energy to the environment of any highway vehicle, and as such, have been identified as major noise sources for regulation. Consequently, in view of the foregoing and data contained in Table 2-1, attention is focused on construction site noise.

CONSTRUCTION EQUIPMENT

The sound level of a product and the level of background noise determine the intrusiveness of a product's sound emission, which has been shown to determine annoyance in some situations. Table 2-2 indicates that pile drivers and rock drills are perceived as the loudest pieces of construction equipment when they are operating, but the sound energy measure indicates that these

Table 2-2

TYPICAL CONSTRUCTION SITE EQUIPMENT SOUND LEVELS(in dBA) AND ASSOCIATED SOUND ENERGY (in KW-hrs/Day)

Construction Equipment	Typical Sound Level at 50 Feet	Estimated Total Sound Energy
1. Dump Truck	88	296
2. Portable Air Compressors	81	147
3. Concrete Mixer (Truck)	85	111
4. Jack Hammer	88	84
5. Scraper	88	79
6. Dozer	87	78
7. Paver	89	75
8. Generator	76	65
9. Pile Driver	101	62
10. Rock Drill	98	53
11. Pump	76	47
12. Pneumatic Tools	85	36
13. Backhoe	85	33

products do not contribute, today, as much sound energy to the environment as other products operating on construction sites. The fact that dump trucks, portable air compressors, and concrete mixers (trucks) produce sound levels equal to or lower than other construction equipment and yet produce higher total sound energy emissions means that these are the most widely used pieces of construction equipment.

A control technology report[14] on dump trucks and concrete mixers indicates that their contribution to construction site noise is largely engine related noise that will be controlled when these trucks meet the standards to be proposed for medium and heavy duty trucks. This leaves portable air compressors as the major source of sound energy and the most widely used product among pieces of equipment contributing to construction site noise. This is further confirmed by the data contained in Tables 2-3 and 2-4, which show that portable air compressors contribute significantly to construction site noise.

Table 2-3 shows the contribution to construction site L_{dn} by individual pieces of construction equipment, while Table 2-4 shows the ranking of portable air compressor noise to construction site noise relative to other pieces of equipment. As shown by the tables, the portable air compressor ranks high on the list of contributors to construction site L_{dn}.

Table 2-3

CONTRIBUTION TO CONSTRUCTION SITE L_{dn} BY INDIVIDUAL PIECES OF CONSTRUCTION EQUIPMENT

Construction Equipment	Per Cent Contribution to Construction Site L_{dn}			
	Residential	Public Works	Industrial	Non-Residential
Backhoe	6.2	2.1	7.1	3.6
Dozer	10.5	7.0	9.1	5.0
Grader	2.1	2.0	0.3	0.2
Loader	2.3	1.1	1.4	0.8
Paner	2.6	10.6	1.8	0.8
Roller	0.1	0.4	-	-
Scraper	3.3	5.1	1.8	1.8
Shovel	2.5	1.0	2.6	1.2
Truck	7.3	22.2	11.5	6.8
Concrete Mixer	29.7	9.0	9.6	6.6
Concrete Pump	- *	-	2.0	2.2
Crane, Derrick	-	1.8	1.8	3.2
Crane, Mobile	6.2	0.7	1.1	2.0
Air Compressor	5.0	6.1	10.7	17.8
Generator	2.0	2.7	1.2	2.7
Pump	1.4	2.9	-	3.6
Jack Hammer	0.8	9.0	5.4	2.7
Pile Driver	-	-	19.4	24.6
Pneumatic Tool	11.5	1.4	6.5	3.4
Rock Drill	2.5	14.0	5.3	5.1
Concrete Vibrator	4.6	-	0.6	0.4
Saw	-	0.2	0.9	5.6

* A dash (-) indicates the equipment is not primarily used at the type of site cited.

TABLE 2-4

CONTRIBUTION OF PORTABLE AIR COMPRESSOR NOISE TO CONSTRUCTION SITE NOISE

Site	% Contribution to the Construction Site Noise by the Portable Air Compressor	Rank at Site
Residential	5.0	7th
Public Works	6.1	7th
Industrial	10.7	3rd
Non-Residential	17.8	2nd

Section 3
BACKGROUND INFORMATION

The sections of this report that follow summarize the background information accrued to date by the Environmental Protection Agency's Office of Noise Abatement and Control in regard to the proposed noise emission regulation for portable air compressors. The regulation will be requisite to protect the health and welfare of the American public, taking into account the degree of noise reduction achievable through the best available technology and the cost of compliance.

The information has been derived from numerous sources. EPA contracted with Bolt, Beranek and Newman (BBN), an acoustical consulting firm; and A. T. Kearney, Management Consultants; utilized the data gathering and information collecting capabilities of Informatics, Inc.; and developed an interagency agreement with the National Bureau of Standards (NBS) for technical assistance. BBN provided cost and technology support;[5,6,7] A.T. Kearney Management Consultants provided economic analysis support;[8] Informatics, Inc. submitted reports addressing United States and foreign regulations relating to construction equipment and portable air compressors,[9,10] and NBS provided technical support in the development of methodology to test and measure portable air compressors.[11]

EPA and contractor personnel made several visits to compressor manufacturers, distributors, and users to obtain the most accurate information available for use in the development of the proposed portable air compressor regulation. NBS personnel held two meetings with industry technical experts to discuss and exchange information on measurement methodology.

The EPA also published an Advance Notice of Proposed Rulemaking (ANPRM) in the Federal Register on February 27, 1974.[12] The ANPRM notified the public that EPA planned to set noise emission standards for portable air compressors under the authority contained in Sections 5 and 6 of the Noise Control Act of 1972. As a result of the publication of the ANPRM, a docket was established (Docket No. ONAC 74-1) to receive comments and data from interested parties. EPA suggested 23 areas of information that those responding might want to address.

The docket closed on March 29, 1974. By the closing deadline, comments were received from the following individuals or organizations.

1. Alabama Tire Dealers and Retreaders Associations.
2. Bureau of Noise Abatement, Department of Air Resources, Environmental Protection Administration, The City of New York.
3. .P.K. Lindsay Company, Inc.
4. Department of Environmental Conservation, State of New York.
5. World Construction Magazine.
6. Robert Beggs.
7. Environmental Activities Staff, General Motors Corporation.
8. Cummins Engine Company, Inc.
9. Portable Compressor Division, Ingersoll-Rand Company.
10. Compressed Air And Gas Institute (CAGI).

The docket responses appear in Appendix A.

Section 4

THE INDUSTRY AND THE PRODUCT

GENERAL DESCRIPTION

Noise associated with construction has become a major problem in many cities and towns. The trend toward urban renewal and more highrise structures has created an almost perpetual din in city streets. Equipment associated with construction sites has become more numerous, and the time span for construction at a given site has lengthened. Residents in proximity to a high-rise construction site may well plan on 2 years of intolerable noise levels as the structure is built.

The basic unit of construction activity is the construction site, which exists in both space and time. The temporal dimension consists of various sequential phases that change the character of the site's noise output as work progresses. These phases are discussed further below. In the case of building construction, the spatial character of the site is self-evident.

Construction sites are typically classified in the 15 categories in which construction data is reported by the U.S. Bureau of the Census and various state and municipal bodies. The categories are:

- Residential buildings:
  - One to four family
  - Five family and larger
- Nonresidential buildings:
  - Office, bank, professional
  - Hotel, motel, etc.
  - Hospitals and other institutions.
  - Schools.
  - Public works buildings.

Industrial.

Parking garages.

Religious.

Recreational.

Store, mercantile.

Service, repair station.

- Municipal Streets
- Public Works (e.g., sewers, water mains).

For purposes of allocating construction effort among the different types of sites, it is possible to group the nonresidential sites into four larger categories differentiated by the cost of the average building in each category, as well as by the distribution of effort among the various construction phases. These four groups, in order of decreasing average cost per building, are:[2]

- Office buildings, hospitals, hotels
- Schools, public works buildings
- Industrial buildings, parking garages
- Stores, service stations, recreational buildings, and religious buildings

Construction is carried out in several reasonably discrete steps, each of which has its own mix of equipment and, consequently, its own noise characteristics. The phases (some of which can be subdivided) are:

- Building Construction

  1. a. Clearing
     b. Demolition
     c. Site preparation
  2. Excavation
  3. Placing foundations
  4. a. Frame erection
     b. Floors and roof

c. Skin and windows

5. a. Finishing

b. Cleanup

- City Streets
  1. Clearning
  2. Removing old roadbed
  3. Reconditioning old roadbed
  4. Laying new subbase, paving
  5. Finishing and cleanup
- Public Works
  1. Clearing
  2. Excavation
  3. Conpacting trench floor
  4. Pipe installation, filling trench
  5. Finishing and cleanup

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

1. Earthmoving equipment (highly mobile)
2. Handling equipment (partly mobile)
3. Stationary equipment. The air compressor is in the latter category.

Typical average noise levels[2] at construction site boundaries are shown in Table 4-1 for each phase of construction activity by construction type category.

It may be generally agreed that construction site noise can be alleviated by reducing the noise levels of the individual pieces of equipment employed within the site.[2,31] Other methods also exist that by themselves or in a complementary nature may be used to control construction site noise, for example:

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

Table 4-1

TYPICAL ENERGY AVERAGE NOISE LEVEL, dBA, AT CONSTRUCTION SITE BOUNDARIES

	Domestic Housing	Office Building Hotel, Hospital School, Public Work	Industrial Recreation, Store Service Station	Highways Roads, Sewers Trenches
Ground Clearing	83	84	84	84
Excavation	88	89	89	88
Foundation	81	78	77	88
Erections	81	87	84	79
Finishing	88	89	89	84

There is no doubt that the construction industry can take steps to reduce its noise; however, regulations are needed to assure that the basic steps are taken uniformly by all components of the industry. Further, while optional equipment selectivity or operational procedure noise control schemes may be effectively employed, it remains that regulation of individual pieces of construction site equipment is needed at the Federal state, and local levels.

THE INDUSTRY

The portable air compressor industry is a mature and highly competitive industry. Manufacturers of portable air compressors vary significantly in size, financial strength, manufacturing capability, applied technology, marketing ability, and extent of product diversification. Seventeen manufacturers currently active in the domestic market have been identified. Two of these import components and assemble units in the United States, and one imports completely assembled units. Their sales in 1972 of $90 million resulted from shipments of more than 12,000 units. Table 4-2 presents a listing of manufacturers and the estimated dollar value of their sales of portable air compressors. Eight manufacturers have over 90 percent of the market. Of these, Ingersoll Rand and Gardner-Denver together account for about 50 percent of the market, with Joy ranking third with about 10 percent of the market.

Table 4-2

ESTIMATED SALES OF PORTABLE AIR COMPRESORS
BY MAJOR MANUFACTURERS, 1972

Manufacturer	Millions of Dollars
American Jenback	$ .5 - 2.0
Atlas Copco	.5 - 2.0
Chicago Pneumatic	2.5 - 4.5
Davey	.5 - 2.0
Gardner-Denver	18.0 - 21.0
Grimmer-Schmidt	.5 - 2.0
Ingersoll-Rand	25.0 - 28.0
Jaeger	6.5 - 8.5
Joy	9.0 - 11.0
Kent Air Tool	.5 - 2.0
Le Roi	2.5 - 4.5
Lindsey	.5 - 2.0
Quincy	.5 - 2.0
Schramm	5.5 - 7.5
Gordon Smith	.5 - 2.0
Sullair	.5 - 2.0
Worthington	2.5 - 4.5

Nine of the 17 manufacturers are divisions or subsidiaries of large corporations with assets in excess of $100 million. These are Atlas Copco (importer), Chicago Pneumatic, Davey, Gardner-Denver, Ingersoll-Rand, Joy, Le Roi, Quincy and Worthington. Sales of these corporations (parent company) in 1972 ranged from $182 to $906 million. These corporations are not highly specialized in the construction equipment industry.[8] They are extensively diversified, producing a wide variety of products sold in other industries.

Three medium-sized manufacturers have assets ranging from $6 to $15 million. These are Jaeger, Schramm, and Sullair (importer). Sales of these corporations in 1972 ranged from $10 million to 18 million. Five manufacturers are small companies with assets ranging from $0.3 million to $1.5 million. They are American Jenback (importer), Grimmer-Schmidt, Kent Air Tool, Lindsay, and Gordon Smith.[8] The medium and small-sized manufacturers typically specialize in portable and stationary compressors and a few other products sold primarily outside the construction equipment market.

Portable air compressor manufacturing facilities are concentrated in the Northeast and North Central United States. Plants vary considerably in terms of size, efficiency, technology, and employment. Detailed plant location, employment, and factory production information is presented in Reference 8. While some firms have efficient plants utilizing the most up-to-date technology, others have old, extremely inefficient plants utilizing technology and production methods that are nearly obsolete. Generally, the larger manufacturers have the efficient plants and the smaller manufacturers have the more inefficient plants.

Most manufacturers utilize only one plant for the production of portable air compressors. Generally, these plants might also be used for the production of related products, including stationary air compressors. Although each plant usually manufactures more than one product, each product is typically manufactured on a separate production line or in a separate area.

Approximately 9,000 people are employed in plants that manufacture portable air compressors. The exact employment attributable to the production of portable air compressors was considered confidential. It has been estimated that the total portable air compressor production employment is in the range of 2,000 to 3,000 employees.

The portable air compressor industry was operating in 1973 in excess of 85 percent of capacity. The industry has been constrained from further expansion by the difficulty in obtaining deliveries of engines and other components. The industry generally operates at lower capacity rates of 65 percent to 75 percent.

Manufacturers obtain raw materials and components used in the manufacturing process from interdivisional transfers, component suppliers, and raw material suppliers. The finished product is distributed through construction equipment distributers (dealers) who sell or lease the product to the primary end users, who are the construction and mining industries, other industries, government agencies, and others. Table 4-3 indicates the estimated distribution of unit shipments by end-use market during the years 1967 through 1972.

Table 4-3

ESTIMATED PERCENTAGE OF TOTAL PORTABLE AIR COMPRESSOR UNIT SHIPMENTS BY END USE MARKET, 1967-1972

End Use Market	Percentage of Units Shipped
Construction Industry	
Public Works and Other Non-building Construction	50
Commercial, Institutional and Industrial Building Construction	20
Mining Industry	8
Industrial Users	7
Government Agencies	12
Other Users	3
Total	100%

The single largest user of portable air compressors is the construction industry, which currently accounts for an estimated 70 percent of total units shipped. Government agencies account for about 15 percent of the units, followed by mining and industrial users, sharing another 15 percent of total shipments.

Channels of distribution traditionally are through independent, authorized distributors and factory-owned distributors or branches. In excess of 50 percent of manufacturer shipments of new portable compressors reach the end user via rental/purchase agreements. Intermittent use requirements result in a large rental market. The trend to increased rental of compressors is expected to continue. Used equipment is also an important factor in the portable air compressor market.

From 6 to 13 percent of total annual shipments are exported each year/ imports have been a minor factor in the market (less than 7 percent of the 1972 unit volume).

Most manufacturers currently offer quieted portable air compressors due to customer demand resulting from OSHA and local noise regulations. Domestic shipments of quieted units vary by compressor capacity and power source type as shown in Table 4-4. The compressors range in noise levels from 70 to 88 dBA at 7 meters for units in the 85 to 250 cubic ft per min. (cfm) range and from 70 to 93 dBA at 7 meters in the 251 to 1200 cfm range.

Table 4-4

ESTIMATED SHIPMENTS OF QUIETED PORTABLE AIR COMPRESSORS AS A PERCENT OF TOTAL UNIT SHIPMENTS BY MARKET SEGMENT

Power Source Type	Air Flow Capacity Range (CFM)	Estimated Percent of Total Shipments
Gasoline Engine	75-124	20
Gasoline Engine	124-250	20
Diesel Engine	124-249	20
Diesel Engine	249-599	20
Diesel Engine	600-899	10
Diesel Engine	900 and over	10

The quieted units as a percent of total domestic shipments are greater in the small capacity units, because a substantially larger investment is required to obtain quieting in the larger capacity units.

THE PRODUCT

Portable air compressors are designed mainly to power pneumatic tools and equipment at a construction job site. Primary applications include the generation of air power for:

1. Operating hand tools
2. Tunneling operations
3. Mixing and atomizing to shoot fine particle material into place
4. Pneumatic conveying of small particle material
5. Air-operated centrifugal pumps
6. Air-powered hoist drums or brakes
7. Snow production.

Compressors generally are rated according to maximum flow rate a a pressure of 100 lbs per sq. in. (psi) (although some firms have units rated up to 150 psi). The maximum flow rate ranges as high as 2000 cfm.

Almost all the larger units are diesel engine driven, screw-type compressors; the intermediates are diesel and gasoline engine driven, screw and rotary type compressors; and the smaller types are primarily gasoline engine driven, screw, rotary, and reciprocating type compressors.

The portable compressors of interest are designed to be towed as trailers on two or four rubber-tired wheels. They have weights ranging from 1 to 14 tons, lengths from . 5 to 19 feet, and heights from a little less than 6 feet to almost 10 feet. Mounted on the trailer are the compressor, an air receiver, the driving engine, the cooling system, the fuel tanks, the tool boxes, and an enclosure. The enclosure itself, when designed for noise insulation, can comprise as much as 10 percent of the total weight.

The most widely manufactured compressor in the U. S. today is the rotary screw type unit. The screw type compressor is a single stage unit that provides a high flow rate-to-size ratio and offers high reliability due to its few moving parts. An engine occupying 5 to 15 times the volume occupied by the basic compressor itself is needed along with the accompanying cooling and exhaust system to drive the compressor. In most cases, the engine is directly coupled to the male screw element, which then drives the female element.

The basic screw type compressor unit accounts for only a small fraction of the weight and size of an operating portable compressor. Typically, rotary screw units used in portable compressors are smaller in size than an automobile automatic transmission. Likewise, the compressor mechanism itself produces little of the noise generated during operations.

Most U. S. manufacturers are phasing out their line of sliding-vane rotary compressors, probably because they are reputed to require more maintenance and are less economical to operate than other types in use. Nevertheless, there are still several portable compresser sets of this type on the market. As in the case of the screw type compressors, the compressor itself is relatively small, but the necessary concomitant equipment is substantial. Sometimes the compressor is mounted in the receiving tank to save space.

The traditional reciprocating compressor is used today almost exclusively in portable compressors delivering less than 250 cfm. Unlike the screw and rotary-vane types, it usually requires several stages to achieve the required pressure. Consequently, the basic unit is a larger fraction of the total weight and size of the complete compressor assembly.

Rotary-screw manufacturers tend to compete by specializing in one or two types of portable air compressors in each market segment. Table 4-5 summarizes the types of compressors offered by each portable air compressor manufacturer.

Table 4-5

TYPE OF COMPRESSOR OFFERED BY MANUFACTURER

Manufacturer	Rotary Screw	Reciprocating	Rotary Vane
American Jenback		x	
Atlas Copco	x	x	
Chicago Pneumatic	x		x
Davey Compressor			x
Gardner Denver	x		x
Grimmer Schmidt		x	
Ingersoll-Rand	x		x
Jaeger	x		x
Joy Manufacturing	x		x
Kent Air Tool			x
Le Roi	x		
Lindsay		x	
Quincy	x		
Schramm		x	
Gordon Smith		x	
Sullair	x		
Worthington	x		x

The basic units used to gauge productive capacity and performance or portable compressors are the engine type (diesel or gasoline) and air flow rating in cfm at 100 psi.

Thirteen manufacturers, shown in Table 4-6, offer a complete line of portable air comressor capacity while the other four offer only the smaller capacity units.

Examination of the noise emissions of present-day compressors suggests that dividing compressors into six categories provides the most meaningful basis for evaluation. One division is into types of drive: gasoline vs. diesel engines. A second is into "standard units" vs. those offered as "quieted units". The two alternatives for the two characteristics, gasoline vs. diesel and "standard" vs. "quieted", define four catagories. The diesel driven units are further subdivided into units providing rated air flow below 501 cfm and units having a rated air flow above 500 cfm.

Table 4-6

PORTABLE AIR COMPRESSOR CAPACITIES IN CFM
OFFERED BY MANUFACTURERS

	Gasoline Engine			Diesel Engine		
Manufacturer	75-124	125-250	125-249	250-599	600-899	900 & over
American Jenback	x		x			
Atlas Copco	x		x	x	x	x
Chicago Pneumatic	x	x	x	x	x	x
Davey Compressor	x	-x	x	x	x	
Gardner-Denver	x	x	x	x	x	x
Ingersoll-Rand	x	x	x	x	x	x
Jaeger	x	x	x	x	x	x
Joy Manufacturing	x	x	x	x	x	x
Kent Air Tool	x	x	x			
Le Roi	x	x	x	x	x	x
Lindsay	x	x	x			
Quincy		x	x	x	x	x
Schramm	x		x	x	x	
Gordon Smith	x					
Sullair	x	x	x	x	x	x
Worthington	x	x	x	x	x	x
Grimer-Schmidt	x	x	x	x	x	x

Section 5

EXISTING LOCAL, STATE, AND FOREIGN NOISE REGULATIONS

According to Section 6 of the Noise Control Act of 1972, the proposed Federal regulations for new portable air compressors will preempt new product standards for compressors at the local and State level* unless those standards are identical to the Federal standard. Further, according to Section 9 of the Act, regulations will be issued to carry out the provisions of the Act with respect to new products imported or offered for importation. Accordingly, EPA reviewed available literature and conducted a survey to determine the number of existing regulations that are applicable to construction equipment and portable air compressors and that may be affected by proposed Federal regulations. In the following sub-sections, the findings of the review are summarized.

LOCAL AND STATE REGULATIONS

Information on state and local construction noise regulations was obtained for 123 cities with populations in excess of 100, 000 and from 226 cities with populations of less than 100, 000. In addition, information was received from 46 of the 50 states surveyed.[9]

As indicated by Table 5-1, 27 of the 123 cities with a population in excess of 100, 000 and 21 of the 226 cities with a population less than 100, 000 have some form of a construction regulation at this time.

*Local and State governments are not prohibited from "establishing or enforcing controls on environmental noise through licensing, regulation or restriction of the use, operation or movement of any product" of from establishing or enforcing new product noise standards for types of construction equipment not regulated by the Federal Government.

Table 5-1

LOCAL NOISE ORDINANCES ON CONSTRUCTION BY TYPE

Population	No Specific Law	Nuisance Law	Ordinance Under Development	Performance Standards	Total
over 100,000	54	37	5	27	123
under 100,000	157	48	0	21	226
TOTALS	211	85	5	48	349

Of the 48 cities with some form of construction equipment regulation, 36 have operational limits and 7 have new product standards as shown by Table 5-2.

Table 5-2

LOCAL NOISE PERFORMANCE STANDARDS FOR CONSTRUCTION BY TYPE

Population	Operational Limits	New Product Standards
over 100,000	18	5
under 100,000	18	2
TOTALS	36	7

Of the 46 states that replied to the survey, 4 had specific regulations for the noise of construction equipment: Colorado, Indiana, New York, and Alaska have performance standards, while Indiana has new product standards currently in force.

Since the proposed Federal portable air compressor regulation will preempt existing or contemplated local and state portable air compressor regulations, cities and states that will be affected have been identified. Figure 5-1 shows that seven cities and no states have new construction equipment noise standards. Also shown is that Grand Rapids, Michigan, and New York City, New York, have the most stringent standard along with the shortest time period for compliance.

These seven regulations then, in part, will be preempted by the new Federal law on portable air compressors. The new Federal law will preempt these jurisdictions only from promulgating or enforcing a new product standard for portable air compressors. It will not prohibit them from enforcing laws against other types of construction equipment and will not prohibit them from establishing or licensing operational limits for portable air compressors.

FOREIGN REGULATIONS

Over 300 inquiries were sent to foreign manufacturers of portable air compressors and representatives of foreign nations who were knowledgeable in the field of environmental noise.[10] These inquiries solicited information and comments in the following five areas.

1. The technology available to reduce the noise of portable air compressors and noise level data for existing models of air compressors.
2. Legislation setting limits on the noise level of construction equipment, especially portable air compressors.
3. The effects of government regulations on the cost of producing or marketing portable air compressors that must be quieted.
4. Specifications for the noise levels produced by portable air compressors used in government contracts.

5. Standards for measuring the noise level of air compressors.

Although information in areas other than regulations was requested, in most instances the individuals and countries responding did not address anything but the applicable regulations on construction equipment.

Generally, it was found that foreign countries have regulations that deal specifically with construction noise in the following ways:

1. Standards of recommended practice such as the Guidelines for Noise issued by the National Federation of Building Trades Employers and the Ministry of Public Works in the United Kingdom.
2. Contract specifications between buyer and builder such as those in Norway or New South Wales, Australia.
3. General nuisance laws such as those in the various municipalities in Canada and in Paris, France.
4. Regulation of the noise level in various land use areas. These laws frequently differentiate between daytime and nighttime levels. Examples include Oslo, Norway; Zurich, Switzerland, Sweden and Vienna, Austria.
5. Regulation of the noise emission level of specific types of equipment, such as portable air compressors.

The levels specified by the cities and nations regulating portable air compressor noise are summarized in Figure 5-2.

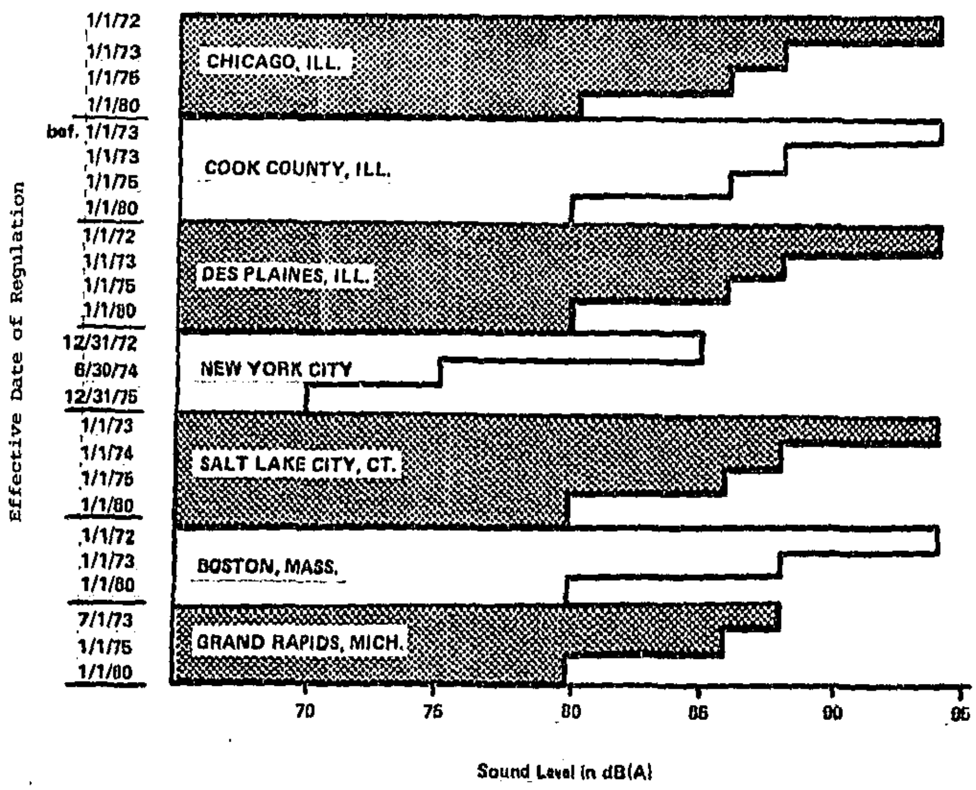
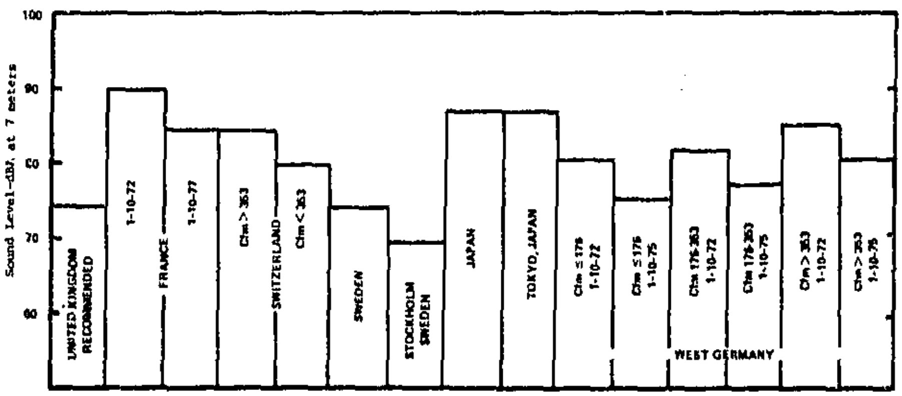


Figure 5-1 New Product Noise Standards for Construction Equipment



NOTES: (1) Some data corrected to 7 meters
(2) Some data corrected for sound level
(3) Levels are for any air flow currently available unless otherwise stated

Figure 5-2 Foreign Compressor Noise Regulations

Section 6

MEASUREMENT METHODOLOGY

MEASUREMENT STANDARDS

Numerous noise measurement recommended practices, standards, and regulations have been promulgated by national and international organizations[13] to standardize measurement methodology for use by industry, consumers, and government regulatory bodies. The Society of Automotive Engineers (SAE) has published recommended practices and standards or draft documents that standardize the noise measurement methods for construction equipment and construction sites.[14,15] The American National Standards Institute (ANSI) for the United states and the International Standards Organization (ISO) have developed, through their member groups, numerous noise measurement standards. Of particular interest to the portable air compressor manufacturers is the Compressed Air and Gas Institute (CAGI) test code for measurement of sound from pneumatic equipment.[16] This standard has been accepted for promulgation by the ISO as ISO2151-1972 and by the ANSI as ANSI S5.1-1971. One section is specifically devoted to portable air compressors and is widely used by portable air compressor manufacturers to describe the sound pressure level of their products.

With consideration given to the possible use of sound power or sound power level to describe portable air compressor noise, methods suitable for this type of description have been investigated. Two methods investigated or under investigation are:

1. The 10 point hemispherical method of Reference 17.
2. The far and near field method of Reference 11.

In both methods, sound pressure levels are measured and sound power or sound power level is computed. Further description of the sound pressure level and the sound power/ sound power level methods follow.

CAGI METHOD – SOUND PRESSURE LEVEL

Octave band sound pressure levels from 63 Hz to 8,000 Hz and A-weighted sound levels are obtained during compressor idle and fullpower conditions at 10 locations around the compressor. The locations are shown in Figure 6-1.

Octave band data are used to show the octave band characteristics of portable air compressor noise at the microphone location at which the highest sound level was recorded.

A-weighted sound levels are used to calculate the average sound level at the 1-meter and 7-meter microphone locations. The average level is calculated by one of the following three methods.

Maximum Variation of 5 dB or Less

If the maximum variation in corrected sound pressure levels is 5 dB or less, average the sound pressure levels arithmetically.

Maximum Variation of 5 to 10 dB

If the maximum variation in corrected sound pressure levels is between 5 and 10 dB, average the sound pressure level values arithmetically and add 1 dB.

Maximum Variation over 10 dB

If the maximum variation exceeds 10 dB, average according to the equation below:

$$\bar{L} = 10 \log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} 10^{(L_i/10)}\right)$$

Where $\bar{L}$ = Average sound level (dB A) (or band average pressure level in decibels).

L_i = Sound level (dB A) (or band sound pressure level in decibels) at the ith position.

n = Number of measuring stations.

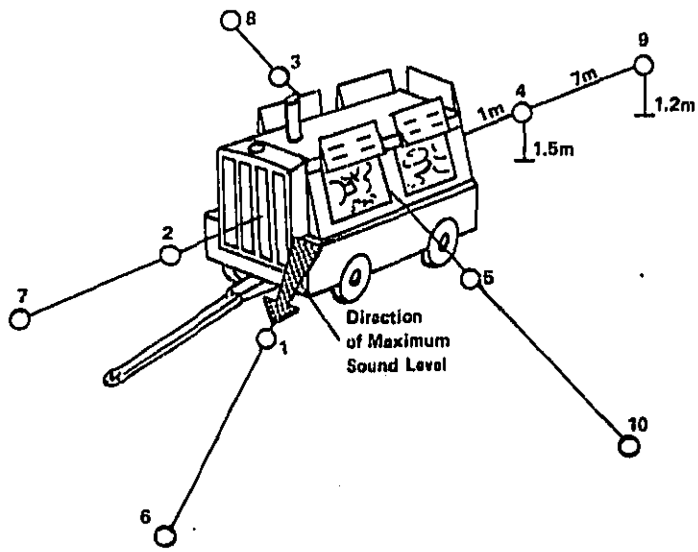


Figure 6-1. CAGI/PNEUROP Method Microphone Locations

10-POINT HEMISPHERE METHOD — SOUND POWER LEVEL

Theoretically, sound pressure levels measured over the entire surface of an imaginary sphere surrounding the source should be used when calculating sound power levels. The practical procedure for approximating the entire sphere exploration is to select a number of points located at the center of elements of equal area that are situated on the surface of an imaginary hemisphere about the source. Figure 6-2 is a schematic of the microphone points used for the 10-point hemisphere method, while Figure 6-3 shows the coordinates (relative to the radius of the hemisphere) for the microphone positions. Sound power level is calculated using Equation 6-1.

$$PWL = \overline{SPL} + 20 \log_{10} r + 0.5 \text{ dB} \quad (6-1)$$

where

PWL = sound power level in dB re 10^{-12} watts
$\overline{SPL}$ = spatial average sound pressure level dB
r = radius of the hemisphere

FAR-FIELD METHOD — SOUND POWER

The far-field measurements are made on a surface of fixed radius (r) from the geometric center of the source. The radius (r) may be any convenient distance subject to the conditions that r is greater than three major source dimensions, but that r need not be greater, in any case, than 10 meters. The major source dimension is the larger of the length, width, or height above the ground plane of the source. The minimum number of measurement positions shall be six (subject to change by the National Bureau of Standards to achieve desired accuracy), including one each in the four principal directions from the source (i.e., perpendicular to the four vertical surfaces of the machine) at a height of 1.5 ± 0.1 meter above the ground plane. The fifth measurement position shall be above the geometric center of the source at a height r above the ground plane.[11]

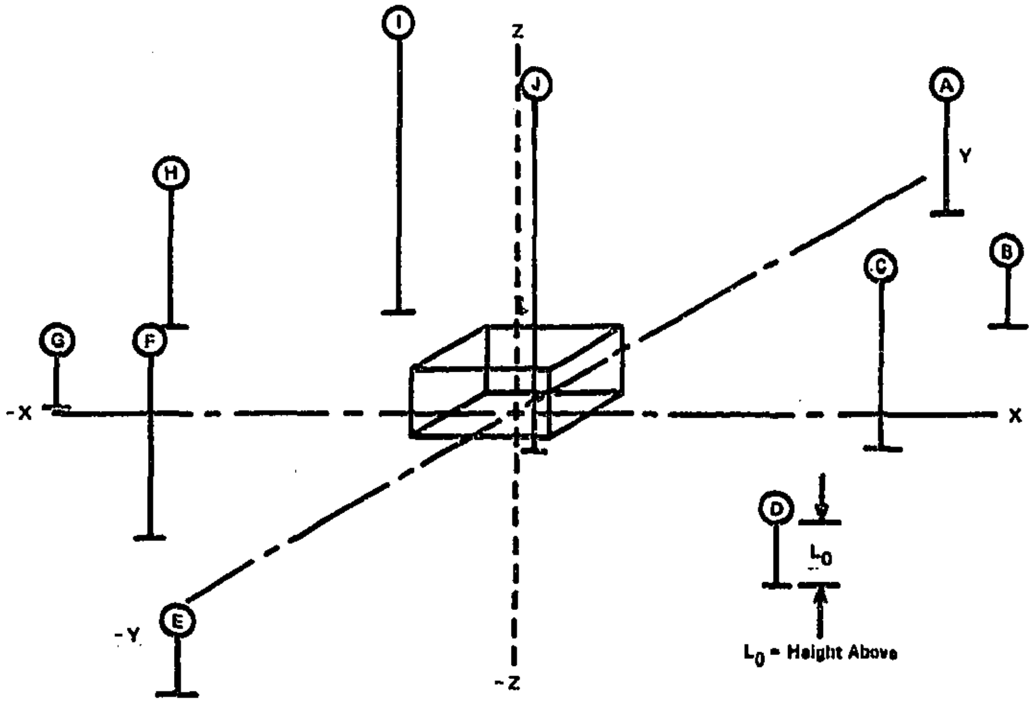
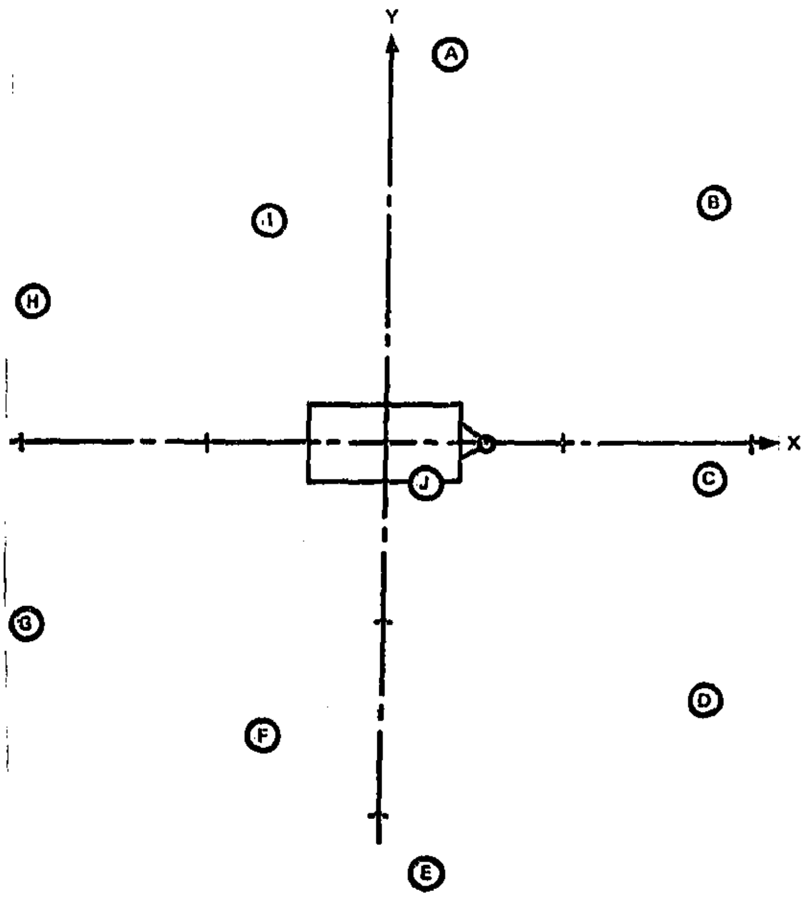


Figure 6-2. Schematic Diagram of 10 Microphone Locations at the Center of Elements of Equal Area on the Surface of a Hemisphere about a Sound Source



POSITION	X/R	Y/R	Z/R
A	0.158	0.898	0.410
B	0.775	0.550	0.313
C	0.738	-0.067	0.671
D	0.775	-0.603	0.193
E	0.158	-0.961	0.224
F	-0.257	-0.652	0.713
G	-0.834	-0.399	0.381
H	-0.834	0.315	0.452
I	-0.257	0.498	0.828
J	0.100	-0.099	0.990

Figure 6-3. Relative Coordinates for 10 Points of Hemisphere of Radius R.

NEAR-FIELD MEASUREMENTS

Determination of Measurement Locations

The near field measurement locations are on five sides of a parallelepiped surface that extends to the ground plane and is 1.0 ± 0.01 meter away from the major surfaces of the unit.[11] For the purposes of this measurement, the major surfaces are defined as including the four sides and top of the source and the exhaust system, if it is mounted on one of these surfaces.

A minimum of six microphone positions is used, one on each of the four vertical sides, one on the top of the measurement surface, and one at the location of the maximum A-weighted sound level at a height of 1.5 meters above the ground plane. The survey position shall be established separately for each measurement. The principal measurements on the four sides are at the horizontal centers, 1.5 meters above the ground plane. The principal measurement position on the top of the measurement surface shall be above the geometric center.

Using the calculation procedures of Section 7 of Reference 11, the A-weighted sound power is calculated for the near-and far-field measurement locations as previously defined.

EPA RECOMMENDED PORTABLE AIR COMPRESSOR TEST PROCEDURE

In arriving at the recommended test procedure, EPA recognized the need for a common, well known descriptor of portable air compressor noise to avoid possible confusion over units of measurement by industry, State/local governments, and the public. Also recognized was the need for a relatively simple method to accurately acquire portable air compressor noise that could be used both for product certification and enforcement.

Candidates for the proposed description of portable air compressor were:

1. A-weighted sound pressure in dBA
2. Sound power level in dB
3. Sound power in milliwatts.

A-weighted sound pressure level in dBA was selected for several reasons, including its utility and ease of acquisition. A-weighted sound pressure level can be measured directly using common, readily available equipment. Thus it is common to and widely used by industry, the scientific community, State and local governments, and the general public to assess human response to noise. This is in contrast to sound power level and sound power, which cannot be measured and have to be calculated, typically from sound pressure level data.

By selection of the A-weighted sound level descriptor, the 10-point hemisphere and far-field/near-field measurement methods, for the acquisition of data to calculate sound power level and sound power, respectively, were eliminated as candidates for the desired test procedure. Their elimination resulted because the rigor involved in the methods is not needed for the simple, direct measurement of A-weighted sound pressure level.

The remaining candidate for the desired test procedure was the CAGI/PNEUROP measurement method. In reviewing this method, consideration was given to whether data was needed at both the 1-meter and 7-meter microphone locations. The EPA concluded that only one set of data was needed, that at 7 meters. This conclusion was based on the fact that the 1-meter measurement locations lie in the near field (see Section 7 of this document). Although the near field data for regulation use, it would not be satisfactory for far-field extrapolation, as is often the case when it is desired to estimate noise levels at residential positions some distance from the construction site (Section 7 discusses the problem in more detail). In other words, the 1-meter data is not as utilitarian as are the 7-meter data.

Consequently, EPA selected the 7-meter microphone locations because:

1. The microphone locations are in the far field.
2. The data satisfactorily and adequately describe compressor noise.
3. The data could be used for extrapolation with some degree of confidence.

The Agency also added an overhead microphone location to guard against compressor design that would direct major sound energy upwards (this would be of significance to persons residing in high rise buildings adjacent to construction sites). Further, the need to search for and report the maximum A-weighted sound pressure of the compressor was eliminated. Since data indicates that the maximum occurs at or near the four horizontal points selected for measurement.

By selection of a modified but more simple CAGI/PNEUROP test method, little education, if any, would be required on the part of industry as the members of CAGI are familiar with and currently use the CAGI/PNEUROP procedure.

The conditions and the measurement procedures requisite to measure the noise of portable air compressors for the purpose of compliance with a noise standard are presented below.

a. Test Site Description. Locations, for measuring noise, employed during noise compliance testing, must consist of an open site above a hard reflecting plane. The reflecting plane must consist of a surface of sealed concrete, sealed asphalt or the equivalent and must extend 1 meter beyond each microphone location. No reflecting surface such as a building, sign board, hillside, etc. shall be located within 10 meters of a microphone location.

b. Measurement Equipment. The measurement equipment must be used during noise standard compliance testing and must consist of the equivalent of the following:

(i) A sound level meter and microphone system that conform to the requirements of American National Standard (ANS) S1.4-1971, "Specification for Sound Level Meters," with regard to the section concerning Type I sound level meter and International Electrotechnical Commission (IEC) Publication No. 179, "Precision Sound Level Meters" with regard to the sections concerning microphone and amplifier characteristics.

(ii) A windscreen must be employed with the microphone during all measurements of portable air compressor noise when the wind speed exceeds 11 km/hr. The windscreen shall not effect sound levels from the portable air compressor in excess of ± 0.5 dB.

(iii) The entire acoustical instrumentation system including the microphone and cable shall be calibrated before and after each test series. A sound level calibrator accurate within ± 0.5 dB shall be used. A complete frequency response calibration of the instrumentation over the entire range of 25 Hz to 11.2 kHz shall be performed at least annually using the methodology of sufficient precision and accuracy to determine compliance with ANS S1-4-1971 and IEC 179. This calibration shall consist, at a minimum of an overall frequency response calibration and an attenuator (gain control) calibration plus a measurement of dynamic range and instrument noise floor.

(iv) An anemometer or other device accurate to within ± 10% shall be used to measure wind velocity.

(v) An indicator accurate to within ± 2% shall be used to measure portable air compressor engine speed.

(vi) A gauge accurate to within ± 5% shall be used to measure portable compressor air pressure.

(vii) A metering device accurate to within ±10% shall be used to measure the portable air compressor compressed air volumetric flow rate.

(c) Portable Air Compressor Operation. The portable air compressor must be operated at the design full speed with the compressor on load, delivering its rated output flow and pressure, during noise standard compliance testing. The discharged compressed air must be piped clear of the test site or silenced.

(d) Test Conditions. Noise standard compliance testing must be carried out under the following conditions:

(i) No rain or other precipitation

(ii) No wind above 19 km/hr

(iii) No observer located within 1 meter, in any direction of any microphone location, nor between the test unit and any microphone.

(iv) Portable air compressor sound levels, at each microphone location, 10 dB or greater than the background sound level.

(e) Microphone locations. Five microphone locations must be employed to acquire portable air compressor sound levels to test for noise standard compliance. A microphone must be located 7 $\pm$ 0.1 meters from the right-, left-, front-, back side and top of the test unit. The microphone position to the right-, left-, front- and back side of the test unit must be located 1.5$\pm$0.1 meters above the reflecting plane. Figure 6-4 shows the microphone array.

(f) Data Required. The following data must be acquired during noise standard compliance testing:

(i) A-weighted and C-weighted sound levels at one microphone location prior to operation of the test unit and at all microphone locations during test unit operations as defined in section (c).

(ii) Portable air compressor engine speed.

(iii) Portable air compressor compressed gas pressure.

(iv) Portable air compressor flow rate.

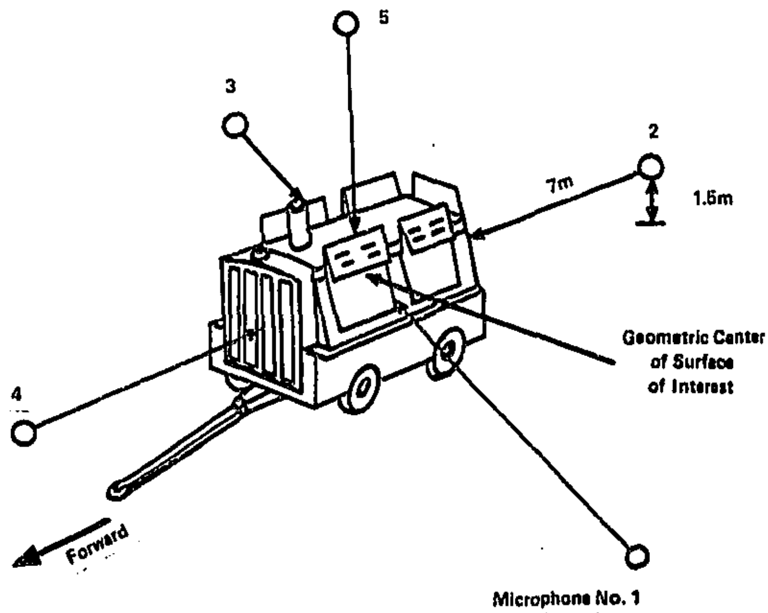


Figure 6-4. Microphone Locations to Measure Portable Air Compressor Noise

(g) Calculation of average sound levels. The average A-weighted and C-weighted sound levels from measurements at the specified microphone locations must be calculated by the following method.

$$\bar{L} = 10 \log_{10}\left(\frac{1}{n} \sum_{i=1}^{n} 10^{(L_i/10)} \right)$$

where:

$\bar{L}$ = average sound level, dBA or dBC as appropriate, in decibels
L = sound level, dBA or dBC as appropriate, in decibels at the i th location

n = number of measurement position

(h) Presentation of information. The following information must be reported:

(i) Background ambient sound level in dBA and dBC.

(ii) Portable air compressor sound levels in dBA and dBC at each microphone location.

(iii) Average portable air compressor sound levels in dBA and dBC.

(iv) Portable air compressor compressed gas pressure, in kg./cm^2.

(v) Portable air compressor compressed gas flow in m^3 /min.

(vi) Portable air compressor manufacture, model and serial no.

(vii) Acoustic instrumentation manufacturer, and model number

The recommended data format is shown in Figure 6-5.

Test Report Number _______

SUBJECT:

Manufacturer: _______________ Model: _______________ Serial No.: _______________
Rated Speed: _______________ rpm: _______________ Rated Capacity: _______ m^3/min (cfm)
Configuration Identification: _______________ Category Identification: _______________

TEST CONDITIONS:

Manufacturers Test Site Identification and Location: _______________
Reflecting Plane Composition: _______________
Operating Speed as Tested: Beginning of Test _______________ rpm
End of Test _______ _______ rpm
Air Pressure Supplied: _______ kg/cm^2. (psi) Ambient wind Speed___ km/hr (mi/hr)
Actual Flow Rate: _______ m^3/min (cfm) Barometric Pressure___ kg/cm^2 (psi)

INSTRUMENTATION:

Microphone Manufacturer: _______________ Model No.: _______ Serial No. _______
Sound Level Meter Manufacturer: _______ Model No.: _______ Serial No. _______
Calibrator Manufacturer: _______________ Model No.: _______ Serial No. _______

DATA:

dB Ref. 2×10^{-5} Pascals	Background Sound Level at Location 'at Location	LOCATION					Average Sound Level
		1	2	3	4	5	
dBC							
dBA							

TESTED BY: _______________ DATE: _______________

REPORTED BY: _______________ DATE: _______________

SUPERVISORY PERSONNEL: _______________ TITLE: _______________

_______________ TITLE: _______________

Figure 6-5. Portable Air Compressor Noise Data Sheet

Section 7
PORTABLE AIR COMPRESSOR NOISE

The basic elements of all noise problems are a (1) source (2) path and (3) receiver. Studies have been conducted on all three of these elements; the first two are discussed in this and the following section and the third discussed in Section 10. Study of the portable air compressor as a source included evaluation of:

- Overhead noise levels of unsilenced and silenced compressors.
- Noise levels of unsilenced and silenced portable air compressors ranging from 85 to 1200 cfm capacity.
- Repeatability of compressor noise measurements.
- Noise directivity of unsilenced and silenced compressors.
- Compressor sound power levels.
- Low frequency compressor noise.
- Identification of major noise sources associated with portable air compressors (see Section 8).
- Degree of quieting with application of present technology (see Section 8).

Study of the propagation path included the following considerations:

- Ground reflections.
- Path discontinuities.
- Calculation of far field data from near field data.

OVERHEAD NOISE

To increase the data base and to provide data to assess the noise characteristics of portable air compressors, noise measurements were made of 4 gasoline and 19 diesel powered compressors ranging in capacity from 85 to 1200 cfm. Table 7-1 list information about the units and the test method employed. As indicated in the table, both silenced and standard versions of some compressors were evaluated, and, in some cases, the compressor housing doors were purposely left open.

The most commonly used portable air compressor measurement scheme, the CAGI/PNEUROP method (see Section 6), does not presently include measurement of sound above portable air compressors. Since engine exhaust often is directed upward, noise radiating in this direction could be of significance, particularly to persons in offices, apartments, etc., located above operating compressors. As such, measurements were made of noise radiating upward and were compared with that radiated to the side of compressors.

Table 7-2 lists the measured CAGI/PNEUROP average and overhead noise levels for the 26 compressor tests. The last column in this table is the difference between these two levels, and figure 7-1 shows a histogram of these differences.

For 4 of 26 compressors, the overhead noise level is greater than the horizontal noise level. All other models show the overhead direction to be quieter than, or equal to, horizontal noise. The mean difference in Figure 7-1 shows the upward-directed noise to be 0.6 dBA less than the CAGI/PNEUROP figure. The spread in the data, however, creates a standard deviation of 2 dBA.

Of the four compressors that are significantly noisier overhead, two results are for the same model (doors open and closed) with a relatively inefficient exhaust muffler. The other two results are for silenced units similiar to companion products with overhead sound levels significantly less than the sideline average. Consequently, if we momentarily ignore these results as atypical or as possible measurement error, the statistics of the remaining 20 are computed. The following values result:

- Mean: − 1.5 dBA
- Standard Deviation = 1.1 dBA

Thus, for this group of compressors, the overhead noise level is about 1.5 dBA less than in other directions.

PORTABLE AIR COMPRESSOR NOISE LEVELS

New Data

As discussed previously, measurements were made of a total of 23 portable air compressor types. Tables 7-3 and 7-4 list noise levels of the standard and silenced compressors, respectively, while Figure 7-2 shows a plot of noise versus cfm capacity. From review of the data in tables and in the figures the following may be concluded:

- Noise levels of both standard and silenced compressors increase with increasing compressor capacity, with noise of the standard units increasing at a more rapid rate.
- Noise levels of standard compressors range in level from 81.4 to 92.6 dBA at 7 meters.
- Noise levels of silenced compressors range in level from 70.1 to 78.2 dBA at 7 meters.
- Silenced compressors are on the average 10 and 15 dBA quieter than standard units.

Table 7-1

COMPRESSORS TESTED

Manufacturer	Model	Silenced or Standard	Type Engine	Type Compressor	Serial No.	Test Condition (cfm, psi)	Test Method: CAGI/PNEUROP	Test Method: Overhead Measurement[2]	Test Method: 10 Point Hemispherical[3]	Test Method: Diagonal[4]
Atlas Copco	ST-48	Standard	Diesel	Reciprocal	51232751	160, 100	x	x		
Atlas Copco	ST-95	Standard	Diesel	Reciprocal	51-274977	330, 105	x	x		
Atlas Copco	VSS-170 Dd	Silenced	Diesel	Reciprocal	51-23507-	170, 850	x	x		
Atlas Copco	VT-85 Dd	Standard	Gas	Reciprocal	ARP203149	85, 100	x	r		
Atlas Copco	VS-85 Dd	Silenced	Gas	Reciprocal	ARP203003	85, 100	x	x		
Atlas Copco	VSS-125 Dd	Silenced	Diesel	Reciprocal	51-345060	125, 100	x	x		
Atlas Copco	STS-35 Dd	Silenced	Diesel	Reciprocal	ARP550924	125, 100	x	x		
Atlas Copco	VSS-170 Dd	Silenced	Diesel	Reciprocal	51-235072	170, 100	x	x	x	x
Gardner-Denver	SPWDA/2	Silenced	Diesel	Rotary-Screw	635851	1200, 000	x	x		
Gardner-Denver	SPQDA/2	Silenced	Diesel	Rotary-Screw	608227	750, 000	x	x	x[5]	
Gardner-Denver	SPHGC	Silenced	Gas	Rotary-Screw	629717	185, 000	x	x		
Ingersoll-Rand	DXL 1200	Standard	Diesel	Rotary-Screw	74430	1200, 125	x	x		
Ingersoll-Rand	DXL 1200 (doors open)	Standard	Diesel	Rotary-Screw	74430	1200, 125	x			
Ingersoll-Rand	DXL 900S	Silenced	Diesel	Rotary-Screw	73693	900, 125	x	x		
Ingersoll-Rand	DXL 900S	Silenced	Diesel	Rotary-Screw	74050	900, 125	x	x		
Ingersoll-Rand	DXL CU1050	Standard	Diesel	Rotary-Screw	75613	1050, 125	x	x	x	
Ingersoll-Rand	DXL 900S	Silenced	Diesel	Rotary-Screw	74051	900, 125	x	x		
Ingersoll-Rand	DXL 900S	Silenced	Diesel	Rotary-Screw	740471	900, 125	x	x	x	
Ingersoll-Rand	DXL 900	Standard	Diesel	Rotary-Screw	75647	900, 125	x	x		
Ingersoll-Rand	DXL 750	Standard	Diesel	Rotary-Screw	77360	750, 125	x	x		
Jaeger	A	Standard	Gas	Rotary-Screw	RS-32189	175, 100	x	x		
Jaeger	A (doors open)	Standard	Gas	Rotary-Screw	RS-32189	175, 100	x	x		
Jaeger	E	Standard	Gas	Vane	RC-32032	85, 100	x	x		
Jaeger	E (doors open)	Standard	Gas	Vane	RC-32032	85, 100	x	x		
Worthington	160 G/2 QT	Silenced	Gas	Vane	821-478	160, 100	x	x	x	x
Worthington	750-QTEX	Silenced	Diesel	Rotary-Screw	848-019	750, 100	x	x	x	x

1. ISO 2151-1972 Method (See Figure 6.1)
2. ISO 2151-1972 Method plus A 7 meter overhead point
3. See Figure 6.9 and 6.10
4. Measurements were made at diagonal locations at 0 meters
5. Measurements were made for the compressor operating at idle and full power

Table 7-2

COMPARISON OF CAGI/PNEUROP AVERAGE SIDE WITH OVERHEAD NOISE LEVELS

No.	Manufacturer	Model	(A) CAGI/ PNEU.	(B) Overhead	B-A
1	Atlas Copco	ST-48	84	83	-1
2	Atlas Copco	ST-95	80.5	79.5	-1
3	Atlas Copco	VSS-170 Dd	71	68	-3
4	Atlas Copco	VT-85 Dd	82.5	79	-3.5
5	Atlas Copco	VS-85 Dd	75.5	76	0.5
6	Atlas Copco	VSS-125 Dd	70	72.5	2.5
7	Atlas Copco	STS-35 Dd	73	77	4
8	Atlas Copco	VSS-170 Dd	71	68.5	-2.5
9	Worthington	160 G/2 QT	75	72	-3
10	Worthington	750-QTEX	75	73.5	-1.5
11	Ingersoll-Rand	DXL 1200 doors open	94.5		
12	Ingersoll-Rand	DXL 1200 doors open	96.5		
13	Ingersoll-Rand	DXL 900S	77.5	75	-2.5
14	Ingersoll-Rand	DXL 900S	75.5	74.5	-1
15	Ingersoll-Rand	DXL CU1050	91	89	-2
16	Ingersoll-Rand	DXL 900S	76	73.5	-2.5
17	Ingersoll-Rand	DXL 900S	75.5	74	-1.5
18	Ingersoll-Rand	DXL 900	90.5	89	-1.5
19	Ingersoll-Rand	DXL 750	88	88	0
20	Gardner-Denver	SPWDA/2	74	73	-1
21	Gardner-Denver	SPQDA/2	78.5	78	-0.5
22	Gardner-Denver	SPHGC	77.5	75	-2.5
23	Jaeger	A doors open	88.5	88	-0.5
24	Jaeger	A doors open	89	89.5	0.5
25	Jaeger	E	81.5	84	2.5
26	Jaeger	E doors open	82	85	3

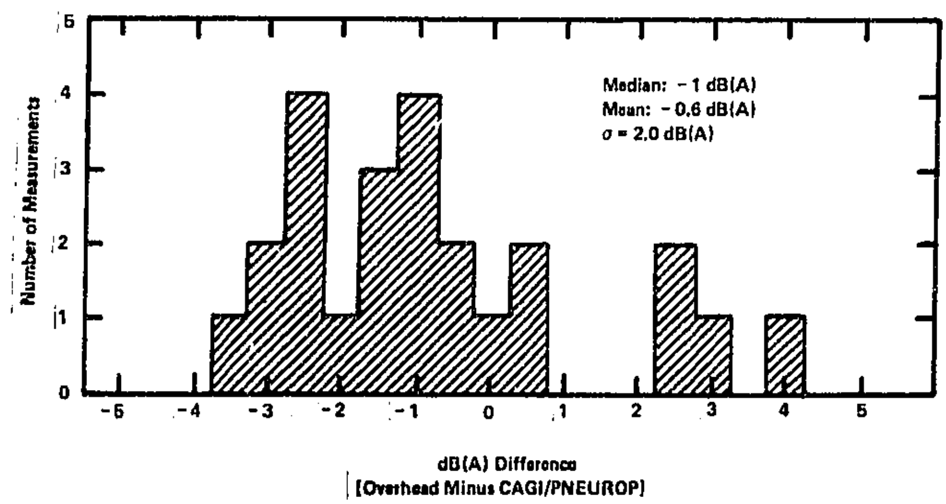


Figure 7-1. Comparison Between Overhead Level and CAGI/PNEUROP Level

Table 7-3

NOISE LEVELS OF STANDARD COMPRESSORS
USING THE CAGI/PNEUROP MEASUREMENT METHOD

Manufacturer	Model	S/N	Cfm	Average Noise Level (dBA)	
				1 meter	7 meter*
Atlas Copco	VT85Dd	ARP203149	85	94.8	81.4
Atlas Copco	ST-48	51-232751	160	96.6	83.6
Atlas Copco	ST-95	51-274977	330	91.9	80.2
Jaeger	E	RC32032	85	92.5	81.5
Jaeger	A	RS32189	175	98.9	88.2
Ingersoll-Rand	DXL750	77380	750	98.6	87.7
Ingersoll-Rand	DXL900	75847	900	97.9	89.9
Ingersoll-Rand	DXLCU1050	75613	1050	100.8	90.2
Ingersoll-Rand	DXL1200	74430	1200	103.0	92.6

*Includes overhead measurement point

Table 7-4

NOISE LEVELS OF SILENCED COMPRESSORS
USING THE CAGI/PNEUROP MEASUREMENT METHOD

Manufacturer	Models	S/N	Cfm	Average Noise Level (dBA)	
				1 meter	7 meter*
Atlas Copco	VS85	ARP203903	85	89.0	75.5
Atlas Copco	STS35Dd	ARP550924	125	85.5	73.5
Atlas Copco	VSS125Dd	51-345060	125	81.0	70.1
Atlas Copco	VSS170Dd	51-235072	170	83.9	70.2
Worthington	160G/2QT	821478	160	84.5	74.2
Gardner-Denver	SPHGC	629717	185	87.0	77.1
Gardner-Denver	SPQDA/2	608227	750	86.1	78.2
Worthington	750QTEX	848-019	750	84.0	74.7
Ingersoll-Rand	DXL 900S	73693	900	82.4	76.0
Ingersoll-Rand	DXL 900S	74050	900	82.0	75.1
Ingersoll-Rand	DXL 900S	74051	900	83.1	75.3
Ingersoll-Rand	DXL 900S	740471	900	82.4	75.0
Gardner-Denver	SPWDA/2	635851	1200	84.1	73.7

*Includes overhead measurement point

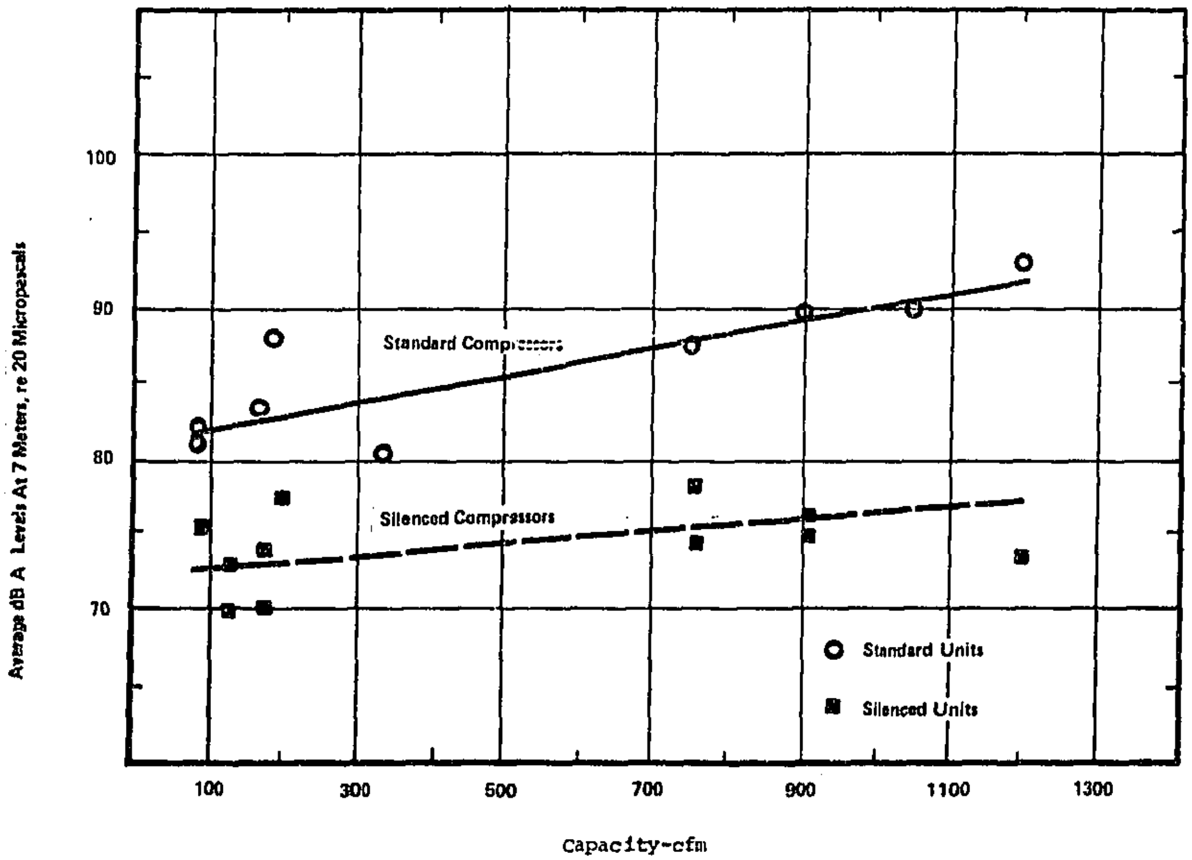


Figure 7-2. Noise of Standard and Silenced Compressors as a Function of Capacity-cfm.

Existing Data

Manufacturers supplied EPA (Contractor BBN) with noise data at 7 meters for 194 compressor models. Table 7-5 lists the data in terms of compressor capacity, engine type, and standard/quieted units. Also shown in the table is the number and percent of units below a particular noise level.

In summary, the data shows:

- Standard models of gas engine powered compressors range in noise level from 71.0 to 92.0 dBA with a mean value of 82.8 dBA.
- Silenced models of gas engine powered compressors range in noise level from 72 to 81 dBA with a mean value of 76.1 dBA.
- Standard models of diesel engine powered compressors of less than 501 cfm capacity, range in noise level from 79.5 to 93.4 dBA with a mean value of 86.1 dBA.
- Silenced models of diesel engine powered compressors, of less than 501 cfm capacity, range in noise from 70.0 to 88.0 dBA with a mean value of 76.4 dBA.
- Standard models of diesel engine powered compressors, of greater than 500 cfm capacity, range in noise level from 86.8 to 101.8 dBA with a mean value of 92.8 dBA.
- Silenced models of diesel engine powered compressors of greater than 500 cfm capacity, range in noise level from 73.0 to 82.0 dBA with a mean value of 78.7 dBA.

Table 7-5(a)

PERCENT AND NUMBER OF PORTABLE AIR COMPRESSORS WITH NOISE LEVELS NOT IN EXCESS OF A PARTICULAR VALUE*

(Major Category of Portable Air Compressors by Capacity and Type of Engine)

Gasoline Engine, All Capacities**					
Standard Models			Quieted Models		
dBA Level	Percent of Cumulative Units Below	Number of Units Below	dBA Level	Percent of Cumulative Units Below	Number of Units Below
71.0	0.0	0			
72.0	3.12	1	72.0	0.0	0
73.0	3.12	1	73.0	11.54	3
74.0	9.37	3	74.0	15.38	4
75.0	9.37	3	75.0	26.92	7
76.0	12.50	4	76.0	50.00	13
77.0	12.50	4	77.0	65.38	17
78.0	18.75	6	78.0	69.23	18
79.0	18.75	6	79.0	84.62	22
80.0	21.87	7	80.0	92.31	24
81.0	28.12	9	81.0	100.00	26
82.0	28.12	9			
83.0	34.37	11			
84.0	50.00	16			
85.0	62.50	20			
86.0	75.00	24			
87.0	81.25	26			
88.0	90.26	29			
89.0	90.62	29			
90.0	93.75	30			
91.0	96.87	31			
92.0	100.00	32			

Mean: 82.8 dBA***
Standard Deviation: 4.92 dBA***

Mean: 76.1 dBA***
Standard Deviation: 2.40 dBA***

---

* Average sound pressure level in dBA at 7m according to the recommended measurement practice of ISO 2151-1972. Manufacturers were sometimes imprecise in defining the noise data submitted to BBN. BBN has treated this data as an average of noise level for a model based on testing a number of units.

** BBN did not document in its report the manufacturers whose model data is included in the 194 data points reported.

*** The mean is a simple average of model noise data. Data is not available to weight by relative model unit volume sold. Partial weighting schemes by capacity and/or manufacturer were not utilized.

Table 7-5(b)

PERCENT AND NUMBER OF PORTABLE AIR COMPRESSORS
WITH NOISE LEVELS NOT IN EXCESS OF A PARTICULAR VALUE*
(Major Category of Portable Air Compressors by Capacity and Type of Engine)

Diesel Engine, Below 501 cfm Capacity**					
Standard Models			Quieted Models		
dBA Level	Percent of Cumulative Units Below	Number of Units Below	dBA Level	Percent of Cumulative Units Below	Number of Units Below
			70.0	0.0	0
			71.0	11.43	4
			72.0	11.43	4
			73.0	14.29	5
			74.0	17.14	6
			75.0	22.86	8
			76.0	57.14	20
			77.0	68.57	24
			78.0	71.43	25
79.5	0.0	0	79.0	77.14	27
80.5	2.22	1	80.0	77.14	27
81.5	2.22	1	81.0	82.86	29
82.5	17.78	8	82.0	88.57	31
83.5	24.44	11	83.0	88.57	31
84.5	31.11	14	84.0	97.14	34
85.5	48.89	22	85.0	97.14	34
86.5	62.22	28	86.0	97.14	34
87.5	71.11	32	87.0	97.14	34
88.5	73.33	33	88.0	100.00	35
89.5	77.78	35			
90.5	86.67	39			
91.5	88.89	40			
92.5	97.78	44			
93.5	100.00	45			

Mean: 86.1 dBA*** — Mean: 76.4 dBA***
Standard Deviation: 3.35 dBA*** — Standard Deviation: 4.07 dBA***

* Average sound pressure level in dBA at 7m according to the recommended measurement practice of ISO 2151-1972. Manufacturers were sometimes imprecise in defining the noise data submitted to BBN. BBN has treated this data as an average of noise level for a model based on testing a number of units.

** BBN did not document in its report the manufacturers whose model data is included in the 194 data points reported.

*** The mean is a simple average of model noise data. Data is not available to weight by relative model unit volume sold. Partial weighting schemes by capacity and/or manufacturer were not utilized.

Table 7-5(c)

PERCENT AND NUMBER OF PORTABLE AIR COMPRESSORS WITH NOISE LEVELS NOT IN EXCESS OF A PARTICULAR VALUE*
(Major Category of Portable Air Compressors by Capacity and Type of Engine)

Diesel Engine, Above 500 cfm Capacity**					
Standard Models			Quieted Models		
dBA Level	Percent of Cumulative Units Below	Number of Units Below	dBA Level	Percent of Cumulative Units Below	Number of Units Below
			73.0	0.0	0
			74.0	4.17	1
			75.0	8.33	2
			76.0	16.67	4
			77.0	45.83	11
			78.0	58.33	14
			79.0	62.50	15
			80.0	66.67	16
			81.0	70.83	17
			82.0	75.00	18
			83.0	79.17	19
			84.0	79.17	19
			85.0	87.50	21
86.8	0.0	0	86.0	91.67	22
87.8	6.25	2	87.0	100.00	24
88.8	15.62	5			
89.8	28.12	9			
90.8	37.50	12			
91.8	46.87	15			
92.8	53.12	17			
93.8	65.62	21			
94.8	68.75	22			
95.8	68.75	22			
96.8	75.00	24			
97.8	84.37	27			
98.8	87.50	28			
99.8	93.75	30			
100.8	96.87	31			
101.8	100.00	32			

Mean: 92.8 dBA*** Mean: 78.7 dBA***
Standard Deviation: 4.08 dBA*** Standard Deviation: 3.90 dBA***

* Average sound pressure level in dBA at 7m according to the recommended measurement practice of ISO 2151-1972. Manufacturers were sometimes imprecise in defining the noise data submitted to BBN. BBN has treated this data as an average of noise level for a model based on testing a number of units.

** BBN did not document in its report the manufacturers whose model data is included in the 194 data points reported.

*** The mean is a simple average of model noise data. Data is not available to weight by relative model unit volume sold. Partial weighting schemes by capacity and/or manufacturer were not utilized.

REPEATABILITY OF DATA

Data acquired using the CAGI/PNEUROP method were compared with available manufacturer's data. Figure 7-3 present a histogram of the compressor in which good repeatability is shown, i.e., both mean and median ratios are approximately zero. Further comparisons are made in Table 7-8, in which noise levels associated with four models of the same compressor are presented. As shown by the data, noise levels repeat to within 1.5 dB at individual measurement positions and to within 1.0 dB on the average.

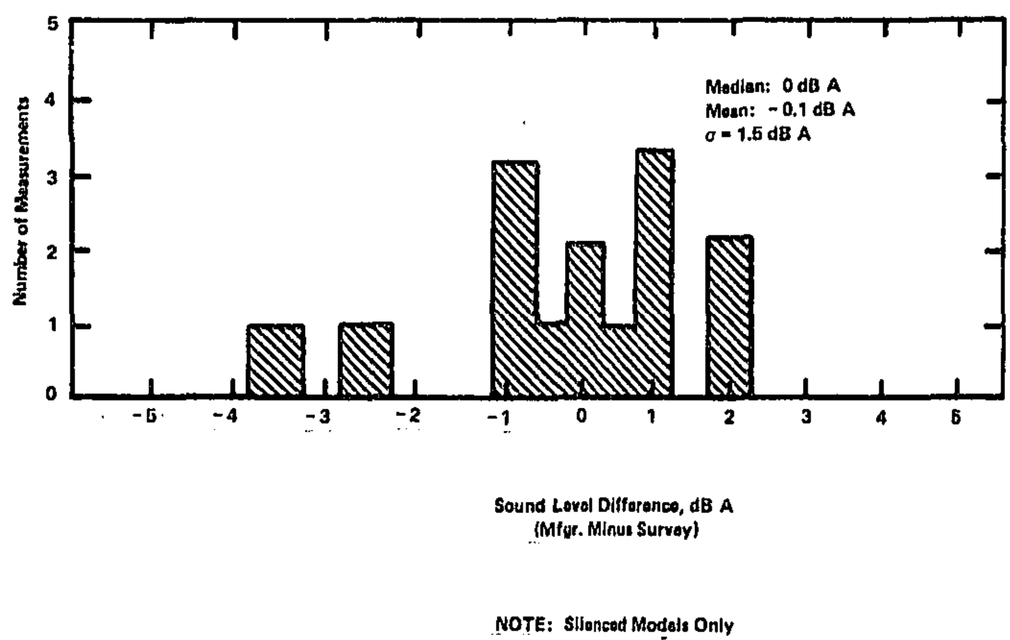


Figure 7-3. Comparison of Manufacturer Supplied with Survey Data

Table 7-6

REPEATABILITY OF NOISE LEVELS OF FOUR MODELS
THE INGERSOLL RAND DXL 900S COMPRESSOR

	Measurement Positions**					Average dBA Level
Serial No.	7	8	9	10	11*	
73693	73	76.5	78.5	77	75	76.0
74050	72.5	75.5	76.5	76.5	74.5	75.1
74041	73	76.5	77	76.5	73.5	75.3
740471	72	76.5	77	75.5	74	75.0

* Overhead Position
** See Figure 6-1

NOISE DIRECTIVITY

Noise levels measured during compressor operation at rated power were analyzed to assess noise directivity around portable air compressors. Table 7-6 lists dBA levels, average dBA levels, and the maximum directivity factor associated with the six types of compressors. The data were acquired using the 10-point hemisphere measurement method. The data show little variance in noise level from position to position, indicating little directivity of noise.

Figure 7-4 show a polar plot of noise at various azimuthal locations, every 30 degrees in the horizontal plane, around a compressor. Again, little directivity is shown.

Table 7-7

AIR COMPRESSOR NOISE DIRECTIVITY

Microphone Location*	Worthington 160G/2QT	Atlas Copco YSS-170	Worthington 750QTEX	Ingersoll Rand DXLCU1050	Ingersoll Rand DXL900S	Gardner Denver SPQDA/2
	Sound Level, dBA					
A	77	71	72	92	77.5	81
B	77	75	72	94.5	76.5	80.5
C	77	72	73	93	80	77
D	77	72	73	94.5	75.5	78.5
E	78	72	71	94.5	78	79
F	77	71	71	93	80.5	79.5
G	78	71	72.5	91	81	80.5
H	77	72	72.5	91.5	81	81
I	77	71	72	92	79	80.5
J	76	70	72.5	89	78	77
Average dBA	77.1	71.7	72.2	92.5	78.9	79.5
Maximum Directivity Factor **	1.23	2.14	1.22	1.58	1.62	1.43

* See Figure 6-2 and 6-3

** Maximum directivity factor = $\text{antilog}_{10}\left(\frac{L_{max} - \bar{L}}{10}\right)$

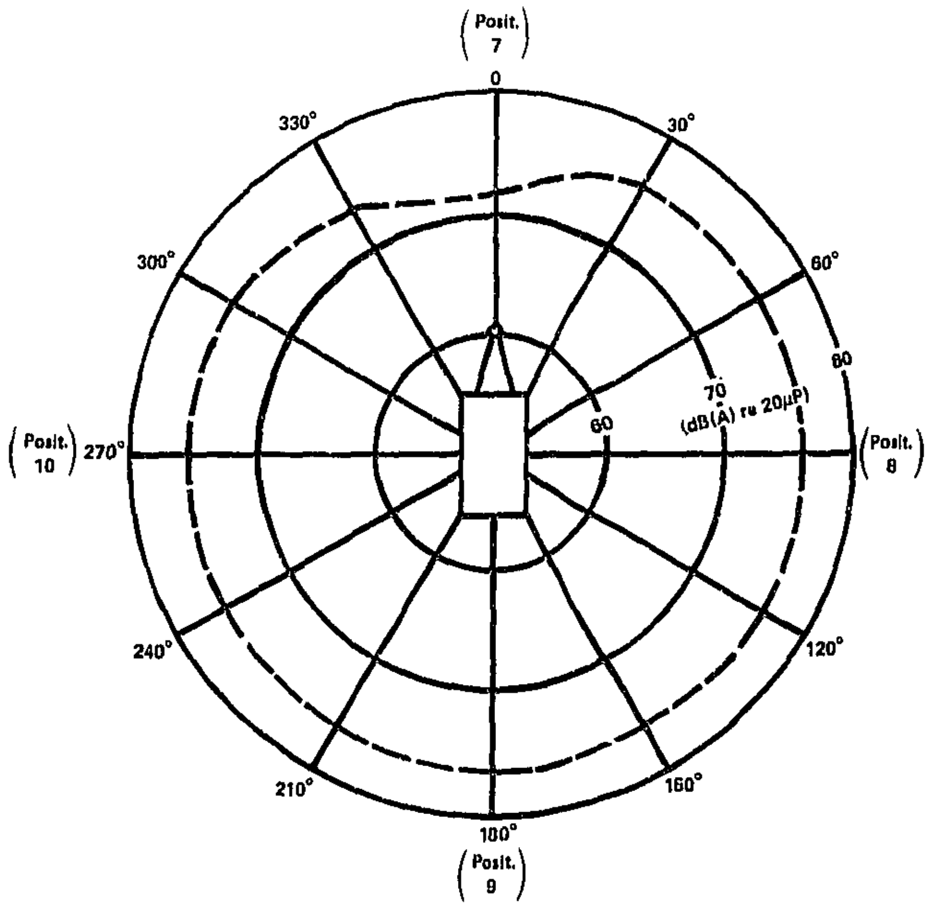


Figure 7-4. Horizontal Directivity of Ingersoll-Rand DXL 900S Compressor

SOUND POWER CALCULATION

Because portable air compressor noise may, in part, be defined in terms of sound power, sound power levels calculated using data acquired by the CAGI/PNEUROP method, with and without the overhead microphone position point, were compared with levels calculated from data acquired by more conventional means, i.e., by microphones located at the center of surfaces of equal area on the surface of an imaginary hemisphere about the sound source.

The results presented in Table 7-7 show that power levels calculated from the CAGI/PNEUROP 4 and 5-point data compare well to those calculated using the more precise 10-point hemispherical measurement method. An average difference of only 0.6 dB was found in each case. These results occurred primarily because the compressors tested were not very directive. In the extreme case of a completely nondirective compressor, all methods would yield exactly the same results. In fact, only one sound level measurement would be required.

Table 7-8

SOUND POWER LEVEL COMPARISONS

Compressor	PWL* (4 pt.) (dBA)	PWL* (5 pt.) (dBA)	PWL* (10 pt.) (dBA)	PWL_{10} minus PWL_4	PWL_{10} minus PWL_5
Atlas Copco VSS 170	96.4	96.3	96.7	0.3	0.4
Worthington 160 QT	100.9	100.5	102.1	1.2	1.6
Worthington 750-QTEX	99.9	99.9	100.2	0.3	0.3
Ingersoll-Rand DXLCU 1050	117.4	117.2	117.5	0.1	0.3
Ingersoll-Rand DXL 900S	102.2	102.1	103.9	1.7	1.8
Gardner-Denver SPQDA/2 (Full Power)	105.0	105.1	104.5	-0.5	-0.6
Gardner-Denver SPQDA/2 (Idle)	96.6	97.1	97.5	0.9	0.4

*PWL = Sound power level

LOW FREQUENCY NOISE

The A-weighting network of sound level meters attenuates low-frequency noise; e.g., -39.4 dB, -26.2 dB, -16.1 dB, and -8.6 dB at frequencies of 31.5 Hz, 63 Hz, 125 Hz and 250 Hz, respectively.[18] As such, great differences can result between A-weighted levels and the unweighted (relatively speaking) C-weighted levels. The significance of this is the possibility that while a compressor's A-weighted data may be decreased, the C-weighted level could conceivably remain the same, or could in fact increase. Though A-weighted sound level decreases might adequately reduce health and welfare impact. C-weighted noise control is desirable as well to preclude the escalation of overall unweighted compressor noise.

Tables 7-9 and 7-10 show dBC/dBA differences for standard and silenced portable air compressors, respectively. As shown, dBC/dBA differences up to 28 dB are noted for silenced models. Figure 7-5 gives insight into the cause for the greater dBC/dBA difference for the silenced models. In the figure, it is shown that a lower dBA level for the silenced unit has been achieved by a shift of peak sound levels to the low frequency range. Note that while the A-weighted sound level of a compressor has been reduced by 6dB (standard to silenced) the C-weighted value has been reduced by only 1dB as a result of the different weighting characteristics of the A and C networks.

In view of (1) the fact that a A-weighted noise reduction does not necessarily imply an attendant C-weighted reduction and (2) the desire to control the C-weighted level of compressor noise as well as the A-weighted value, Figure 7-5 was prepared from the data of Tables 7-9 and 7-10 to give insight into achievable C-weighted levels. The line in Figure 7-5 represents a best-fit curve through the data points and indicates that a dBC minus dBA limit of 20dB would be a reasonable control limit.

Table 7-9

COMPARISON OF dBA LEVELS WITH dBC LEVELS OF STANDARD PORTABLE AIR COMPRESSORS

Manufacturer	Model	S/N	Cfm	dBC Level Minus dBA Level* dB
Atlas Copco	VT85Dd	ARP203149	85	11
Atlas Copco	ST-48	51-232751	160	8.5
Atlas Copco	ST-95	51-274977	330	9.5
Ingersoll-Rand	DXL750	77380	750	5
Ingersoll-Rand	DXL900	75847	900	3
Ingersoll-Rand	DXLCU1050	75613	1050	7
Ingersoll-Rand	DXL1200	74430	1200	3
Jaeger	E	RC32032	85	12.5
Jaeger	A	RS32189	175	13.5

*Average levels at 7 meters

Table 7-10

COMPARISON OF dBA LEVELS WITH dBC LEVELS
OF SILENCED PORTABLE AIR COMPRESSORS

Manufacturer	Model	S/N	Cfm	dBC Level Minus dBA Level* dB
Atlas Copco	VS85	ARP203903	85	16.0
Atlas Copco	STS35Dd	ARP550924	125	23.5
Atlas Copco	VSS125Dd	51-345060	125	28.0
Atlas Copco	VSS170Dd	51-235072	170	21.0
Worthington	160G/2QT	821478	160	15.0
Gardner-Denver	SPHGC	629717	185	12.0
Gardner-Denver	SPQDA/2	608227	750	7.5
Worthington	750QTEX	848-019	750	10.5
Ingersoll-Rand	DXL 900S	73693	900	7.7
Ingersoll-Rand	DXL 900S	74050	900	6.9
Ingersoll-Rand	DXL 900S	74051	900	7.8
Ingersoll-Rand	DXL 900S	740471	900	7.5
Gardner-Denver	SPWDA/2	635851	1200	10.0

*Average levels at 7 meters

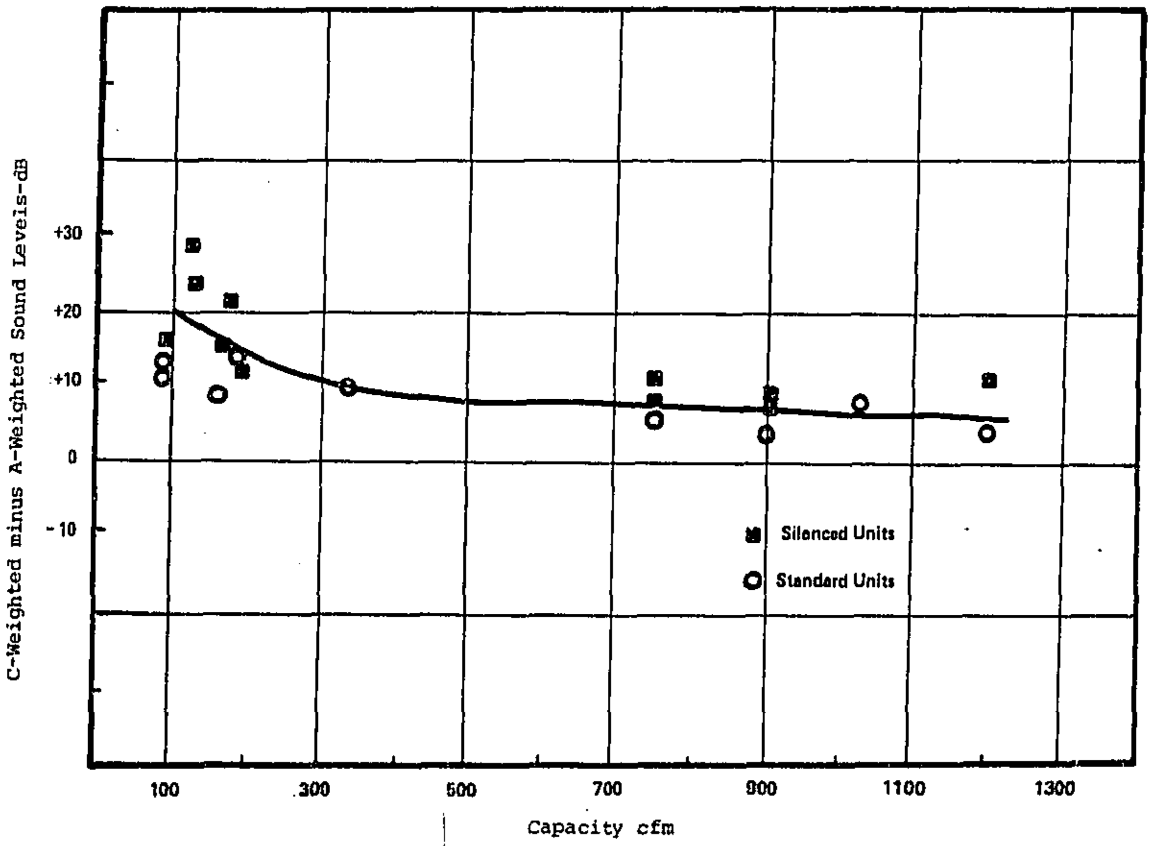


Figure 7-5. Portable Air Compressor C-Weighted minus A- Weighted Levels Versus Capacity-cfm

ACOUSTIC VALUE OF PORTABLE AIR COMPRESSOR DOORS

At a construction job site, portable air compressor equipment compartment doors are often left open because of the operators' misguided intent of furnishing more engine and compressor cooling. Actually, portable air compressors are designed to provide adequate cooling with the access doors closed. Since the access doors, when closed, eliminate a direct line of sight to the engine (which is the major source of noise) an escalation of portable air compressor noise is expected to occur when the doors are left open.

Six tests were conducted, three of the standard units and three of silenced units, to assess the magnitude of escalation of portable air compressor noise due to opening the access doors. Table 7-11 presents the results of the tests of the standard units; shown is a noise increase of up to 5dB.

Table 7-11

EFFECT ON STANDARD PORTABLE AIR COMPRESSOR NOISE OF OPENING THE EQUIPMENT COMPARTMENT ACCESS DOORS

Manufacturer	Model	A-weighted Increase, dBA*
Ingersoll-Rand	DXL 1200	5
Jaeger	A	1.5
Jaeger	E	1.5

* Difference in level at the right side of the unit between door open and closed position.

Table 7-12 list the results for the silenced units; shown is an increase up to 12 dBA when the access door of the Worthington 750 QTEX was left open.

Table 7-12

EFFECT ON SILENCED PORTABLE AIR COMPRESSOR NOISE OF OPENING THE EQUIPMENT COMPARTMENT ACCESS DOOR

Manufacturer	Model	A-weighted Increase, dBA
Worthington	160 QT	5
Atlas Copco	VSS170Dd	11
Worthington	750 QTEX	12

In view of the data of tables 7-11 and 7-12, portable air compressor equipment compartment access doors must remain closed during compressor operation to preclude acoustic degradation of the portable air compressor.

PORTABLE AIR COMPRESSOR NOISE PROPAGATION

If the propagation of sound away from compressors to points more than several hundred feet in the community is of concern, then meteorological factors (wind, temperature, humidity, and precipitation) may be significant. In addition, obstacles and variations in ground cover may be important. For shorter distances, the propogation may be complicated by interference phenomena between the sound waves radiating directly from a source and those reflected from nearby surfaces, especially the ground.[19, 20, 21]

Ground Reflections

Contributions arising from constructive/destructive interference between direct sound waves and sound waves reflected from the ground plane at measurement positions have been evaluated. Figure 7-6 shows A-weighted compressor noise measured 7 meters away from a compressor at various heights above the ground. While it is shown that sound level variations in some 1/3 octave bands of up to 7 dBA from one height to another, the variation in overall sound level is ± 1 dBA from the central position.

The effects of ground reflections on the measured sound levels at the 7-meter positions appear to be "averaged out" by the spatial distribution of the individual noise generating components of the compressor. Thus, it is concluded that at 7 meters ground reflections do not modify the measured sound levels.

Path Discontinuities

As compressor noise propagates away from the source, propagation path discontinuities can affect the sound waves. The six configurations in Figure 7-7 comprise those typical at construction sites. The half sapce shown in this figure represents the area surrounding a compressor during testing per ISO-2151-1972 or when used during construction in a residential or light industrial area. Sound propagating in a half space is subject to the interference effects discussed previously. When a compressor in a residential or light industrial area is next to a building, the buildings usually are far enough apart to be described by the "L" space in Figure 7-7. Anderson[22] reported that sound propagates in an "L" cross section as it does in free space. The sound level at a point in an "L" space is expected to be on the order of 3 dB higher than the sound level measured at the same point in a free field over a reflecting plane, because the sound energy is concentrated in a smaller volume in an "L" space than in a half space. Francois and Fleury[19] measured a corresponding 2 dB increase in compressor noise in an "L" space.

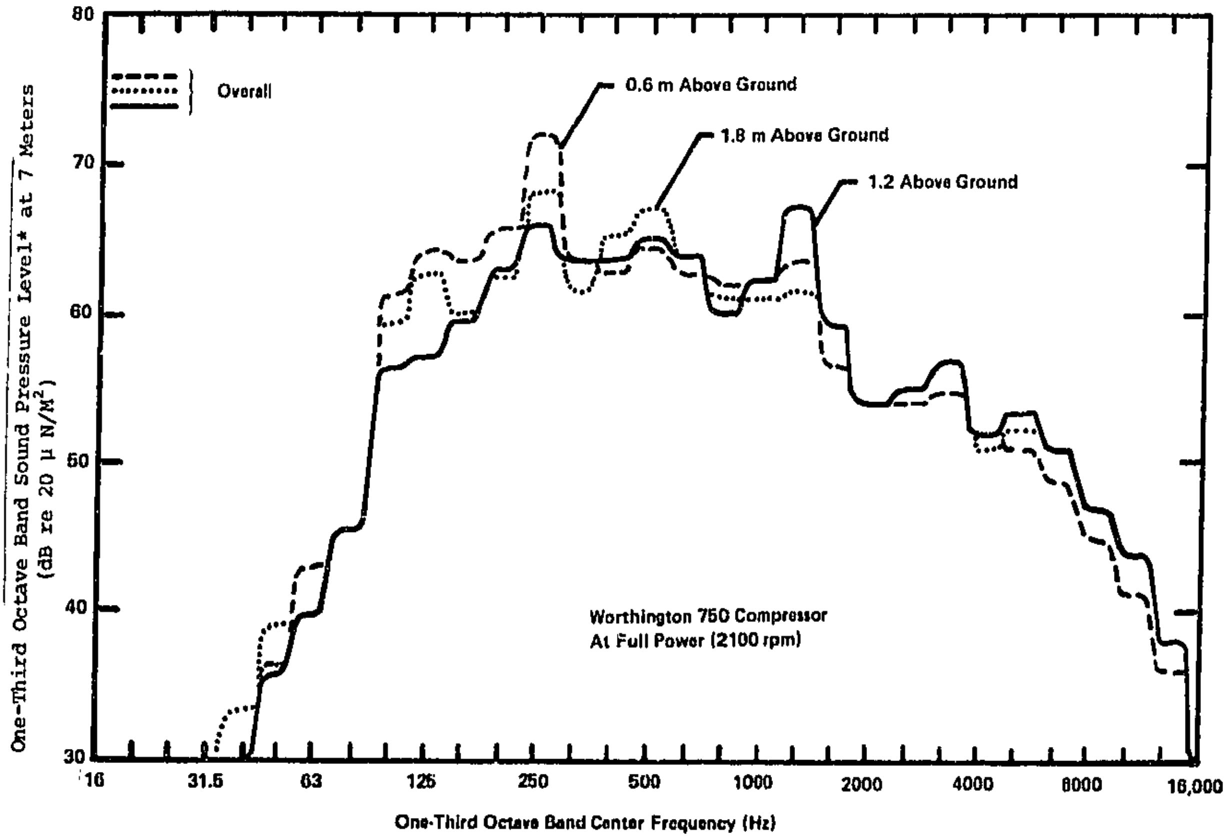


Figure 7-6. Effect of Microphone Height on A-Weighted Sound at 7 Meters.

*Sound was prefiltered by A-weighing network prior to 1/3 octave band analysis

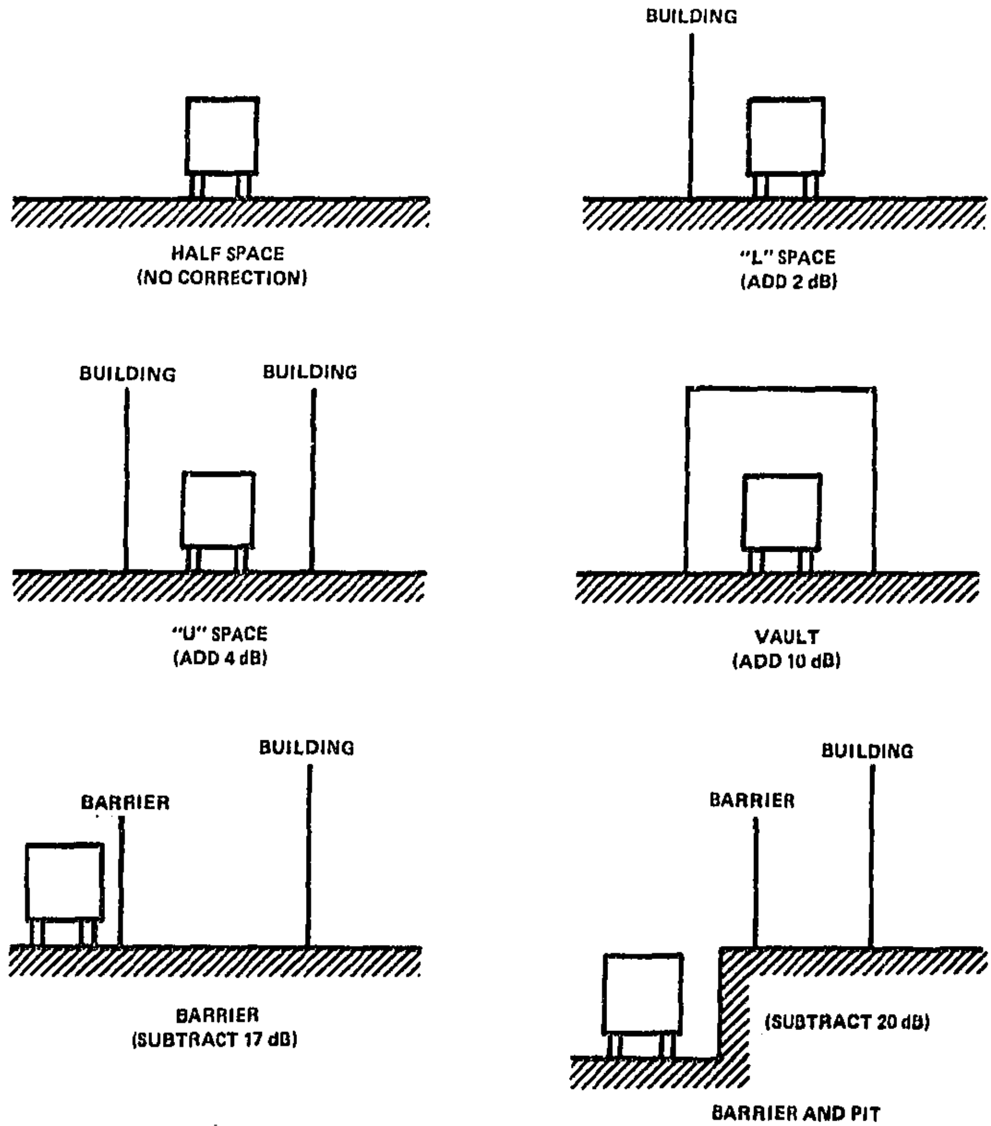


Figure 7-7. Configurations of Locations of Compressors at Construction Sites (Corrections are for Sound Levels at 7 Meters from the Machine Surface When Compared to the Half-Space Levels)

The "U" space in Figure 7-7 is representative of city "canyons" formed by a street or alley and the vertical walls of nearby buildings. Appendix A of Reference 10 discusses the propagation of sound in city canyons in more detail and also includes the results of calculations carried out using an extension of the theory of Weiner, et al.[23] The theory shows that a nondirectional source produces sound levels in a typical city canyon that are 6 dB higher 100 feet from the source than the levels present in a half space. Francois and Fleury[19] measure a corresponding 4-dB increase for a "U" space of different dimensions from the "U" space analyzed in Appendix A of Reference 6.

There is some concern that the sound levels experienced in the upper stories of city buildings might be unusually high if the observers are located above a compressor with pronounced vertical directivity, particularly if the compressor sound is confined within a city canyon. However, Appendix A of Reference 6 shows that an air compressor that radiated sound four times as efficiently (in terms of intensity) in the vertical direction as in the horizontal direction will expose people in city buildings to less than 4 dB higher sound levels than an air compressor that uniformly radiates an amount of sound energy. Thus, this assertion does not appear to be valid.

A compressor operated under a bridge or overpass can be described in terms of the vault space in Figure 7-7. The sound levels generated in such a space can be more than 10 dB higher than the sound levels generated in a half space.

The barrier and pit configurations depicted in Figure 7-7 are typical of construction sites in cities. Usually the construction of a building in a city center begins with the erection of a tall broad fence. During the initial ground breaking, compressors operate at ground level behind the fence. As excavation proceeds, compressors operate within the pit dug for the basement floors. Calculations presented in Appendix B of Reference 24 show that pits and barriers can reduce the noise levels experienced by outdoor ground level observers by as much as 20 dB below the levels experienced in an unobstructed half space. The benefits to upper story observers in buildings across the street depend on the construction stage, on the observer's elevation, and on if there are vertical reflecting surfaces in addition to those shown in the barrier configurations in Figure 7-7.

Extrapolation of Data

The near and far field are described in terms of wave propagation. The near field is close to the source, though how far it extends depends on the wave length of the radiated sound. Normally, the acoustic near field extends a distance of about one quarter of a wave length. Sound pressure fluctuations with the near field correspond to the hydrodynamic response of the fluid to the motion of the adjacent surface. In the far field, the sound pressure fluctuations are caused by the propagation of sound waves away from the source. Typically, noise decreases 6 dB per doubling of distance away from the boundary between the near and far field. Within the near field, no typical decay rate is known. Thus, projection of far field levels from near field levels using the 6 dB doubling rule may not give accurate results. If the 1 meter CAGI/PNEUROP points in the near field are used for far field noise predictions, inaccurate estimates may result.

One way to verify that the 1 meter data are taken in the near field is to compare 1- and 7- meter levels. A histogram of the difference in these levels is presented in Figure 7-8 for the 26 compressors that were measured. This figure clearly shows negligible correlation between the two sets of measurements. Spherical spreading of the sound field between 1 and 7 meters would yield about 17 dB difference between these two points. No compressor showed this large a decrease. Moreover, the differences are randomly spread from 5 to 15 dB.

The preceding results indicate that it is erroneous to use 1-meter levels to calculate far-field noise levels and vice versa, for that matter. Further, inaccurate sound power estimates might also result from simillar predictions. To see if 1-meter data are useful in determining the noisiest side of the machine, the three dimensional histogram of Figure 7-6 was derived. The loudest side at 7 meters is plotted against the noisiest side at 1 meter in this figure.* Again, the 1-meter data show poor correlation with the 7-meter data, in that in half the cases the noisiest direction is incorrectly indicated. Good correlation would place most on the measurements on the diagonal line in Figure 7-9.

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* The abscissa in Figure 7-8 use the following convention: 0 degrees is the forward direction, with angular position measured clockwise looking down on the compressor. (See appendix C of Reference 6).

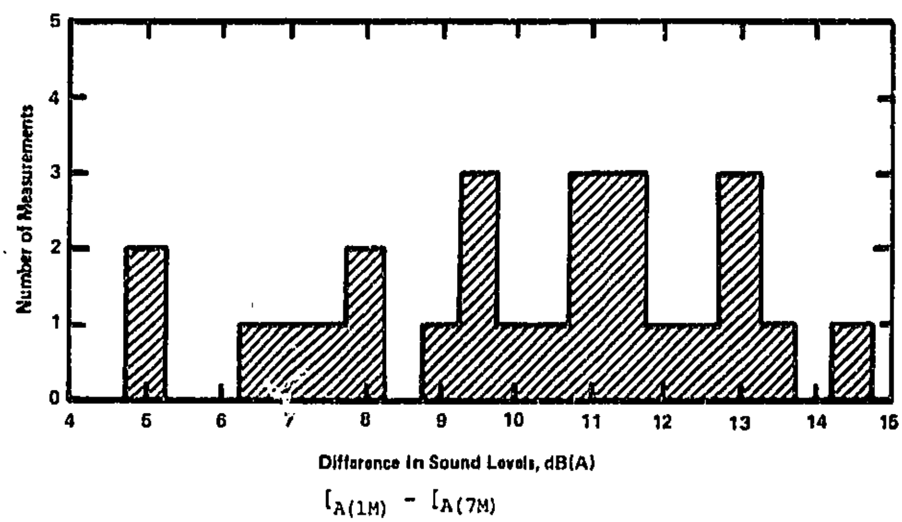


Figure 7-8. Comparison of 7-M with 1-M CAGI/ PNEUROP Average Sound Levels

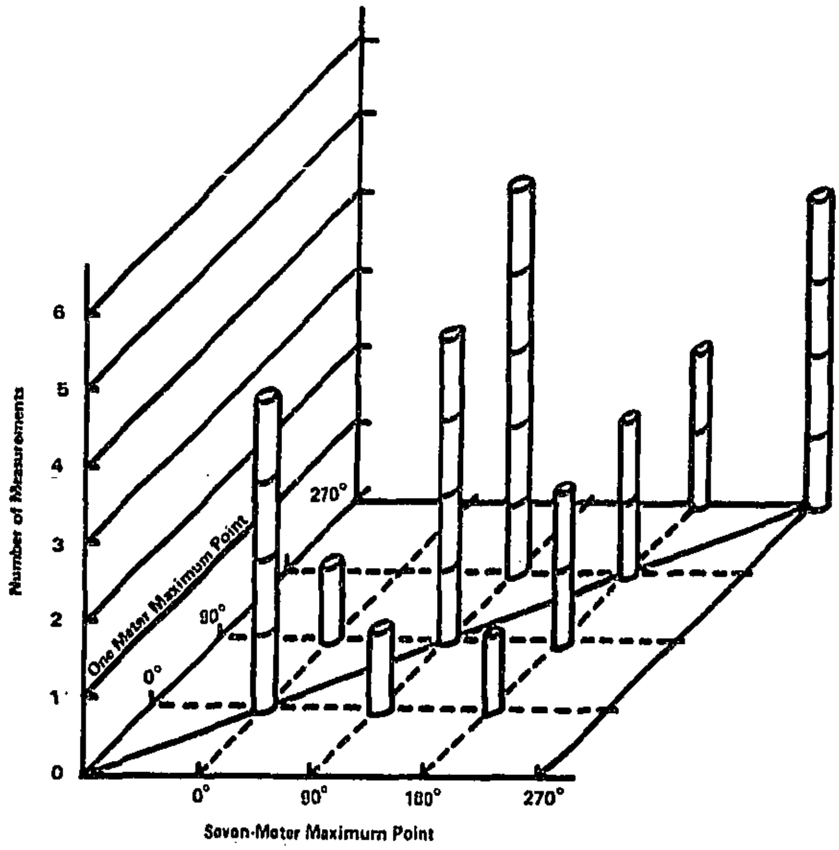


Figure 7-9. Histogram Comparing Maximum Point at 7-M and 1-M Distances

Section 8

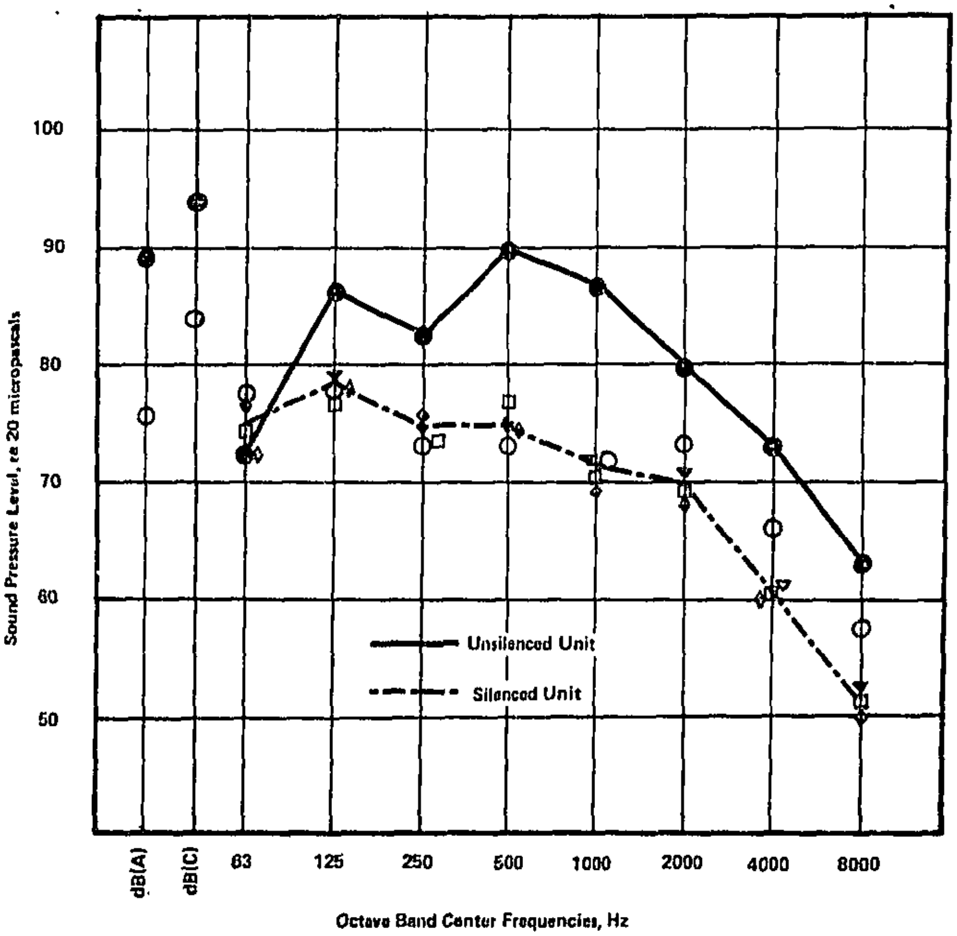
AVAILABLE NOISE CONTROL TECHNOLOGY

UNITED STATES TECHNOLOGY

In 1968, a major manufacturer of portable air compressors demonstrated significant noise reduction by the use of muffling devices and acoustic enclosures.[25, 26] Since then, numerous manufacturers in the United States and abroad have applied various degrees of noise control technology and have reduced portable air compressor noise. Figures 8-1 and 8-2 show two examples of effective noise control. In this section, the current state-of-the-art of compressor noise control is discussed and noise control techniques is summarized.

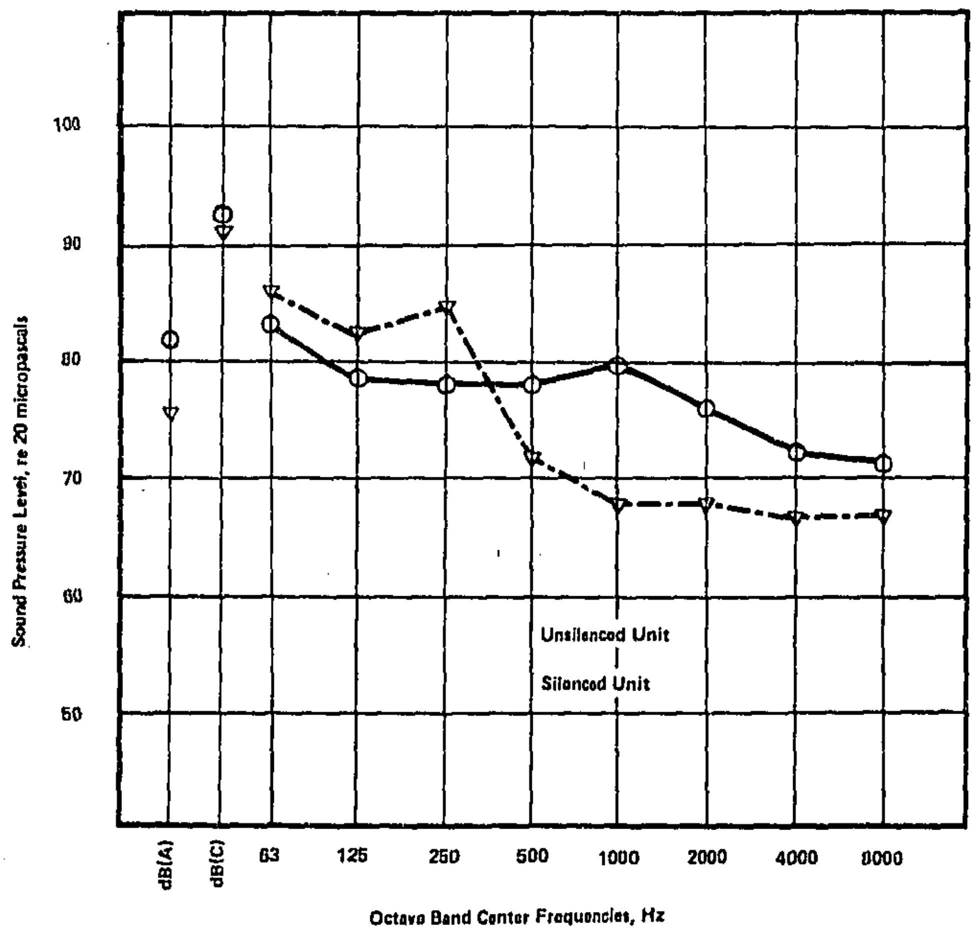
Most large air compressors are diesel engine driven, screw type compressors. The intermediate sizes are diesel and gasoline engine driven, screw and rotary type compressors while the smaller types are primarily gasoline engine driven, screw, rotary and reciprocating type compressors. For all standard types, the major noise sources are the driving engine itself and the fan associated with the engine and compressor cooling air system. A description of the various types of compressors is contained in References 5 and 6.

Application of acoustic insulation, effective mufflers, shock mounts, damping material, and some fan, cowling, and duct hardware modifications/improvements generally describe the technology used to quiet compressors. Use of this technology has produced the mean noise reductions listed in Table 8-1.



NOTES: (1) CAGI/PNEUROP Position 10
(2) 900 cfm, 125 psi

Figure 8-1. Noise Control Applied to the Ingersoll-Rand Model DXL 900



NOTES: (1) CAGI/PNEUROP Position 9

Figure 8-2. Noise Control Applied to the Atlas-Copco Model VT85 Dd

Table 8-1

MEAN NOISE REDUCTION BETWEEN "STANDARD", QUIETED", AND "QUIETEST" UNITS

	Gasoline	Diesel Below 500 CFM	Diesel Above 500 CFM
Standard to quieted units	6.7 dB	9.7 dB	14.1 dB
Quieted to quietest units	3.8 dB	6.4 dB	5.2 dB

The values listed in Table 8-1 may be compared with the potential for noise reduction discussed in Reference 3. As indicated in Reference 3, the potential noise reduction was 5 . . . and 10 dB by the use of improved intake silencers and engine mufflers, respectively. Note that the 5 dB and 10 dB noise reductions are not additive, because the total noise reduction is dependent upon individually reducing the noise level of all the major sources of noise. To determine more accurate potential noise reduction capabilities for compressors, a study was conducted of the three quieted units:

1. A gas engine powered air compressor
2. A diesel engine powered air compressor of less than 500 CFM capacity
3. A diesel engine powered air compressor of greater than 500 CFM capacity

The purposes of the study were to determine the major sources contributing to compressor noise, the effectiveness of the noise control techniques used by the manufacturers, and the evaluation of additional noise control required to reduce each unit's noise to 65 dBA, measured at 7 meters from the unit.

Gas Powered Engine Compressor

A Worthington 160 QT was selected for analysis. Significant noise sources of this unit are the compressor, the engine and its cooling fan, the exhaust and muffler shells, and the air intake.[7]

The engine and compressor assembly radiate noise directly, with the compressor assembly somewhat attenuated by the surrounding air-oil tank. In addition, since they are rigidly attached to the chassis and the shell of the machine, engine and compressor vibration is transmitted directly to the frame and outer sheet metal, which also vibrate and radiate noise.

The engine cooling fan can produce considerable broadband noise as the result of design practices that would cause the fan to excessively agitate the air surrounding the fan. In addition to generating noise, such practice would also reduce efficiency of both the fan and the overall cooling system.

The engine exhaust and muffler arrangement produces noise because of the direct discharge; it can also radiate noise from the large muffler shell vibrating with the internal pressure fluctuations. The air intake system supplies the engine and compressor through a common air filter and silencer. The two air induction pressures thus combine to form a separate noise source.

The noise level at 7 meters to the right side of the unit (as sold) was 76 dBA. The contribution of the principal noise sources to this level are tabulated below in Table 8-2.

Table 8-2

WORTHINGTON COMPRESSOR 160 QT COMPONENT NOISE LEVELS

Component	dBA
Engine and Compressor Casing	74
Engine Cooling Fan	69
Muffler Shell	66
Exhaust	62
Intake	61

The individual noise sources were carefully studied to determine the methodology to further reduce the unit's noise level to the 65 dBA study level. By use of the following noise control techniques with resulting attenuation of Table 8-3, a compressor noise level of 65 dBA at 7 meters could be achieved.

Table 8-3

PORTABLE AIR COMPRESSOR NOISE REDUCTION

Source	Noise Control Technique	Noise Reduction
• Engine and compressor casing	Vibration isolation plus increased transmission loss through side doors	14 dB
• Engine cooling fan	Shroud redesign, blade twist and reduced fan speed	11 dB
• Muffler shell	Lagging with acoustic insulation	10 dB
• Exhaust	Additional muffling	5 dB
• Intake	Improved silencer	4 dB

Diesel Powered Compressor, less than 500 CFM

The quieted Atlas Copco Super Silensair VSS170 Dd was selected for analysis.[7] This unit produces approximately 72 dBA at 7 meters distance from the unit. The analysis of the unit's noise signature indicates that the principal noise sources are the engine casing, engine exhaust, engine intake, compressor casing, and compressor cooling fan, each of which produce the sound levels at 7 meters listed in Table 8-4.

Table 8-4

ATLAS COPCO COMPRESSOR VSS170 Dd COMPONENT NOISE LEVELS

Component	dBA
Engine Casing	63
Engine Exhaust	60
Engine Intake	61
Compressor Casing	64
Compressor Cooling Fan	63

Mid-frequency silencing is achieved by use of an enclosure having side walls and end doors lined with a foam type acoustic absorption material. The enclosure has built-in ducting for the engine and compressor air intake and cooling. Cooling air exhausted from the diesel engine and the compressor and intercooler is ducted through another part of the enclosure prior to discharge. These ducts are primarily effective in blocking direct, line-of-sight, internal noise radiation from the engine and compressor to the ambient. An additional 5 to 7 dB in radiated sound could probably be obtained by employment of the following noise reductions techniques.

1. Application of damping material to the enclosure panels; damping will reduce panel vibration levels and improve panel transmission loss due to the added mass.
2. Increasing the internal sound absorption by (a) treating a larger amount of the internal surface area and (b) using a thicker absorptive material. Note: the absorptive material should be treated to prevent degradation due to contamination.
3. Use of a more effective vibration isolation mount to decouple the engine and compressor from the chassis.
4. Use of a more effective diesel exhaust muffler.

By using the above noise control techniques, the attendent 7 dB overall reduction could result in a compressor noise level of 65 dBA at 7 meters.

Diesel Engine Powered Air Compressor Greater than 500 CFM Capacity

The "Blue Brute" 750-QTEX single stage, portable, rotary screw compressor manufactured by Worthington CEI was selected for study.[7] The 750-QTEX is a quieted unit; it has been silenced to product 75 dBA at 7 meters. Among diesel powered compressors delivering greater than 500 CFM, the 750-QTEX is one of the quietest. It is only 1.5 dB noisier than the mean for the lowest decile.

The technology by which the 750-QTEX has been quieted is also characteristic of the quietest compressors in its category. It has rubber engine mounts, nonrigid hose coupling, sealed doors, damped panels, interior sound absorption, silenced fan louvers for cooling air intake and exhaust, 2-stage custom designed muffler, bottom pan, and a special cooling fan. Principal sources of the noise are listed in Table 8-5 along with their individual noise levels.

Table 8-5

WORTHINGTON COMPRESSOR 750 QTEX COMPONENT NOISE LEVELS

Component	dBA
Engine and compressor casing	69
Engine cooling fan	62.5
Muffler shell	70
Exhaust outlet	67

The 750-QTEX enclosure presently provides adequate noise reduction of engine and compressor airborne sound, except at the cooling air intake and exhaust ducts. Additional noise reduction is possible with design improvement of both the ducts and the material used for acoustic absorption.[7] Analysis showed that the 750-QTEX cooling fan is lightly loaded (aerodynamically). A noise reduction of 3 dB could be effected by fan redesign to provide greater fan loading (aerodynamic). The muffler shell radiated noise level can be reduced by building an enclosure around the shell, whereas, exhaust outlet noise can be reduced by employment of a manifold type muffler. Use of the noise reduction techniques discussed can result in achievement of a 65-dBA compressor.

EUROPEAN TECHNOLOGY

Atlas Copco and CompAir compressors use a double-wall construction, with cooling air ducted between the walls. All the "Super Silenced" Atlas Copco air compressors are the reciprocating type. Discussions with Atlas Copco indicate that reciprocating air compressors are more efficient, with less heat rejection. Atlas Copco uses air cooled engines with cooling fans built in, which demonstrate a much better performance than the fans measured on domestic air compressors. CompAir compressors use a sliding vane or rotary screw type compressor with a water cooled Perkins diesel engine. The pusher type fan is well shrouded. Proper air flow through either unit requires door-shut type operation. The noise control technology used in Europe is simillar to that used in the United States, but a more systematic approach is applied to quieting air compressors. Noise control design is more from the frame up and uses an integrated approach rather than merely adding on quieting silencers. Foreign "super silenced" air compressors tend to have a boxy look. The outer enclosure is double walled and serves as an air duct and silencer as well as a barrier to engine and compressor radiated noise.

To achieve low noise levels, enclosures should be absolutely sealed under operation in order to avoid noise leaking out through even small openings. It has been reported that large compressors emitting less than 65 dBA under full power are already on the market.[27]

Section 9

ECONOMIC STUDY

Section 6 of the Noise Control Act of 1972 provides that the Administrator of the Environmental Protection Agency (EPA) shall establish noise emission standards (where feasible) on products that are found to be major sources of noise or that are in specific product categories named in the law. This regulatory program is applicable to construction equipment products in both instances.

Section 6 further states that the regulation:

> shall include a noise emission standard which shall set limits on noise emissions from such product and shall be a standard which . . . is requisite to protect the public health and welfare, taking into account the magnitude and conditions of use of such product . . . the degree of noise reduction achievable through the application of the best available technology, and the cost of compliance . . . Any such noise emission standards shall be a performance standard. In addition, any regulation . . . may contain testing procedures necessary to assure compliance with the emission standard in such regulation, and may contain provisions respecting instructions of the manufacturer for the maintenance, use, or repair of the product.

The EPA, to adequately address the potential economic impact of noise emission regulations upon the various affected societal units (industry, user, suppliers), acquired data that related to pricing characteristics, dollar volume and unit volume of the portable air compressor market. Additionally, information was developed that related to the costs-to-quiet portable air compressors using the technology currently being utilized and also the best available technology, whether or not it was actually being applied. The information that was developed and that related to the market and the costs-to-quiet formed the background for the economic impact/analysis report the major conclusions of that report are contained in Section 9 of this document.

The basic objective of the study was to assess the economic impact of the adoption of alternate noise emission standards on the portable air compressor industry. This assessment included consideration of the impact on raw material and component suppliers, distributors, manufacturers, end users, and the general public. The industry-wide impact and the distribution of impacts on market segments and individual companies were determined. The impact on key governmental policy concerns such as employment and the balance of trade was also assessed.

COST DATA

The following discussion presents cost data for quieting portable air compressors. The data addresses the costs to quiet compressors utilizing currently available technology as well as the best available technology. From the data the cost and economic impact were developed.

TOTAL SALES VOLUME

All portable air compressor pricing is based on discounts from published list prices. The manufacturers published discount schedule typically ranges from 20 to 25%. However, discounts to distributors can vary from 15 to 45%, depending on volume and other transaction factors.

According the the United States Department of Commerce, prices of portable air compressors rose 24% between 1967 and 1972, or at a compound annual rate of 4.4%. This price trend is expected to continue because of the general increases in labor and material costs. Table 9-1 presents the average prices of portable air compressors by power source and capacity-cfm.

Table 9-1
ESTIMATES OF PORTABLE AIR COMPRESSOR AVERAGE LIST PRICES - ALL MODELS

Capacity-cfm and Power Source Type	Estimated Average List Price,
75 - 124 Gas	$3,982
124 - 249 Gas	5,741
124 - 249 Gas	6,791
250 - 599 Diesel	17,509
600 - 899 Diesel	29,376
900 and over Diesel	48,918

DOLLAR VOLUME

Sales of portable air compressors are sensitive to government and private funding of construction activity. Sales of large units have historically followed trends in the construction industry, while smaller units have followed the general economy. Dollar value of portable air compressor shipments has fluctuated between $58.7 million and $89.7 million during the years 1967-1972. Portable air compressor sales are projected to reach approximately $93 million during 1973.

Table 9-2 presents the value of total portable air compressor shipments during 1967-1972. No adjustments have been made to account for inflation. The data of Table 9-2 were derived from information made available by the Compressed Air and Gas Institute and the Department of Commerce. The derivation of these data is discussed in Reference 8.

Table 9-2

ESTIMATED DOLLAR VALUE OF ANNUAL SHIPMENTS OF PORTABLE AIR COMPRESSSORS: 1967-1972

Year	Value of Shipments
1967	$ 58, 700, 000
1968	59, 915, 000
1969	75, 295, 000
1970	70, 295, 000
1971	74, 131, 000
1972	89, 732, 000

PERCENT DISTRIBUTION BY TYPE COMPRESSOR

The portable air compressors currently manufactured are primarily powered by gasoline or diesel engines. Three basic design types of compressors are used in portable air compressors: rotary screw, sliding vane, and reciprocating. Table 9-3 illustrates the distrubtion of engine and compressor type according to engine capacity.

Table 9-3

DISTRIBUTION OF ENGINE TYPES AND COMPRESSOR DESIGN TYPES ACCORDING TO RATED ENGINE CAPACITY IN CFM AT 100 PSIG

Compressor Type	75-200 cfm			201-500 cfm			Above 500 cfm		
	Gasoline	Diesel	Gasoline and Diesel	Gasoline	Diesel	Gasoline and Diesel	Gasoline	Diesel	Gasoline and Diesel
Reciprocating	16.6%	10.3%	26.9%	0%	30.8%	30.8%	0%	6.8%	6.8%
Vane	25.6%	19.2%	44.8%	10.3%	33.3%	43.6%	0%	17%	17%
Screw	15.4%	12.8%	29.2%	2.6%	23.1%	25.7%	0%	76.3%	76.3%
All types	57.6%	42.3%	99.9%	12.9%	87.2%	100.1%	0%	100.1%	100.1%

UNIT VOLUME

Table 9-4 presents total unit shipments which presents a clearer picture of the portable air compressor market than does dollar value. Dollar value is not an accurate form of relative importance due to inflation and industry price increases based on improved features and performance. Furthermore, dollar sales by size category provides a distorted view of the market due to the high purchase price of the larger units.

Table 9-4

TOTAL PORTABLE AIR COMPRESSOR UNIT SHIPMENTS, 1967-1972

Year	Unit Shipments	Yearly Change (%)
1967	9,969	
1968	9,719	-2.5
1969	12,277	25.8
1970	9,973	18.8
1971	9,901	-.7
1972	12,154	22.8

Table 9-5 concentrates on 1972 portable air compressor sales and breaks it down by power source type and capacity.

Table 9-5

PORTABLE AIR COMPRESSOR 1972 SALES BY POWER SOURCE TYPE AND CAPACITY CATEGORY

Power Source Type and capacity cfm	Unit Shipments	Total (%)
75 - 124 gasoline	3,082	25.4
125 - 250 gasoline	4,827	39.7
125 - 249 gasoline	2,101	17.3
250 - 599 diesel	576	4.7
600 - 899 diesel	1,095	9.0
900 and over diesel	473	3.9
Total	12,154	100.0

COST PER CFM

The EPA in its initial evaluation of the portable air compressor market divided compressors into six categories based on engine type and whether or not they were "standard" or "quieted" units. This division was done to get as clear a picture as possible as to the price differentials.

Provided in the following table, for each category, is the mean and standard deviation of price/cfm and sound levels at 7 meters (measured according to ISO 2151-1972). Accordingly, Table 9-6 presents a summary of the present state of noise emissions and price of portable air compressors.

Table 9-6

PRESENT STATUS OF PORTABLE COMPRESSORS
WITH RESPECT TO NOISE EMISSIONS AND PRICE PER RATED CFM

	Gasoline Driven		Diesel Driven			
			Below 501 cfm		Above 500 cfm	
	Standard	Quieted	Standard	Quieted	Standard	Quieted
Number of Units in Samples	32	26	45	35	32	24
Price/cfm						
Mean	$39.23	$43.32	$46.16	$52.11	$43.57	$48.70
Standard deviation	$ 4.40	$ 6.10	$ 4.57	$ 8.30	$ 3.56	$ 3.16
SPL at 7m						
Mean	82.8 dB(A)	76.1 dB(A)	86.1 dB(A)	76.4 dB(A)	92.8 dB(A)	78.7 dB(A)
Standard deviation	4.92 dB(A)	2.40 dB(A)	3.35 dB(A)	4.07 dB(A)	4.08 dB(A)	3.90 dB(A)
Quietest Machines (Lowest decile)						
No. in decile	3	3	6	4	4	2
Mean SPL at 7m	72.6 dB(A)	72.3 dB(A)	82 dB(A)	70 dB(A)	87.5 dB(A)	73.5 dB(A)
Deviation of average price in lowest decile from mean price of quieted	+$5.42	+$5.14	+$0.43	+$10.23	+$0.31	+$2.50

A 10.2 dB mean difference between "standard" and "quieted" compressors is offered at a mean price difference of $5.05 per cfm. Of particular interest is the fact that in the "standard" categories, the quietest machines are priced on the average at only $2.05 above the mean price whereas the quietest of the "quieted" machines is on the average 9.1 dB quieter than the quietest "standard" machine but is priced about $5.96 above the mean price of the "quieted" machines.

NOISE LEVELS FOR STUDY

Two studies have been performed to estimate the cost to quiet portable air compressors.

In the initial study, noise levels associated with three broad categories of portable air compressor capacities were evaluated. The levels selected for study were based on sound level data of 194 portable air compressors representing about 55% to 65% of the all models offered for sale. The levels selected are listed in Table 9-7 along with underlying rationale for their selection.

Table 9-7

INITIAL SOUND LEVEL LIMITS SELECTED FOR STUDY

	Gasoline Driven all cfm Ratings	Diesel Driven Below 501 cfm	Diesel Driven Above 500 cfm
Level One	76 dBA	76 dBA	78 dBA
Level Two	73 dBA	70 dBA	73 dBA
Level Three	65 dBA	65 dBA	65 dBA

Notes: (1) Levels constitute a "not to exceed" criteria

(2) Average sound pressure level in dBA at 7 m. according to the recommended measurement practice of ISO 2151-1972 modified to include an overhead measurement.

(3) Level One corresponds to the average quieted portable air compressor model currently on the market.

(4) Level Two corresponds to the lowest decile of the quieted portable air compressor model currently on the market.

(5) Level Three corresponds to an analytical estimate of a possible portable air compressor noise emission level based on a number of assumptions.

(6) The value for Level One and Level Two are arithmetic averages. The information required to weight the noise levels by relative model sales is not available. Weighting by estimates of capacity and/or manufacturer market share was not utilized.

These data were used to assess the cost and economic impact associated with achieving the levels selected for study. The results of the study are presented in Reference 8.

In the second study, a single sound level value for all portable air compressors, independent of capacity, was selected for each level. The selected values are listed in Table 9-8.

Table 9-8

SOUND LEVELS SELECTED FOR SUBSEQUENT STUDY OF ALL PORTABLE AIR COMPRESSORS

Level One	76 dBA
Level Two	73 dBA

Notes: (1) Levels constitute a "not to exceed" criteria

(2) Average sound pressure level in dBA at 7 meters according to the recommended practice of ISO 2151-1972 modified to include an overhead measurement.

The following considerations led to the selection of the single sound level values:

1. They would enable EPA to make a more reasoned choice as to the levels ultimately selected for the proposed regulation in that there would be several additional data points around which the economic impact analysis could be constructed.
2. A single, uniform level for all compressors would bring the costs to quiet compressors into approximately the same price per cfm range. This would equalize costs and tend to mitigate any significant market shifts from one compressor size category to another.

3. It has been demonstrated that there is little difference in the noise levels porduced by quieted compressors regardless of cfm capacity. Thus for this reason alone, it would make little sense to apply differing noise regulatory levels.
4. A single noise level would create less confusion or uncertainty in enforcement at the Federal, state or local levels. The enforcement official would have to keep only one level in mind. There would be no necessity for extensive cross-checking of model, cfm capacity, or production year. Additionally, it would not matter if the compressor data plate which would also contain the permissible noise level, were missing or obscured.

Missing from Table 9-8 is a level-three value of 65 dBA. The 65 dBA value represents an engineering prediction for an attainable noise level, with the assumption that analytical estimates of noise reduction will be achieved in practice. Although estimates of the cost to quiet portable air compressors to 65 dBA were made,[5,7] EPA is not satisfied with the estimates. In view of the foregoing, evaluation of the economic impact associated with quieting portable air compressors to 65 dBA was not made. Thus, the data reported in the discussions that follow reflect the economics of quieting all compressors to either 76 or 73 dBA.

ESTIMATED COSTS-TO-QUIET PER CFM

The costs of quieting portable air compressors were estimated in terms of list price differentials per cfm of compressor capacity (References 5 and 7 provides details on the estimating procedure employed). Table 9-9 lists the estimated costs to quiet for the sound levels of Table 9-8.

Table 9-9

ESTIMATED COST OF QUIETING PER CFM
BASED ON ANALYSIS OF LIST PRICE DIFFERENTIALS

	Current Mean To Level One Model Type *		Level One To Level Two **
Capacity/ Engine Category	Standard ($/ cfm)	Quiet ($/ cfm)	All Models ($/ cfm)
Gasoline Engine Below 251 cfm (all)	$ 6.11	2.45	6.43
Diesel Engine Below 501 cfm	8.40	3.19	5.79
Diesel Engine Above 500 cfm	7.30	2.50	1.60

These costs reflect quieting a typical average model to each level on a "not to exceed" basis incorporating a 2 dBA manufacturing tolerance based on the A-weighted sound level reduction required from the mean noise levels. From the data in the table it can be noted that the costs required to reach Level Two are significantly lower per cfm for the units above 500 cfm capacity.

This indicates an increase in the economies of scale of larger machines.

METHODS TO ASSESS TOTAL COST

The cost to quiet portable air compressors was estimated using the cost and technology data discussed previously. Estimates were developed on the basis of full margin and incremental margin costs, which are defined below.

* Current mean dBA values of Table 7-5(a) to 76 dBA
** 76 dBA to 73 dBA

1. Full Margin Costs - Full margin method is based on actual increase in direct material purchased and direct labor of fabrication and assembly as reflected in the accounting system. It allocates the full margin of other costs (overhead, profit, etc.) at the same rate to a quieted unit as is currently allocated to a standard unit. This method can be expected to overstate the actual cost change.
2. Incremental Margin Costs - The incremental margin cost reflects an adjustment to the full margin data. Full margins include overhead accounts that will not change with the introduction of quieting or change less than the estimates based on application of margin dollars at the same percentage rate as on a standard machine. The incremental margin rate that has been estimated reflects inclusion of changed costs in overhead accounts and profit margins required to fully reflect all incremental costs and profits on increased investments (i.e., raw material inventories) as well as direct labor and material costs designed to leave the company in the same overall position as with current production. This method attempts to reflect the actual cost change incurred.

The basic findings using estimating techniques described above are as follows:

1. Full Margin estimates are often above the list price estimates particularly without the 2 dBA tolerance considered.
2. Incremental Margin estimates are below the list price estimates for the smaller air flow capacities and about the same as the estimates with tolerance for the larger air flow capacities.

Neither of these estimating techniques takes into account the marketing discounts that the industry typically gives. These discounts may range from 15 to 40% of the list price.

A detailed discussion of the methodology used and the results obtained is contained in Reference 8.

ECONOMIC IMPACT ANALYSIS

The economic impact analysis that follows is built upon the cost data presented in the discussion of Cost Data. The economic impact analysis study was separated into the following six segments:

1. Volume Impact - This segment includes the analysis of changes in industry volume that will occur relative to a baseline forecast.
2. Resource Costs - This segment includes the cost of the resources used to achieve noise abatement and reflects the increased costs to purchase the noise abated equipment and the cost associated with any performance and maintenance changes.
3. Market Impacts - This segment includes an analysis of broad changes in industry and market conditions that might be attendant with the adoption of the proposed noise emission standards.
4. Foreign Trade - This segment covers an assessment of the impact on exports, imports and the balance of trade.
5. Individual Impacts - This segment considers assessment of market impacts that fall differentially on specific companies or industry segments. The impact shakedown might include economic dislocations, unemployment, lowered sales volume and profits, and change in market shares.
6. Disruptive Impacts - This segment considers changes that may occur in an orderly way within the market in response to various shut downs, unemployment, etc., that may be caused by the regulation of portable air compressors.

Two approaches were used to assess economic impact - obtaining direct estimates based on field interviews and published information and making indirect estimates by analyzing the impacts in a supply/demand model based on economic theory. The actual measurement of impact was made by projecting market conditions for 1976 to 1978, both with and without noise emission standards. Specific impacts were considered in isolation and then the interrelationships were developed.

It should be emphasized that the following economic impact analysis is based on estimates. The data used to base the estimated impacts were obtained from several sources including portable air compressor manufacturers themselves. Obviously, precise figures as to the real impact of the proposed regulations will not be available until sometime after the effective date of the regulation.

ECONOMIC IMPACT

The portable air compressor industry/market reaction to adoption of the noise emission levels that were suggested for study are as follows:

1. The total costs to manufacture the equipment will increase.
2. The manufacturers will pass this cost on in the form of an increase in the distributor price (list price).
3. The distributor will pass its cost increase on in the form of an increase in the negotiated customer price.
4. The portable air compressor end user will pass the increase in his equipment purchase costs on to his customers as an increase in the price of products and services provided.
5. Final changes in industry prices and volumes will reflect the changes in portable air compressor purchase prices and operating costs.
6. Ultimately, the consumer will pay a higher price for products due to the required increased cost to reduce noise.

If there are overall cost reductions, as opposed to cost increases, from the adoption of noise control technology, competitive pressures will cause cost decreases to be passed on up the economic chain to the consumer in the form of lower prices.

The scenario under which the economic impacts were estimated is based on the technology and costs contained in References 5 and 7. It is assumed that the technology and costs provided would be the actual future technology adopted and costs incurred. This approach is conservative. It is possible, if not likely, that new technology at lower costs will be developed. Thus, if the current costs based on an assessment of on the shelf technology are reasonably accurate, they are essentially an upper bound estimate. Noise standards can be attained at these costs, but possibly they will be attained at less cost based on better future technology.

Volume Impact

This discussion analyzes the impact of the noise levels suggested for study on the volume of production of portable air compressors.

Pricing

Purchasers of portable air compressors will be presented with a price increase associated with each noise emission level selected for study. Price increases attributable to sound attenuation and compliance and enforcement costs were estimated using estimated marginal cost of quieting based on list price differentials. The list proce was selected as the basis for the economic impact analysis because it is a conservatively constructed estimate and is based on the broadest sample of cost and noise suppression data available. It is indicative of the upper bound on the expected economic impact.

Table 9-10 presents estimates for average list price percentage increase to bring existing models of portable air compressors into compliance with the Level One and Level Two study noise emission levels.

Table 9-10

ESTIMATED AVERAGE LIST PRICE PERCENTAGE INCREASE
BY NOISE LEVEL AND CATEGORY

Power Source Type and Air Flow Capacity	Level One		Level Two
	Standard	Quiet	
Gasoline Engine, all cfm ratings	16.2%	6.1%	33.2%
Diesel Engine, below 501 cfm	18.4	6.3	47.2
Diesel Engine, above 500 cfm	14.4	2.9	20.5

Price Elasticity. Since it is anticipated that the added costs of production associated with quieting portable air compressors will be passed on to consumers (buyers of air compressors), the price of air compressors is expected to increase. Rising prices can be expected to result in reduced sales as demand falls off because users will either find more efficient ways to use gasoline or diesel engine driven air compressors in an effort to cut costs or will switch to substitute products that provide a lower cost alternative method of performing the same work. The degree to which sales will fall depends on the ease with which buyers can change their compressor use habits in different applications to cut rising costs.

Contractor studies indicate that the decrease in demand due to price rises is low until price increases exceed 20 percent of current levels (in constant dollars). After prices rise in excess of 20 percent, demand falls off more rapidly as it becomes worthwhile to substitute hydraulic or electric systems for compressed air systems.

When price rises are below 20 percent (constant dollars), current air compressor users will probably refrain from widespread immediate substitution because:

1. Portable air compressors are a convenient power source for many

2. Users currently have a high investment in tools that operate on compressed air (costing 10 to 200 percent as much as the compressor).
3. Costs of using compressors can be lowered somewhat without substitution through more renting of equipment and other practices.

Industry estimates of the price elasticity of demand (percent decrease in demand due to percent rise in price, $n = \frac{dq/q}{dp/p}$ are about 0.35 for price rises under 20 percent, which is generally considered to be price in elastic.

Contractor studies indicate that the price elasticity of demand is higher when the price increases are in the 20 to 50 percent range. Price increases of such significance would be expected to have a major impact on demand for new and used portable air compressors. Industry estimates of the price elasticity of demand are 0.9 for compressors below 500 cfm and 0.55 for compressors above 500 cfm. The increase in price elasticity when price increases exceed 20 percent, occurs because:

1. The price increase is sufficient to cause users to consider replacing the whole compressed air system, including tools, with a hydraulic or electrically powered system for some applications, especially when lighter tools are required. This assumes that the work output of these competing systems is comparable to that of the compressed air system.
2. The price increase is sufficient to cause users to replace parts for as long as possible on old compressors to avoid buying new compressors.
3. The price increase is sufficient to cause increasing use of air compressors that are not regulated, including large stationary compressors, self-propelled compressors, and power takeoff compressors for use with engine-powered construction equipment.

When prices increase more than 50 percent, the rate of substitution can be expected to decline and the demand should stabilize because there are a number of applications in which the portable air compressor performs a function that is difficult to perform with an alternative power source. However, at such high prices, it can be expected that less expensive alternatives would be developed over time to replace the portable air compressor in more and more situations, unless alternatives subsequently become more expensive due to Federal regulations.

Within the levels under consideration for the proposed standards, Level One corresponds to the 0 to 20 percent price increase analysis, and Level Two corresponds to the 20 to 50 percent price increase analysis.

Estimates of required lead times for an orderly adoption of technology necessary to meet Federal standards vary for each of the levels included in the proposed standards. BBN estimated a lead time of six months for compliance for Level One, while the compressor industry estimated 12 to 24 months. For the purpose of this economic impact analysis, it is assumed that the regulation will take effect on January 1, 1976. The estimated reduction in sales is shown in Table 9-11 based on previous elasticity estimates.

Table 9-11

LEVEL ONE - ESTIMATED FIRST YEAR
UNIT REDUCTION FROM BASELINE FORECAST-1976

Power Source and Capacity	Unit Reduction	Percent Reduction (%)
Gasoline Engine (all)	358	4.5
Diesel Engine, below 500 cfm	148	5.0
Diesel Engine, above 500 cfm	121	4.9
TOTAL	627	4.6

BBN estimated a lead time of 18 months for compliance with Level Two, while the industry estimated much longer periods. For the purpose of this analysis, it was assumed that the Level Two regulation would take effect January 1, 1978. The reduction in sales is shown in Table 9-12 based on previous elasticity estimates.

Table 9-12

LEVEL TWO -ESTIMATED FIRST YEAR
UNIT REDUCTION FROM BASELINE FORECAST-1978

Power Source and Capacity	Unit Reduction	Percent Reduction (%)
Gasoline Engine (all)	2,100	25.6
Diesel Engine, below 500 cfm	742	23.2
Diesel Engine, above 500 cfm	244	9.3
TOTAL	3,086	22.0

These calculations are based on prices of quieted units currently on the market. To the degree that prices are less than current ones due to production changeover making the quiet models the standard models, actual reductions in sales will be less than the estimates in the tables.

Resource Costs

This discussion presents a summary of the resources that will be used to meet the noise standard at each level. The resource costs are estimated in three ways.

1. The annual increase in capital cost required by end user industries in the first year of enforcement.
2. The annual increased annual total costs of the end user industries in the first year of enforcement.
3. The annual increased total costs of operation for a 100 percent quieted population of portable air compressors.

Resource Cost Factors

The estimates of first-year capital costs for end user industries are based on the increased purchase price paid and volume of purchases estimated. The pricing is at the list price level. This measure represents the additional capital that must be financed by end user industries due to the enforcement of the noise standard.

The resource cost factors included in the estimate of the total annual increased cost for end users are:

- depreciation
- capital costs
- transportation costs
- operating costs
- maintenance costs

These factors are discussed in greater depth in the Economic/Impact study (Reference 8).

The analysis has developed both upper bound and a lower bound resource cost estimate to bracket the range of costs incurred from quieting portable air compressors at each level.

Level One. Table 9-13 presents the estimated end user capital cost increases for enforcing a Level One Noise Standard in 1976.

Table 9-13
TOTAL ESTIMATED FIRST YEAR INCREASED CAPITAL COSTS FOR END USER INDUSTRIES-LEVEL ONE-1976

Portable Air Compressor Power Source Type and Capacity	Increased Capital Costs *	
	Lower Bound	Upper Bound
Gasoline Engine, all cfm capacities	$ 4,839	$ 5,113
Diesel Engine, below 501 cfm	3,579	3,809
Diesel Engine, above 500 cfm	11,397	12,092
TOTAL	$19,815	$21,014

Note: * Capital costs equal the adjusted forecast volume (lower bound) and baseline forecast (upper bound) multiplied by the increased capital cost per unit.

Table 9-14 presents estimated total annual cost increased for end user industries after the adoption of a Level One standard in 1976.

Table 9-14

TOTAL ESTIMATED FIRST YEAR INCREASED
ANNUAL COSTS (IN THOUSANDS)
FOR END USER INDUSTRIES-LEVEL ONE-1976

Portable Air Compressor Power Source Type and Capacity	Increased Annual Costs	
	Lower Bound	Upper Bound
Gasoline Engine, all cfm capacities	968	1,022
Diesel Engine, below 501 cfm	716	762
Diesel Engine, above 500 cfm	2,280	2,418
TOTAL	$3,964	$4,202

Note: (1) Annual total costs include depreciation, capital costs, transportation cost, operating costs, and maintenance costs. costs.

(2) Ten year, straight line depreciation of 10% per year is used.

(3) A return on investment or capital cost rate of 10% of the capital investment is used.

(4) There are no increased transportation costs associated with Level One.

(5) The analysis indicates that there will be only negligible increases in operating costs.

(6) Maintenance costs associated with Level One are projected to be negligible.

From the data in the table it can be seen that the total estimated increased annual costs for the first year of enforcement are estimated to be in the range of $3.9 to $4.2 million.

Level Two. Increased end user capital cost estimates in the first year of enforcement after adoption of a Level Two noise standard in 1978 is presented in Table 9-15.

Table 9-15

TOTAL ESTIMATED FIRST YEAR INCREASED CAPITAL COSTS (IN THOUSANDS) FOR END USER INDUSTRIES-LEVEL TWO-1978

Portable Air Compressor Power Source Type and Capacity	Increased Capital Costs *	
	Lower Bound	Upper Bound
Gasoline Engine, all cfm capacities	8,378	11,749
Diesel Engine, below 501 cfm	5,489	7,454
Diesel Engine, above 500 cfm	13,997	15,718
TOTAL	$27,864	$34,921

Note: * Capital costs equal the adjusted forecast volume (lower bound) and the baseline forecast (upper bound) multiplied by the increased capital cost per unit.

Estimated total annual cost increases in the first year of enforcement after adoption of Level Two noise standard in 1978 are presented in the following table (Table 9-16).

Table 9-16

TOTAL ESTIMATED FIRST YEAR INCREASED ANNUAL COSTS FOR END USER INDUSTRIES-LEVEL TWO-1978

Portable Air Compressor Power Source Type and Capacity	Increased Annual Costs	
	Lower Bound	Upper Bound
Gasoline Engine, all cfm capacities	1,723	2,416
Diesel Engine, below 501 cfm	1,127	1,538
Diesel Engine, above 500 cfm	2,943	3,304
TOTAL	$5,793	$7,258

Notes: (1) Annual total costs include depreciation, capital costs, transportation costs, operating costs, and maintenance costs.

(2) Ten year, straight line depreciation of 10% per year is used.

(3) A return on investment or capital cost rate of 10 percent of the capital investment is used.

(4) An explanation of the method used to calculate the increased transportation costs associated with Level Two appears in Reference 8.

(5) The analysis indicate that there will be only negligible increases in operating costs.

(6) Maintenance cost increased associated with Level Two are projected to be minor.

From the data in the table it can be seen that the total estimated increased annual costs for the first year of enforcement are estimated to be in the range of $5.8 to $7.2 million.

<u>100 Percent Quieted Population.</u> Based on an extrapolation of the 1976 to 1978 portable air compressor population baseline, estimates were made using a 2.2 percent annual growth rate to determine the estimated population of

portable air compressors in 1990. It is estimated that using the 2.2 percent annual growth rate figure that the population would be 140,000 by 1990.

It has further been calculated that a Level One noise standard may result in reducing the estimated 1990 portable air compressor population by about 5 percent. On this basis, it can be concluded that the Level One total 1990 population will be approximately 133,000 units. A Level Two noise standard may result in reducing the estimated 1990 population by 27.7 percent. Based on that reduction, the Level Two total 1990 population would be approximately 101,000 units.

Table 9-17 summarizes the increased annual operating cost of a 100-percent quieted portable air compressor in 1990.

Table 9-17

TOTAL ESTIMATED ANNUAL INCREASES IN COST (IN THOUSANDS)
FOR END USER INDUSTRIES BY LEVEL - 1990

Noise Standard	Increased Annual Cost	
	Lower Bound	Upper Bound
Level One	34.6	36.6
Level Two	46.7	61.3

Of significance, it should be noted that:

1. Estimated Level One annual increased costs range closely from $34.6 to $36.6 million. Level Two cost estimates range more widely from $46.7 to $61.3 million.
2. As the required noise emission level is reduced, the cost of quieting increases. Although the total number of units at Level Two is less than at Level One, estimated Level Two costs are increased over Level One by over 59 percent for the upper bound estimate and slightly over 74 percent ofr the lower bound estimate.

Summary

The analysis of the cost of the resources required to quiet portable air compressors indicates that:

1. The capital costs associated with sound attenuation are significant. Total portable air compressor sales were approximately $90 million in 1972. First year capital costs are projected to be approximately $19.8 to $21 million for Level One and $27.8 to $34.9 million for Level Two.
2. Total operational costs for a 100% quieted population will also be significant. These operational costs are projected to be $34.6 to $36.6 million annually for Level One and $46.7 to $61.3 million annually for Level Two.

Market Impact

The impact of promulgating noise emission levels for portable air compressors on the market and industry as a whole was discussed in greater detail in Section 4 of this project report. However, this discussion treats in a summary form those impacts on the market that can be expected from the adoption of noise control technology. Included in this summary are the impacts on upstream component suppliers, downstream distributors, and end users.

Suppliers

General supplies to portable air compressor manufacturers will not be adversely affected by the adoption of noise control technology primarily because most suppliers to the industry derive only a small portion of their business from manufacturers of portable air compressors. The portable air compressor industry, due to its relatively small size when compared to its component suppliers, will not have an appreciable effect on them without regard to the level established for the emission regulation. The component suppliers to the industry are: (1) engine manufacturers, (2) muffler manufacturers, (3) fan manufacturers, and (4) enclosure and vibration isolator manufacturers.

Distribution

At Level One, channels of distribution and portable air compressor operations are not expected to materially change due to the noise emission standards.

Level Two will not cause channels of distribution to change. However, it will have a greater impact on distributor operations. Many distributors will add other air source lines and competitive systems to their present product lines. The portable air compressor sales mix will change in the lower capacity models reflecting a shift toward more gasoline engine models.

End Users

It has been estimated that the increased costs to be incurred by portable air compressor owners at Level One will be less than 0.1 percent of total operating costs of end user industries. Therefore, little, if any, changes in portable air compressor end user industries are expected at Level One.

Capital and operational cost increases at Level Two are significant. Some end users having a requirement to work on or move material will purchase alternative compressed air sources or competitive systems. Others will switch to rentals as a method to fulfill their compressed air requirements. There will be a tendency to extend portable air compressor life through preventive maintenance programs.

Manufacturers

This discussion presents additional impacts that are anticipated from the adoption of noise standards on portable air compressor manufacturing operations.

Level One. The analysis undertaken shows that there will be no need for increased factory floor space. There will be minor investments required for production equipment. It is not felt that employment will be significantly affected because of (1) a slight reduction in employment due to decreased sales volume and (2) the need to hire additional personnel to incorporate modifications in the portable air compressors required by the Level One regulations.

Level Two. The analysis of the impact of Level Two upon the manufacturers is not as clear as would be desired due to the uncertainty that the manufacturers themselves expressed as to what engineering, production, and employment changes would be necessary to ensure that the recommended modification (contained in Section 8) produces the level of quieting desired.

However, estimates have been made as to the requirements for increased factory floor space within range from 10 to 50 percent. Increases in production time will also be necessary. These estimates range from 15 to 35 percent.

The estimated 27.7% decline in unit volume will have a definite impact on the market. However, because manufacturers do not know the extent of the engineering modifications that Level Two will necessitate, a quantitative analysis of either employment increases or decreases cannot be made. However, a general employment forecast can be made as follows:

1. Firms having plants primarily engaged in portable air compressor production may be faced with sizable layoffs due to reduced unit volume. An order of magnitude estimate of the extent of the employment decrease is ten to twenty-five percent.
2. Firms with plants in which portable air compressors represent a moderate portion of total production may be able to transfer some porduction workers to other functions, and only moderate employment decline is anticipated. Some of these plants will be benefited by increased sales of other air systems or hydraulic systems. An order of magnitude estimate of the extent of employment decrease is five percent to ten percent.
3. Firms with plants in which portable air compressor represent only a small portion of total employment may be able to transfer all affected production workers to other functions and no decline in employment is anticipated.

Foreign Trade

This discussion covers the impact of the adoption of noise standards on export and import patterns for portable air compressors. Noise regulations do not apply to export products but do apply to products imported for use in the United States.

Exports

Domestic portable air compressor manufacturers will be able to export quieted and unquieted products to foreign countries, depending on the competitive requirements of the foreign market with respect to the noise regulations. To the extent that some foreign markets require quiet compressors, domestic manufacturers will be in an improved competitive position since they will have made progress in the application of noise technology to their products under the impetus of noise regulation.

Study inputs from portable air compressor manufacturers indicated that no changes in export patterns were expected due to noise regulations.

Imports

Imports currently account for five to ten percent of total domestic portable air compressor unit consumption. Imported portable air compressor prices are generally competitive or lower than domestic manufacturer prices. However, imports have not significantly penetrated the United State portable air compressor market because of lack of effective distribution networks, poor product quality, in some instances, poor service and parts delivery, and intensive competition by domestic producers.

At Level One, quieted imported portable air compressors are not expected to make significant inroads into the domestic market. The costs associated with quieting, plus the import costs would be more than the costs incurred by domestic producers to meet Level One.

At Level Two, significant inroads into the domestic market could be made by foreign firms. The extent of their market penetration will depend upon the lead time given to meet the Level Two noise standard and price increase required.

Some foreign firms currently produce some models that have noise emission levels at or below Level Two standards. It appears that if adequate lead time is not allowed for domestic producers to engineer and manufacture portable air compressors on a production basis, these foreign manufacturers may be presented a good opportunity to gain an effective distribution system in the United States. If this occurs, and their products sell at a price less than the Level Two domestic product, then their combined order of magnitude market penetration could range anywhere from 15 to 40 percent.

Estimates of what constitutes an adequate lead time vary, depending on the source, from two to six years. Estimates of what constitutes a significant price differential vary from 1 to 40 percent.

If adequate lead time is allowed and domestic manufacturers remain price competitive at Level Two, no shifts in the domestic/import market share are expected.

Balance of Trade

Based on the factors reviewed:

1. No material impact on the balance of trade is anticipated from setting Level One.
2. No material impact on the balance of trade is anticipated from setting Level Two if an adequate lead time is given and domestic producers remain cost competitive.
3. A moderate impact on the balance of trade is anticipated from setting Level Two if adequate lead time is not provided and domestic producers cannot remain price competitive.

Individual Impacts

This discussion addresses differential impacts that may develop affecting a single firm or set of firms.

Small Portable Air Compressor Manufacturers

Small manufacturers may not have sufficient manpower and funds to allocate to the larger and more costly development programs that will be required. However, at Level One, costs and quieting technology are not expected to create a problem to which small manufacturers cannot adjust with adequate lead time.

At Level Two some of the smaller firms in weaker financial positions may be forced out of the portable air compressor market. It has been estimated that 50 percent of the firms with under $5 million of sales, currently operating at losses, or employing less than 100 persons in their portable air compressor operations are likely to withdraw from the market. These firms collectively account for less than ten percent of dollar sales. The exit of half of these companies from the market would not cause a dramatic redistribution of market share. However, it would cause a loss of jobs at the local level in this industry.

Firms Experienced in Noise Technology

Those firms having attained a degree of noise technology and currently having quieted products on the market are much better prepared to meet the noise emission levels suggested for study. This will give firms experienced in quieting technology an advantage in the market for a limited period.

Distruptive Impacts

This discussion assesses the potential for disruptive economic impacts due to the establishment of noise standards per se. It concerns real-world impacts as opposed to impacts that are a change in a forecasted future. With adequate lead time and appropriate planning, business management is able to adjust its plans to reflect changing conditions and to avoid adverse impacts on its operations. Through adjustments in planning future over-capacity, unemployment, and other adverse conditions are avoided.

Assessment

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

1. Level One - 1976. No disruptive impacts are indicated at this level. Cost changes are from ten to twenty percent. However, volume changes

are minor from baseline conditions. The portable air compressor industry would be expected to continue its normal growth pattern with a Level One noise standard. No unemployment would be anticipated.

2. Level Two - 1977. Adoption of a Level Two standard will result in estimated higher costs reflected in substantial price increases (33.2 percent, 47.2 percent, and 20.5 percent for gasoline, diesel below 501 cfm and diesel above 500 cfm units, respectively). It has been estimated that this may result in an overall 27.7 percent decrease in domestic portable air compressor demand. Portable air compressor production shifts may occur in the small capacities to more gasoline engine compressors. A shift may occur to alternative air sources and competitive systems. Under Level Two, the growth pattern of the portable air compressor industry may be curtailed. Some unemployment can be anticipated. A January 1, 1978 enforcement date for Level Two is considered inadequate lead time by many manufacturers. If this estimate is correct, enforcement of the Level Two time frame is likely to permit foreign manufacturers to establish distribution systems and significantly increase their penetration of the domestic market.

Given the size of the portable air compressor industry, no significant economic disruption will be caused the national or regional economy from these changes. Some small unemployment (measured in tens) may occur in specific communities.

SUMMARY

In this section, the economic impact has been assessed based on technical and cost estimates provided by EPA through its contract with BBN. A brief summary of the results is presented as follows:

1. Estimated compressor list prices may increase as shown below in Table 9-18.

Table 9-18

SUMMARY OF ESTIMATED LIST PRICE INCREASES

Power Source Type and Capacity	List Price Increase (%)	
	Level One	Level Two
Gasoline Engine, all cfm capacities	16.2	33.2
Diesel Engine, below 501 cfm	18.4	47.2
Diesel Engine, above 500 cfm	14.4	20.5
Average Price Increase	16.3	33.6

The price increases will be passed on to end users.

2. Unit volume may be affected as indicated in Table 9-19.

Table 9-19

SUMMARY OF ESTIMATED FIRST YEAR UNIT REDUCTION FROM BASELINE FORECAST

Power Source Type and Capacity	Unit Reduction	
	Level One (1976)	Level Two (1978)
Gasoline Engine, all cfm capacities	358	2,100
Diesel Engine, below 501 cfm	148	742
Diesel Engine, above 500 cfm	121	244
TOTAL	627	3,086

Level One may result in an overall 4.5 percent decline in unit volume. Level Two may result in as much as an overall 25.0 percent decline in unit volume.

3. The estimated cost of noise abatement for portable air compressors is presented below in Table 9-20.

Table 9-20

SUMMARY OF THE ESTIMATED RESOURCE COSTS (IN MILLIONS) ASSOCIATED WITH NOISE ABATEMENT

Noise Standard	First Year of Enforcement		100% Quieted Population
	Capital Costs	Annual Costs	
Level One - 1976			
Lower Bound Estimates	$ 19.8	$ 3.9	$ 34.6
Upper Bound Estimates	21.0	4.2	36.6
Level Two - 1978			
Lower Bound Estimates	27.8	5.8	46.7
Upper Bound Estimates	34.9	7.2	61.3

4. There will be little effect on upstream component suppliers. Distributors and end users will be affected in that alternative air sources and competitive systems will become a more important factor in working on or moving material.
5. There will be no effect on factory operations at Level One. Level Two may require more floor space and assembly time and possibly some production line changes.
6. No unemployment is expected to occur due to Level One. Moderate unemployment in isolated localities may occur is Level Two is adopted.
7. No changes in export patterns will occur because of noise regulations. Import patterns are not expected to change due to Level One. Imports may significantly penetrate the domestic market with a Level Two if adequate lead times are not established and domestic manufacturers cannot product a unit that is price-competitive with imported units.
8. If Level Two is adopted, some small manufacturers with weak financial positions are likely to withdraw from the portable air compressor market.

9. There is a potential for disruptive impacts from adoption of a Level Two noise standard. However, no significant impact will be transmitted to the national or a regional economy.

Section 10

EVALUATION OF PORTABLE AIR COMPRESSOR NOISE ON PUBLIC HEALTH AND WELFARE OF THE U.S. POPULATION

Pursuant to the Noise Control Act of 1972, EPA has selected and published noise measures believed to be most useful for describing environmental noise and its effect on people, independent of the sources(s) of noise. In addition, information has also been published on the noise levels "requisite to protect the health and welfare with an adequate margin of safety". The phrase "public health and welfare" includes personal comfort and well being, as well as the absence of clinical symptoms (e.g., hearing loss). Using information published in References 1 and 2, an analysis has been conducted to assess the effects of the proposed air compressor regulation on the public health and welfare of the United States population.

The approach taken for the analysis was to first evaluate the effects of the proposed air compressor regulation alone and then in combination with other possible regulations for other pieces of construction equipment, since air compressors are often operated with other equipment.

The methodology presented in Appendix B has been applied to the specific case of construction noise to evaluate the potential effect of the portable air compressor proposed noise on the public health and welfare. The basis of the analysis has been the model presented in EPA Report No. NTID 300.1.[2]

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

The basic unit of construction activity is the construction site. A construction site exists in both time and space. Four different types of construction sites were evaluated in the analysis:

1. Domestic housing and residential
2. Office Buildings, hotels, hospitals, schools, government buildings, including highrise
3. Industrial, parking garage, religious monuments, amusement and recreation, stores, service stations, but no highrise
4. Public works, municipal streets and sewers.

Construction activity is carried out in several discrete steps, each of which has its own mix of equipment and attendant noise output. The phases of construction studied were those of Reference 2. The data presented in Reference 2 have been adopted for the present analysis, since they provide all the necessary input for deriving the variation in noise output with time. Basically, the process involved in deriving the noise history at each site consists of identifying the equipment found at each site in each construction activity phase in terms of:

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

The original information given in Reference 2 has been reviewed and revised to include data that has since become available. The revisions appear in Table 10-1 a, b, c and d.

The usage factors presented in Table 10-1 were combined with the typical number of hours, H, the equipment operated for a particular task to yield a value of L_{eq} for the site as measured 50 feet from the site during an average

Table 10-1(a)

USAGE FACTORS OF EQUIPMENT IN DOMESTIC HOUSING CONSTRUCTION*

Equipment**		Construction Phase: Clearing	Excavation	Foundation	Erection	Finishing	$L_{eq(50')}$ during work periods for each item, over one project
Air Compressor	[81]	-	.1	-	-	.25	68.7
Backhoe	[85]	.02	.2	-	-	.02	69.6
Concrete Mixer	[85]	-	-	.4	.08	.16	76.4
Concrete Pump	[82]	-	-	-	-	-	-
Concrete Vibrator	[76]	-	-	-	-	-	-
Crane, Derrick	[88]	-	-	-	-	-	-
Crane, Mobile	[83]	-	-	-	.10	.04	69.6
Dozer	[87]	.10	.1	-	-	.04	71.9
Generator	[78]	.4	-	-	-	-	64.6
Grader	[85]	.05	-	-	-	.02	64.8
Jack Hammer	[88]	-	-	-	-	.01	60.8
Loader	[79]	.2	.1	-	-	.04	65.2
Paver	[89]	-	-	-	-	.025	65.8
Pile Driver	[101]	-	-	-	-	-	-
Pneumatic Tool	[85]	-	-	.04	.1	.04	72.3
Pump	[76]	-	.1	.2	-	-	63.0
Rock Drill	[98]	-	.005	-	-	-	65.6
Roller	[74]	-	-	-	-	.04	52.8
Saw	[78]	-	-	.04(2)	.1(2)	.04(2)	68.3
Scraper	[88]	.05	-	-	-	.01	66.8
Shovel	[82]	-	.2	-	-	-	65.6
Truck	[88]	.04	.1	-	-	.04	70.3

------------------ $L_{eq\,(50')}$ per site during work periods = 81.6 dBA

	Clearing	Excavation	Foundation	Erection	Finishing	
Hrs. at site	24	24	40	80	40	Σ = 208 hrs. = 26 days

Total number of sites = 514,500 (Table X of reference 2)

* Numbers in parentheses represent average number of items in use, if that number if greater than one. Blanks indicate zero or very rare usage.

**Numbers in brackets [ ] represent average noise levels [dBA] at 50 ft.

Table 10-1(b)

USAGE FACTORS OF EQUIPMENT IN NONRESIDENTIAL CONSTRUCTION*
($190K-4000K)

Equipment**		Construction Phase: Clearing	Excavation	Foundation	Erection	Finishing	$L_{eq(50')}$ during work periods for each item, over one project
Air Compressor	[81]	-	1.0(2)	1.0(2)	1.0(2)	.4(2)	83.4
Backhoe	[85]	.04	.16	.4	-	.04	76.4
Concrete Mixer	[85]	-	-	.4	.4	.16	79.1
Concrete Pump	[82]	-	-	.08	.4	.08	74.3
Concrete Vibrator	[76]	-	-	.2	.2	.04	66.9
Crane, Derrick	[88]	-	-	-	.16	.04	75.9
Crane, Mobile	[83]	-	-	-	.16(2)	.04(2)	73.9
Dozer	[87]	.16	.4	-	-	.16	77.9
Generator	[78]	.4(2)	1.0(2)	-	-	-	75.2
Grader	[85]	.08	-	-	-	.02	63.5
Jack Hammer	[88]	-	.1	.04	.04	.04	75.2
Loader	[79]	.16	.4	-	-	.16	69.9
Paver	[89]	-	-	-	-	.1	69.7
Pile Driver	[101]	-	-	.1	-	-	84.8
Pneumatic Tool	[85]	-	-	.04	.16(2)	.04(2)	76.2
Pump	[76]	-	1.0(2)	1.0(2)	.4	-	76.4
Rock Drill	[98]	-	.04	-	-	.005	78.0
Roller	[74]	-	-	-	-	.1	54.7
Saw	[78]	-	-	.04(3)	1.0(3)	-	78.4
Scraper	[88]	.55	-	-	-	-	73.1
Shovel	[82]	-	.4	-	-	-	71.8
Truck	[88]	.16(2)	.4	-	-	.16	79.2
		$L_{eq(50')}$ per site during work periods =					90.9 dBA
Hrs. at site		80	320	320	480	160 Σ =	1360 hrs. 170 days

Total number of sites = 12,500 (Tables X and B-1 of reference 2)

* Numbers in parentheses represent average number of items if number is greater than one. Blanks indicate zero or very rare usage.

** Numbers in brackets [ ] represent average noise levels [dBA] at 50 ft.

Table 10-1(c)

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

Equipment**		Clearing	Excavation	Foundation	Erection	Finishing	$L_{eq(50')}$ during work periods for each item, over one project
Air Compressor	[81]	-	1.0	.4	.4	.4	78.2
Backhoe	[85]	.04	.16	.4	-	.04	76.4
Concrete Mixer	[85]	-	-	.4	.16	.16	77.3
Concrete Pump	[82]	-	-	.05	.16	.08	70.9
Concrete Vibrator	[76]	-	-	.2	.1	.04	65.4
Crane, Derrick	[88]	-	-	-	.04	.02	70.2
Crane, Mobile	[83]	-	-	-	.08	.04	68.2
Dozer	[87]	.2	.4	-	-	.04	77.5
Generator	[78]	.4	.4	-	-	-	68.7
Grader	[85]	.05	-	-	-	.02	62.3
Jack Hammer	[88]	-	.1	.04	.04	.04	75.2
Loader	[79]	.16	.4	-	-	.04	69.4
Paver	[89]	-	-	-	-	.12	70.5
Pile Driver	[101]	-	-	.04	-	-	80.8
Pneumatic Tool	[85]	-	-	.04	.1(3)	.04	76.0
Pump	[76]	-	.4	1.0(2)	.4	-	53.1
Rock Drill	[98]	-	.02	-	-	.003	75.1
Roller	[74]	-	-	-	-	.1	54.7
Saw	[78]	-	-	.04(2)	.1(2)	-	67.5
Scraper	[88]	.14	-	-	-	.08	70.5
Shovel	[82]	-	.4	-	-	.06	72.1
Truck	[88]	.16(2)	.26(2)	-	-	.16	78.5
		$L_{eq\ (50')}$ per site during work periods =					87.8 dBA
Hrs. at site		80	320	320	480	160 Σ	= 1360 hrs 170 days

Total Number of sites = 50,000 (Tables X and B-1 of Reference 2)

* Numbers in parentheses represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

** Numbers in brackets [ ] represent average noise levels [dBA] at 50 ft.

Table 10-1(d)

USAGE FACTORS OF EQUIPMENT IN PUBLIC WORKS CONSTRUCTION*
(Municipal Streets and Sewers)

Equipment**		Clearing	Excavation	Foundation	Erection	Finishing	$L_{eq(50')}$ during work periods for each item, over one project
		Construction Phase					
Air Compressor	[81]	1.0	1.0	.4	.4	.4(2)	79.0
Backhoe	[85]	.04	.4	-	-	.16	74.4
Concrete Mixer	[85]	-	-	.16(2)	.4(2)	.16(2)	80.7
Concrete Pump	[82]	-	-	-	-	-	-
Concrete Vibrator	[76]	-	-	-	-	-	-
Crane, Derrick	[88]	-	.1	.04	.04	-	73.8
Crane, Mobile	[83]	-	-	-	.16	-	69.7
Dozer	[87]	.3	.4	.2	-	.16	79.6
Generator	[78]	1.0	.4	.4	.4	.4	74.9
Grader	[85]	.08	-	-	.2	.08	74.1
Jack Hammer	[88]	.5	.5	-	.04	.1(2)	80.7
Loader	[79]	.3	.4	.2	-	.16	71.6
Paver	[89]	-	-	0.1	.5	-	81.4
Pile Driver	[101]	-	-	-	-	-	-
Pneumatic Tool	[85]	-	-	.04(2)	.1	.04	72.6
Pump	[76]	-	.4(2)	1.0(2)	.4(2)	-	75.7
Rock Drill	[98]	-	.02	-	-	-	82.6
Roller	[74]	-	-	.01	.5	.5	67.4
Saw	[78]	-	-	.04(2)	.04	-	63.4
Scraper	[88]	.08	-	.2	.08	.08	78.2
Shovel	[82]	.04	.4	.04	-	.04	71.1
Truck	[88]	.16(2)	.16	.4(2)	.2(2)	.16(2)	84.6
		$L_{eq(50')}$ per site during work periods =					91.1 dBA
Hrs. at site:		12	12	24	24	12	Σ = 84 hours, 10 1/2 days

Total number of sites - 336,600 (Table XIII of Reference 2)

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

work period. For the purpose of this analysis, a construction site is viewed as a complex source in which equipment is centered at 50 feet from an observer. This consideration provides a model with which to establish a base set of data.

The L_{eq} obtained using the model was converted to an L_{dn} for a 24-hour day and then converted to an annual L_{dn} by adding 10 log (H/(8 x 365)). Thus, each construction site was viewed as a complex noise source with a fixed annual value of L_{dn}. The analysis was repeated for each type of site.

The human impact of construction noise was brought into the analysis by use of the data presented in Reference 2 with regard to the number of construction sites of various types in a number of geographical regions, as well as the density of people in these geographical regions. The number of sites per year was taken from Table 10 of Reference 2, and the population density data was taken from Table 9 of the same reference. For the office building category, the transfer of people from the suburbs to the central city during the average working day was considered by adjusting the population data, consistent with the model presented in Reference 2, which is summarized in Table XI of the Reference. This adjustment was necessary to account for the fact that most construction in cities occurs during the working day. Thus, population estimates were obtained for 20 different cases corresponding to the four construction types (residential buildings, non-residentials, municipal streets and public works) and five categories of regions:

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

Two models were used for the propagation of site noise into the community. In residential areas and other lightly built up areas, noise was assumed to be attenuated at the rate of 6 dB per doubling of distance. Accordingly, around each site there exists a series of annuli each of which represent successive 3 dB areas of greater attenuation. A mean noise level L_{dn} (Annual L_{dn}) was associated with each annulus as well as the area in square miles. The latter figure when multiplied by the population density typical of the region yielded the number of people, P, on the average, living within that annulus. It was assumed that on the average, only half of these people were affected by the noise because it is reasoned that only half of the rooms in structure in proximity to the site face the site. This assumption appears reasonable but must be recognized as somewhat arbitrary.

In the case of office building category, a different model was considered. For this situation, it was assumed that noise confined in a builtup area is attenuated by only 3 dB per doubling of distance due to the canyon effect[6] for the first 400 feet and then attenuated by 6 dB beyond the 400 feet, since at that point noise is free to decrease by classical spherical divergence. Further, it was assumed that only 25% of the people in each annulus were affected by the construction noise since in most office buildings not all the rooms have outside exposure. This assumption appears reasonable, but it is somewhat arbitrary.

In the computation of the fractional impact (FI) associated with each annulus around the construction site for office buildings and for industrial sites, computations were performed relative to an exterior L_{dn} of 65 dB rather than the 55 dB assumed for residential areas and public work areas. The rationale for this assumption was that in office buildings adjoining construction sites, windows are normally closed rather than open, which increases the noise reduction between outside and inside from 15 dB to 25 dB (Reference 30). Thus, the additional 10 dB.

From knowledge of the various fractional impacts and number of people associated with each annulus, the equivalent population impacted at 100% for each annulus was obtained and then summed to obtain the total impact (P_{eq}).*

From knowledge of the various fractional impacts and number of people associated with each annulus, the equivalent population impacted of 100% for each annulus was obtained and then summed to obtain the total impact (P_{eq}). *

Computations were performed for several conditions, with a baseline condition established using the noise levels of all construction site equipment listed in Table 10-1. Also computed were conditions in which portable air compressors were reduced to levels of 76 dBA, 73 dBA, 70 dBA, and 65 dBA at seven meters from the compressor housing. Since new truck noise regulations currently being formulated will, in time, cause lower truck noise levels at the construction site, the effect of the combined reduction of portable air compressors and new truck noise were additionally evaluated. The effect of reducing portable air compressor and new truck noise levels are summarized in terms of L_{dn} and P_{eq} in Table 10-2. The effects of the change on the United States population are summarized in terms of P_{eq} in Table 10-3.

Figures 10-1 and 10-2 have been prepared from the data of Table 10-3 to better show the impact of reducing new portable air compressor and new truck noise levels.

Figure 10-1 shows that for portable air compressors, noise reduction at the construction site, only, a sizable (approximately 11%) impact reduction is achieved for portable air compressor noise reduction to 76 dBA at 7 meters, while little (approximately 1% additional relief is obtained for further noise reduction to 65 dBA at 7 meters.

*P_{eq} is numerically equal to the equivalent number of people which have a fractional impact equal to unity (100% impacted). See Appendix B for further details.

Table 10-2

SUMMARY CONSTRUCTION ACTIVITY L_{dn} @ 50' and Peg

	Residential		Non Residential		Industrial		Public Works		U. S.
	L_{dn}	Peq	L_{dn}	Peq	L_{dn}	Peq	L_{dn}	Peq	Peq
I. Baseline All Equipt at Present levels	65.5776	136,600	82.3690	302,300	79.7737	85,300	71.0212	519,000	1,042,000
II. Trucks & Conc. Mixers at 75 dBA @ 50'	63.3394	35,250	82.3052	261,000	78.8558	62,280	69.5449	338,260	696,790
III. As II & Air Compressors @ 72 dBA @ 50'	63.0140	21,614	81.4699	200,780	78.3248	49,700	69.2126	297,460	564,554
IV. As II & Air Compressors @ 69 dBA @ 50'	62.9897	20,592	61.4032	198,316	78.2841	49,166	69.1878	294,427	562,501
V. As II & Air Compressors @ 66 dBA @ 50'	62.9774	20,075	81.3694	197,062	78.2635	48,885	69.1752	292,881	558,903
VI. As II & Air Compressors @ 61 dBA @ 50'	62.9650	19,722	81.3352	195,794	78.2493	48,692	69.1666	291,825	556,033
VII. Trucks & Conc. Mixers @ 83 dBA @ 50' Air Compressors @ 72 dBA @ 50'	64.2304	72,763	81.7707	221,756	78.7711	59,859	69.8527	376,045	730,423
VIII. Trucks & Conc. Mixers @ 83 dBA @ 50' Air Compressors @ 69 dBA @ 50'	64.2120	71,989	81.7085	217,194	78.7343	58,808	69.8313	373,417	721,406
IX. Trucks & Conc. Mixers at Present Levels Air Compressors @ 72 dBA @ 50'	65.1539	111,596	82.1423	249,012	79.3443	76,244	70.7862	490,632	927,484
X. Trucks & Conc. Mixers at Present Levels Air Compressors @ 69 dBA @ 50'	65.1391	110,974	82.0853	244,832	79.3120	75,321	70.7689	488,505	919,635
XI. Trucks & Conc. Mixers at Present Levels Air Compressors @ 66 dBA @ 50'	65.1316	110,659	82.0564	242,713	79.2958	74,858	70.7602	487,440	915,670
XII. Trucks & Conc. Mixers at Present Levels Air Compressors @ 61 dBA @ 50'	65.1264	110,440	82.0365	241,253	79.2846	74,538	70.7542	486,705	912,936

Table 10-3

THE EFFECT OF CHANGE ON THE UNITED STATES POPULATION DUE TO THE PROPOSED PORTABLE AIR COMPRESSOR AND NEW TRUCK NOISE LEVELS

	P_{eq}	Percent Reduction
Baseline date, 1974	1,042,000	0
Only Air Compressors Reduced		
a) 72 dBA @ 50'	927,484	10.99
b) 69 dBA @ 50'	919,635	11.74
c) 66 dBA @ 50'	915,070	12.12
d) 61 dBA @ 50'	912,936	12.39
date, <u>1977</u>: Trucks reduced 83 dBA		
a) Air Comp @ 72 dBA @ 50'	730,423	29.90
b) Air Comp @ 69 dBA @ 50'	721,408	30.76
date, <u>1983</u>: Trucks reduced 75 dBA		
a) Air Comp @ present levels	696,790	33.13
b) Air Comp @ 72 dBA	569,554	45.34
@ 69 dBA	562,501	46.02
@ 66 dBA	558,903	46.36
@ 61 dBA	556,033	46.64
Baseline date, 1983		
Trucks at 75 dBA @ 50'	696,790	0
a) Air Comp @ 72 dBA	569,554	18.26
@ 69 dBA	562,501	19.27
@ 66 dBA	558,903	19.78
@ 61 dBA	556,033	20.20

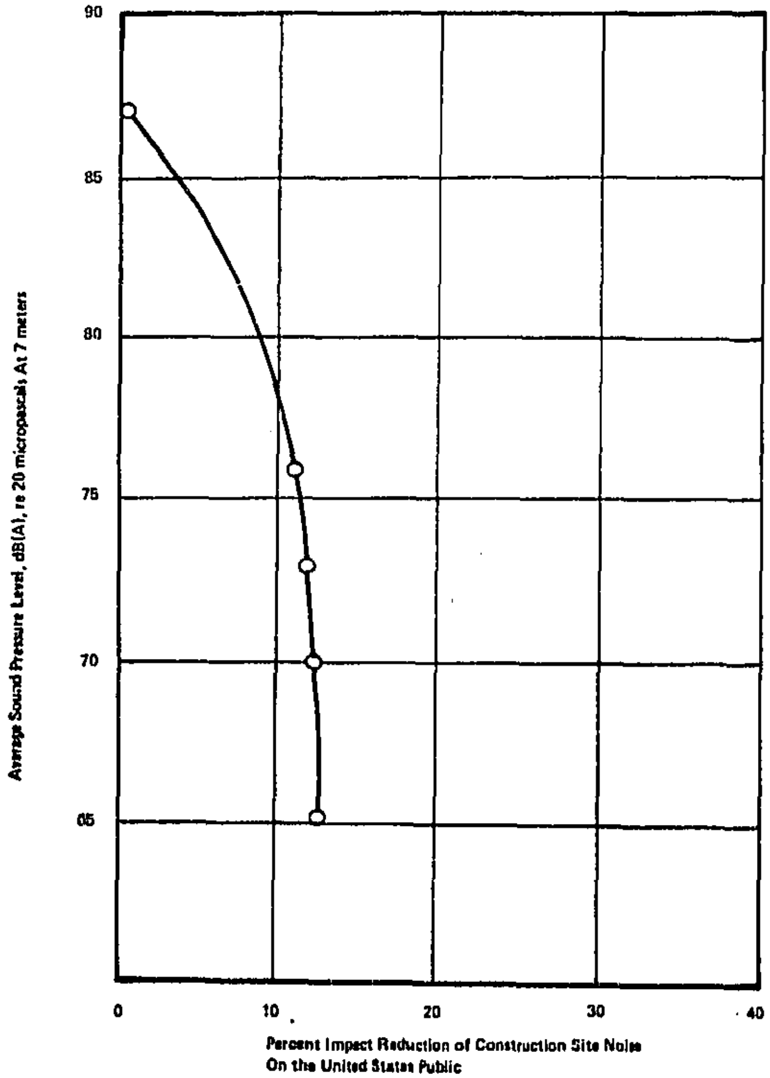


Figure 10-1. Effect on the United States Public Due to Portable Air Compressor Noise

In view of the results of Figure 10-1, Table 10-4 shows that construction site noise impact relief, after portable air compressors are reduced to 76 dBA at 7 meters, is obtained as the result of new truck noise reductions. Specifically, shown by the data is:

1. When truck noise at the construction site is reduced to 83 dBA, the percent impact reduction of construction site noise increases to approximately 30%. This represents an approximate 19% additional (over the compressor reduction alone case) impact relief.
2. When truck noise at the construction site is reduced to 75 dBA, the percent impact reduction of construction site noise increases to approximately 45%. This represents an approximate 34% additional (over the compressor reduction alone case) impact relief.

The results of the public health and welfare study showed that portable air compressor noise reduction to an average of 76 dBA at 7 meters produces a significant and desirable impact relief. Table 10-4 has been prepared to show the contribution of portable air compressor noise to total construction site noise for portable air compressor reduced to 76 dBA (from a current average level of 88 dBA at 7 meters). Also shown in the table, for comparison, is the contribution to construction site by current compressor noise levels. Shown by the data of Table 10-5 is that when portable air compressors are reduced to 76 dBA, the percent contribution to the construction site is reduced approximately one percent, down from 17.8 percent in the worst present case. This decreases the importance of portable air compressor as a source of acoustic energy, from the 2nd noisiest source after trucks at present to the 16th noisiest piece of equipment comprising the hardware mix at a typical construction site.

Table 10-4

EFFECT ON THE UNITED STATES PUBLIC DUE TO PORTABLE AIR COMPRESSOR AND TRUCK NOISE REDUCTIONS TO VARIOUS LEVELS OVER TIME

Noise Level dB A		Percent Impact Reduction Of Construction Site Noise
Portable Air Compressor	Trucks	
88	88	0
76	88	11
76	83	30
76	75	45

Table 10-5

CONTRIBUTION OF PORTABLE AIR COMPRESSSOR NOISE TO CONSTRUCTION SITE NOISE

	Percent of Site Noise		Rank at Site	
Site	Compressor Noise at 88 dBA*	Compressor Noise at 76 dBA**	Compressor Noise at 88 dBA*	Compressor Noise at 76 dBA**
Residential	5.0	1.0	7th	16th
Public Works	6.1	1.0	7th	16th
Industrial	10.7	1.0	3rd	17th
Non-Residential	17.8	1.0	2nd	17th

* Current average level at 7 meters of all compressors.
** Proposed average level at 7 meters.

Section 11

ENFORCEMENT

Enforcement of new product noise emission standards applicable to new portable air compressors may be accomplished through:

- Certification or production verification testing of compressor configurations.
- Assembly line testing using continuous testing (sample testing or 100% testing).
- Selective enforcement auditing of production compressors and in-use compliance programs.

The predominant portion of any certification or production verification testing and assembly line compressor testing can be carried out by the manufacturer and audited or confirmed by EPA personnel as necessary.

Any test used for certification or production verification testing and any test used for assembly line testing of production compressors should be the same test or else should be correlative so that compliance may be accurately determined. A measurement methodology that can be used both for certification or production verification testing and any assembly line testing is a modified version of the CAGI/PNEUROP test code.

CERTIFICATION

Certification is the testing of selected prototype products by a manufacturer or by EPA to determine whether the products conform to a standard. Certification serves the purpose of verifying that a manufacturer has the technology in hand and, when required, it may be used to verify that the applied technology will last for some period of use.

Certification may involve the testing of every configuration of a manufacturer's production to verify whether each conforms, or configurations may be grouped into categories having similar emission characteristics and so that only selected configurations are tested. The configurations tested are then considered representative of the other untested configurations in a category.

The concept of certification has associated with it the issue of approval certificates by EPA after a manufacturer has demonstrated conformity through testing.

Because certification normally deals with a few prototype models, it does not give any indication of the conformance to standards of the manufacturer's product. The ability of a manufacturer to apply the technology to a prototype model does not necessarily mean that actual production line models will also conform. Verification that production models conform can only be made by actual testing of production models.

PRODUCT VERIFICATION

Production verification is the testing of selected pilot line (first production models) by a manufacturer or by EPA to verify whether a manufacturer has the technology in hand and is capable of applying the technology in a manufacturing process. The tested pilot line models (or first production models) must conform with the standard prior to any distribution of that model into commerce.

Production verification does not involve any formal EPA approval or issuance of certificates subsequent to manufacturer testing, nor is any extensive testing required of EPA. Any regulations would require that prior to distribution into commerce of any manufacturer configuration, as defined within the regulations, the configuration must undergo production verification. A compressor model would be considered to have been production-verified after the manufacturer has shown, based on the application of the noise measurement tests, that a configuration or configurations of that model conform to the standard. Production verification testing of all configurations produced by a manufacturer may not be required when a manufacturer can establish that the noise levels of some configurations within a model are consistently higher than others or are always representative of other configurations. In such a case, the higher emitter would be the only configuration requiring verification. Manufacturers must reverify whenever they implement engineering changes to their products after initial verification that are likely to adversely affect noise emissions. Additionally, further testing on some continuing or other periodic basis or production line products will still be necessary to assure, with some confidence, that all products being manufactured conform to the standards prior to being distributed into commerce.

Production verification provides EPA with confidence that production models will conform to the standards and limits the possibility that nonconforming compressors will be distributed in commerce because initial testing is performed on pilot line or first production, models. Because the possibility still exists that subsequent models may not conform, assembly line compressor testing should be made a part of any enforcement strategy, to determine whether production compressors continue to actually conform to the standard.

ASSEMBLY LINE TESTING

Assembly line testing of a production compressor is a process by which compressors, as they are completed on the assembly line, are tested to determine whether they conform to applicable standards. This determination as to whether production compressors comply with the standard can be made by the use of either continuous 100% testing of newly assembly compressors or by testing of representative samples of newly produced compressors and drawing inferences with regard to the conformity with the standard of other newly assembled compressors. In the case of the production of nominally identical compressor configurations exhibiting the same or similar noise emission characteristics through the application of the same or similar noise attenuation technology, the use of sample testing is a realistic way of determining compliance by other untested compressors produced by a manufacturer.

Continuous, 100-Percent Testing

In the absence of a short inexpensive test, 100-percent testing can be costly and time consuming and in most cases unnecessary in the absence of some justification to the contrary since sample testing can yield the desired result. At this time, 100-percent testing is not proposed as a primary enforcement tool; however, 100-percent testing may be required should a manufacturer be discovered to be producing compressors in violation of the regulation.

Sample Testing

Sample testing involves the testing of a percentage of compressors on some continuous basis, the auditing of production line compressors on some random basis, or for specific cause. An auditing strategy would enable EPA to determine if production compressors meet any promulgated emission standards and would provide a deterrent to the distribution in commerce of nonconforming products. An auditing strategy involves the random testing of a representative number of production compressors. Because the number of compressors tested under an auditing strategy is nominal, the cost and effort associated with implementation of such a strategy for a conforming manufacturer is only a fraction of the cost of a program involving continuous testing because fewer compressors are involved.

Any sampling strategy adopted by EPA would not attempt to impose a quality control or quality assurance scheme upon a manufacturer but would merely audit the conformity of his products and would provide a deterrent to the distribution in commerce of non-conforming products.

ENFORCEMENT ACTION

The prohibitions in the Act would be violated when:

- The manufacturer fails to properly certify or verify the conformance of production compressors.

- Where it is determined on the basis of assembly line testing or other information that nonconforming production compressors are knowingly being distributed into commerce.
- When the manufacturer fails to comply with an Administrator's order specifying appropriate relief when nonconformity is determined.

REMEDIES

In addition to the criminal penalties associated with violations of the prohibitions of the Act, which include fines and imprisonment, the Administrator has the option of issuing an order specifying such relief as he determines necessary to protect the public health and welfare. Such an order could include the requirement that a manufacturer recall products distributed into commerce not in conformity with the regulations and that a manufacturer effect any remedies whether or not the manufacturer had knowledge of the nonconformity. Such recall orders would be issued in situations in which assembly line testing demonstrated that compressors of a particular configuration has been distributed into commerce not in conformity with the applicable emission standards.

LABELING

Any enforcement strategies should be accompanied by the requirement for labeling of products being distributed into commerce. The label will provide notice to a buyer and user that the product is sold in conformity with applicable regulations, that the compressor possesses noise attenuation devices, and that such items should not be removed or rendered inoperative. The label should also indicate the associated liability for such removal or rendering inoperative.

IN-USE COMPLIANCE

If the goal of protecting the public health and welfare is to be fully achieved, the noise levels of compressors must not degrade above the standards prescribed for assembly line compressors. The standards should therefore extend over the life of the products, as authorized by the Act. Several compliance strategies can be used to ensure the maintenance of standards. The manufacturer is required (by Section 6 (d)(1)) to warrant for the life of the compressor that it conformed to standards at the time of initial sale. Recall is an appropriate remedy (under Section 11(d)(1)) to require the manufacturer to remedy a class of compressors that fails to conform while in actual use, despite proper maintenance and operation. The tampering with noise emission control devices and elements of design is prohibited by Section 19(a)(2). Finally, the manufacturer can be required (by Section 6(c)(1)) to provide instructions to purchasers specifying the maintenance, use, and repair to keep the compressor within standards.

Section 12

ENVIRONMENTAL EFFECTS OF PROPOSED REGULATIONS ON PORTABLE AIR COMPRESSORS

IMPACT RELATED TO ACOUSTICAL ENVIRONMENT

The proposed regulations will immediately stop the noise emitted by portable air compressors from increasing and will limit their output to a level that will reduce the number of people impacted by construction site noise by 114,000 (approximately). When reviewed in concert with new truck noise regulations, the number of people relieved of impact will be 474,000 (approximately). These regulations are a first step in a comprehensive noise abatement effect aimed at reducing the total environmental noise to which the population is subjected. The composite impact of all Federal noise emission regulations will be aimed at a level of environmental noise consistent with protecting human health and welfare.

Studies have been conducted to estimate the reduction in noise levels and the number of people who will benefit as a result of noise.

IMPACT RELATED TO LAND

Portable air compressor regulations will have no adverse effects relative to land.

IMPACT RELATED TO WATER

Portable air compressor regulations will have no adverse effects on water quality or supply.

IMPACT RELATED TO AIR

These regulations, when promulgated, will have only a slight impact on air quality.

One of the engineering methods that will be utilized to quiet portable air compressors is the installation of a more efficient muffler to reduce noise emissions. This will cause an increase in the back pressure and will reduce the efficiency of the power source from 1 to 9%. Sources differ concerning the increase in back pressure and resulting increased fuel consumption. Additionally, technology studies have been done that indicating that with the appropriate reengineering of portable air compressors to enable them to comply with the noise emission regulations, fuel economy and efficiency will improve rather than deteriorate.

There also exists a possibility of market shifts from gasoline-powered to diesel-powered portable air compressors, which depends to a large extent upon the elasticity factors discussed in Section 9. If these shifts occur in favor of diesel-powered compressors, total air emissions will be substantially reduced.

There also exists the possibility of a reduction of total unit volume after promulgation of the regulation. This may amount to as much as 27% of the total unit volume projected depending upon the regulatory level chosen. If this reduction occurs, then there will be a corresponding decrease in pollutants emitted.

At this time, based on the interrelationship of: (1) potential increase in fuel consumption, (2) elasticity of the market, and (3) potential total unit volume reduction, the possibility of the portable air compressors having an adverse effect on air quality is negligible.

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Appendix A
DOCKET ANALYSIS

LIST OF TABLES

Appendix A

DOCKET ANALYSIS

On February 27, 1974, an Advance Notice of Proposed Rule Making (ANPRM) inviting public participation in the development of a regulation for new portable air compressors, which EPA might establish under Section 6 of the Noise Control Act, was published in the Federal Register. There were ten submissions to the ANPRM docket, four of which required no response as the commenter either misinterpreted the purpose of the ANPRM, requested an extension of time to submit comments, or provided no information. The remaining entries, with the exception of that submitted by Richard H. Gimer (the Washington Counsel for the Compressed Air and Gas Institute, whose members manufacture approximately 85% of the air compressors sold in the United States), are not specifically addressed to the 23 areas of information solicited in the ANPRM.

Insofar as possible, an effort has been made in analyzing the docket to distinguish between information and issues contained in the responses. The attached docket analysis is organized as follows:

1. Summary Index - (citing specific references to the docket entry in the Information and Issues Section)
2. Information Section (pages 1-19)
3. Issues Section (pages 20 - 36)

Docket entries are available for public inspection at the Office of Noise Abatement and Control, Environmental Protection Agency, 1921 Jefferson Davis Highway, Arlington, Virginia 20460.

INFORMATION CONTAINED IN DOCKET

Composition of Industry and Conditions of Product Use

Manufacturer Data (ANPRM #15)

P.K. Lindsey stated that while not one of the larger U.S. manufacturers,

TABLE A-1
SUMMARY INDEX OF DOCKET RESPONSES

Docket #	Name of Respondent	Type of Respondent	Digest of Comments	Docket Analysis References *
C001	Alabama Tire Dealers and Retreaders Association	Trade Association	Misinterpreted ANPRM; addresed comments to air pumps used for inflating tires.	None (no comments required
C002	Environmental Protection Agency, City of New York	Local Government	1) Submitted copy of New York Code (includes noise emission standards for sale of air compresesors).	I. Information A3, B2, C1, D3
			2) Suggested noise emission standards for new portable air compressors	II. Issues B6, B7
			3) Recommended retrofit program.	
C003	P. K. Lindsay Company, Inc. Deerfield, New Hampshire	Manufacturer	1) Submitted information on noise levels and specifications of Company's compressor models.	I. Information A1, B1, B5
			2) Maintained noise reduction dependent on quieter engines.	II. Issues A2, B4, B7
			3) Questioned selection of air compressors rather than all construction equipment.	
			4) Advocated standard no lower than 65dBA at 7 meters and reasonable lead time for compliance.	
C004	Department of Environmental Conservation, State of New York	State Government	Developing construction site noise regulation which is anticipated to be a performance standard setting decibel limits at fixed distances from construction sites based on adjoining property use.	I. Information C1

* Refer to sections of Appendix A

TABLE A-1 (continued)
SUMMARY INDEX OF DOCKET RESPONSES

Docket #	Name of Respondent	Type of Respondent	Digest of Comments	Docket Analysis References
C005	World Construction	Construction Trade Publication	Submitted copies of two editorials:	
			a) arguing for consistency and local air compressor noise regulations.	I. Information A5, C1, C2
			b) including chart on existing international and U.S. cities permissible sound levels for compressors.	II. Issues A2, B5
C006	Robert Beggs	Private citizen	Misinterpreted ANPRM: (requested transcripts of hearing proceedings).	None (no comment required).
C007	General Motors Corporation	Manufacturer	Asked for extension of comment period	None (no comment required).
C008	Cummins Engine Company, Inc.	Engine Manufactuer	Indicated had very limited information on portable air compressors and addressed comments to new truck docket.	None (no comment required).
C009	Portable Compressor Division, Ingersoll-Rand Company	Manufacturer	1) Recommended maximum silencing of 70 dBA at 7 meters.	I. Information B3, C2
			2) Contested noise levels of PACs and estimated average costs to achieve levels contained in BBN draft report.	II. Issues B2, B7
			3) Contested specific statement contained in draft A. T. Kearny Report.	

TABLE A-1 (continued)
SUMMARY INDEX OF DOCKET RESPONSES

Docket #	Name of Respondent	Type of Respondent	Digest of Comments	Docket Analysis References
C010	Richard A. Gimer	Counsel for Compressed Air & Gas Institute (CAGI members manufacturer approximately 85% of compressors sold in U.S.) Specific Responses to Suggested Areas of Information Entry responded to 15 of the 23 suggested areas of information.	Lengthy entry divided into general issues and specific responses to suggested areas of information solicited in ANPRM Proviso: CAGI and its members presume contractor, NBS reports etc. used in developing regulation will be made available for public review and comment. General Issues: 1) No finding has yet been made that portable air compressors are major noise sources and should be subjected to mandatory noise emission standards-appears EPA determined compressors are "major noise sources" on an ad hoc basis. 2) EPA should place primary emphasis on safety factors in determining noise emission standards rather than letting the best available technology dictate the standards as EPA appears to be doing. 3) Internal combustion engines should be subject to noise emission limits rather than shifting regulatory burden to engine-powered machines and equipment. 4) Advocated retention of CAGI-PNEUROP Test Code as EPA Measurement Methodology. 5) EPA should consider conditions of use of product.	I. Information A1, A2, A3, A4, A5, B1, B2, B3, B4, B5, B6, C1, C2, D1, D2, D3

the Company's 1973 sales exceeded $2 million. The Company manufactures air-cooled compressors of their own design and performs the machining and fabrication of the compressors, chassis, air tanks and housing in their own plant.

Gimer stated that members of the Compressed Air and Gas Institute's Portable Compressor Air Section manufacture approximately 85% of the compressors sold in the United States. The twelve members of this national trade association representing portable air compressor manufacturers are Atlas Copco, Inc.; Chicago Pneumatic Tool Co.; Davey Compressor Co.; Gardner-Denver Co. (Quincy Division); Gordon Smith & Co., Inc.; Ingersoll-Rand Co.; the Jaeger Machine Co.; Joy Manufacturing Co.; Le Roi Division--Dresser Industries, Inc.; Quincy Compressor Division, Colt Industries Operating Corp.; Schramm, Inc.; and Worthington-CEI, Inc.

Recommended Methods for Classifying Portable Air Compressors (ANPRM #13)

Gimer commented that portable air compressors have historically been classified by power source (diesel or gas) and by output measured in cfm. Typical catagories are noted in Table A-2.

Table A-2

CAGI SUGGESTED CLASSIFICATION OF COMPRESSORS

Gas Powered Machine (2)	Diesel Powered Machines (4)	
75-124 CFM	125-249 CFM	600-899 CFM
125-250 CFM	250-599 CFM	900 and over CFM

Number and Type of Portable Air Compressors In-Service and Sold (ANPRM #9)

Gimer submitted the following data compiled by the U.S. Department of Commerce, CAGI and EPA contractors:

- For the seven-year period 1966-1972, approximately 72,000 portable air compressors were shipped (approximately 51,000 were gasoline engine powered, the remainder were diesel powered).
- Total sales during each of seven years ranged between 9,600 and 12,300 units.
- Approximate annual dollar value of shipments: 1970--61.5 million; 1971--64.2 million; 1972--78.1 million.

The City of New York commented that it is estimated in New York City alone there are approximately 5,000 air compressors available for use.

Portable Air Compressor Typical Duty Cycles (ANPRM #12)

Gimer pointed out that a high percentage of portable compressors are used for less than one day in any particular location and submitted following estimates on duty cycles:

- On the average, portable air compressors can be expected to work a normal cycle of 60 to 75% on full load requirement and 20 to 40% on a no-load requirement;
- Smaller portable units (up to 501 CFM) normally accumulate an average of 1,000 operating hours per year and larger units (over 500 CFM) 1,000 to 1,500 operating hours per year.

Types of Activities in Which Portable Air Compressors are Used, Number Used at One Time and Contribution to Total Noise of These Activities (ANPRM #16 and #17)

Gimer commented that, in most instances, portable air compressors are used to power other devices that in turn perform a particular work application. Depending upon the size of the unit, the task to be accomplished, and the nature of the job site, anywhere from one to twelve portable air compressors might be utilized in a single location at one time. If a job situation required three or more portable air compressors, they would probably be widely dispersed.

Gimer further stated that, in most cases, the equipment powered by the compressor or the nature of the work itself being performed with that equipment is noisier than the compressor itself. This point was also alluded to by World Construction and Ingersoll-Rand.

Current Noise Levels, Abatement Techniques and Their Effects

Current Noise Levels of In-Use and Newly Manufactured Foreign and Domestic Portable Air Compressors (ANPRM #1)

P.K. Lindsay submitted the following chart (Table A-3) of noise levels produced by current production units of their eight compressor models.

Table A-3

NOISE LEVELS OF P. K. LINDSAY COMPRESSORS
SOUND LEVEL READINGS IN dBA

COMPRESSOR MODEL	1 meter	5 feet	7 meter	50 feet
15-HU	89	87	75	68
25-HU	98	88	77	71
T-40HA	95	93	81	75
55-H	94	92	79	73
80-H	96	93	81	75
125-H	98	95	82	76
150-A	99	96	84	78
175-D	100	97	85	79

Tests were taken on current production units with standard engine mufflers.

These readings are in decibels on the "A" weighting network scale and are the arithmetic average of four readings at the compass point for each distance from the compressor unit. Compressors are operating at full load (100 psig) and the air is discharged to atmosphere beyond the test area.

Gimer submitted the following table (Table A-4) showing a range of noise emissions on currently available domestic and foreign produced portable air compressors for standard machines and silenced machines.

Table A-4
RANGE OF NOISE LEVELS OF COMPRESSORS (supplied by CAGI)

Standard Machines	
82-250 CFM	251-1200 CFM
92.5 dBA to 105 dBA at 1 meter	97.1 dBA to 112 dBA at 1 meter
80.5 dBA to 92 dBA at 7 meters	82 dBA to 103 dBA at 7 meters

Silenced Machines	
82-250 CFM	251-1200 CFM
82 dBA to 104 dBA at 1 meter	82 dBA to 104.5 dBA at 1 meter
70 dBA to 88 dBA at 7 meters	70 dBA to 93 dBA at 7 meters

This data was collected on a confidential basis by the Compressed Air and Gas Institute over the past two years using the CAGI-PNEUROP test cost codified as a national consensus standard and an international standard in ANSI S. 1-1971 and ISO 2151, respectively. Gimer placed two qualifications on the analysis of this data.

1. The noise emission data reflects side emission measurements only, and the precise impact on the dBA rating of any given compressor of factoring in a measurement of upward radiating noise (under considera-

tion by the appropriate ISO committees) cannot be known. Gimer pointed out that tests which have been made using various proposed methods for measuring upward radiated noise indicate that the addition of a top-level measurement will change the dBA rating for most compressors currently available; and

2. The data does not reflect the ability of the entire industry to meet any particular emission level. Based upon information available to CAGI the dBA rating of the quietest compressor available on the market is several decibels below that which the industry as a whole is currently capable of producing.

Currently Available Noise Abatement Technology (ANPRM #2)

Gimer commented that the major sources of noise from portable air compressors are the areas of engine exhaust, cooling fan, air intakes, and miscellaneous mechanical structure noises arising from the workings of the engine and compressor air-end, withe the engine itself being the primary noise source. Current noise-abatement technology focuses on enclosing and muffling these engine/compressor operating components. This is currently best accomplished by the application of large and often, expensive mufflers to the engine exhaust; complete enclosure of all working mechanisms with acoustically-lined air-tight housings; and attenuation of the cooling system fan-noise through acoustically treated airduct systems. The acoustical attenuation materials used to line the housing and cooling airducts are usually fiberglass or plastic-based foam materials. The basic silencing technology utilized by foreign and domestic manufacturers is the same.

The City of New York stated that air compressors are presently available as shelf items that can providé reductions in noise levels by as much as 80% of cost over conventional units of approximately 9%.

Additional Noise Reduction Technology and Associated Costs (ANPRM #4 and #5)

Gimer stated that foreign and domestic individual compressor manufacturers are currently utilizing all of the known technology to reduce noise emission levels of their equipment. These efforts do not lead to uniform results due to the firm's differing capabilities. Silencing a compressor adds to its cost and thus to the manufacturer's ability to sell the end product. Gimer commented that these costs can be expected to rise significantly as the noise emission level to be achieved is reduced which he asserted will be shown through data being collected under contract to EPA.

Pointing out that the sound emissions are a recognized competitive aspect in the manufacture, promotion and sale of portable air compressors today, Gimer stated that in the opinion of CAGI, market forces are: (1) causing a high degree of individual firm utilization of currently available silencing technology; and (2) encouraging intensive research efforts aimed at further noise reduction.

Ingersoll-Rand took issue with the findings and statements contained in EPS'a draft contractor reports. The Company submitted the following tables reflecting noise level of portable air compressors and cost to achieve the noise levels in lieu of those submitted by Bolt Beranek & Newman.

Table A-5
PORTABLE AIR COMPRESSOR NOISE LEVELS, dBA*
(provided by Ingersoll-Rand)

Level Limit	Gasoline Driven 75-249 CFM	Diesel Driven 125-249 CFM	Diesel Driven 250-599 CFM	Diesel Driven 600-899 CFM	Diesel Driven Above 900 CFM
Level 1 (3)	81 dBA	83 dBA	86 dBA	88 dBA	88 dBA
Level 2 (4)	75 dBA	76 dBA	73 dBA	78 dBA	81 dBA
Level 3 (5)	68 dBA	70 dBA	73 dBA	70 dBA	70 dBA .

Notes: * (1) Levels constitute a "not to exceed" criteria
(2) Maximum sound pressure level in dBA at 7 meters according to the recommended measurement practice of ISO 2151-1972.

(3) Level 1 is associated with the average quieted air compressors on the market today. It would correspond to using adequate enclosures, sound insulation and mufflers.
(4) Level 2 is associated with the best quieted machine on the market. It would correspond to extensive enclosures, sound insulation, sealing, cooling air silencing ducts and vibration isolators.
(5) Level 3 is associated with the best demonstrated technology. It would correspond to Level 2 plus more insulation, sealing and possibly double walled enclosures.

Table A-6

ESTIMATED AVERAGE COSTS
(provided by Ingersoll-Rand)

Level Limit	Gasoline Driven 75-249 CFM	Diesel Driven 125-249 CFM	Diesel Driven 250-599 CFM	Diesel Driven 600-899 CFM	Diesel Driven Above 900 CFM
Level 1 (2)	$2.59	$2.59	$3.14	$1.80	$1.60
Level 2 (3)	$5.20	$5.20	$10.76	$9.00	$8.36
Level 3 (4)	$26.00	$26.00	$10.76	$13.50	$12.25

Notes:
(1) Costs are estimated in additional dollars per CFM at manufacturers retail list price level.
(2) The costs cited in Level 1 represent the average increased costs over standard unit to meet the dBA levels as specified in Table I.
(3) The costs cited in Level 2 represent the average increased costs over standard unit to meet the dBA levels as specified in Table I.
(4) The costs cited in Level 3 represent the average increased costs over standard unit to meet the dBA levels as specified in Table I.

Ingersoll-Rand submitted no data to substantiate their altered figures. The Company's additional comments on the draft A. T. Kearney and BBN reports are addressed under II. General Issues.

Estimates of Time Required to Place State of the Air Technology into Production (ANPRM #6)

Gimer stated that in the general experience of portable air compressor industry members, a minimum of three years for market introduction of equipment involving redesign is required; a minimum of five years for market introduction of technology involving entirely new design. He qualified this statement by:

- Variation among firms would occur depending on firms' financial and technical position and the technology currently available to that firm
- The noise emission standard that must be met has yet to be specified.

Gimer warned that any suggestion that the industry is capable of meeting requirements significantly below the current best available technology within shorter time intervals (18 months was cited) would be regarded by the industry as inaccurate and misleading and must be clearly substantiated.

Problems Resulting from Existing Noise Reduction Techniques (ANPRM #11)

Both P.K. Lindsay and Gimer contended that quieting the compressor as a unit was limited to a great extent by the noise emissions of the engine powering the compressor. P.K. Lindsay enclosed catalog sheets citing specifications for their various compressor models which incidentally made no reference to the models' noise characteristics. All of the compressors manufactured by P.K. Lindsay are powered by Teledyne Wisconson Engines with the exception of the smallest, which is powered by a 9.2 hp Briggs and Stratton Engine, and the largest, which is powered by an 81 hp Ford Diesel Engine. P.K. Lindsay pointed out that the operating noise levels of these engines alone approach 85 dBA at seven meters.

Docket inputs dealing with the availability of quieter engines from major manufacturers of industrial engines, the relationship between compressor silencing and engine noise emissions, and EPS's regulation of engine-powered equipment prior to regulation of the engine itself are discussed under General Issues in this Appendix.

Effects of Portable Air Compressor Noise Reduction
(ANPRM #10 and #19)

Gimer commented that noise reduction of portable air compressors would affect the following performance factors:

Size and Weight of Units. Generally, the manufacturer seeks to maintain the performance parameters for each compressor when the standard unit in each size category is silenced. As a consequence, the resulting machine is invariably larger and heavier than the standard model with the same capabilities. The silenced compressor is more difficult to tow than its standard counterpart. Due to the physical size increase, in some instances the unit requires a larger vehicle for towing than would be true of the standard unit of the same output capability. Because it is not uncommon to transport compressors several units at a time, increased size has also frequently meant that additional trucks or flat beds are required to transport the same number of units.

Operating Conditions. It is estimated that anywhere from 5 to 15 degrees Fahrenheit lower maximum ambient temperature must be available for safe operation of a silenced unit.

Maintenance Costs. Maintenance costs on silent units will be higher due to the lack of quick accessibility to some components, and the cost to replace seals.

Fuel Consumption. Data collected recently by CAGI on a confidential basis indicates that for gas-powered units an average increase of 5% and up to 9% in fuel consumption in shifting from a standard to a silenced model. For diesel-powered equipment, the average increase is 3% with a maximum of 5%.

Gimer pointed out that while data collected by the Institute was not comprehensive enough to accurately project on a nation-wide basis the total impact of silencing on fuel consumption, their studies clearly indicate that transition from current standard models to silenced machines will have a definite fuel consumption penalty. Gimer commented that any EPA regulation requiring silencing beyond the noise emission levels associated with the silenced counterparts (ranging from 82 to 104 dBA at one meter) of current standard models, would have an even more serious impact on total fuel consumption.

Component Storage. A shortage in both steel and platic components, required in greater quantities in silenced units, can also be expected.

Current Regulations and Their Effects

Information on Existing and Planned Noise Regulations (ANPRM #18)

The City of New York submitted a copy of its Noise Control Code (effective September 1, 1972) Section 1403.3-5.11 of which regulates both the sale and operation of air compressors. Air compressor is defined as a "device which draws in air or gas, compresses its, and delivers it at a high pressure." The specific provisions of Section 1403.3-5.11 are as follows:

The Administrator of the New York City Environmental Protection Agency is to promulgate regulations for measurement procedures which must be substantially in compliance with similar ones promulgated by generally recognized professional standard-setting organizations (including the Compressed Air and Gas Institute).

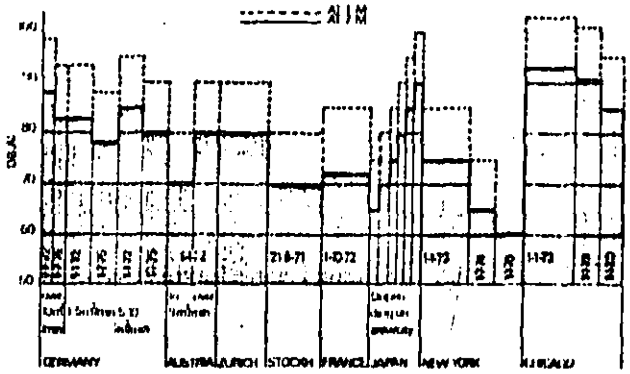
The Code also provides discretionary authority to the Administrator for the testing, inspection and registration of devices (Article II) and established hours of operation for construction activities with variance provisions (Article III, Section 1403.3-4.11).

Gimer commented that in a very recent request for bids by New York City for equipment to be delivered after June 1974, no compressor manufacturers were able to respond as the step standard effective June 30, 1974 is 75 dBA at one meter.

World Construction submitted the following chart citing various international and municipal sound levels for compressors.

Table A-7

INTERNATIONAL AND MUNICIPAL
PERMISSIBLE SOUND LEVELS FOR COMPRESSORS



The State of New York is developing a construction noise regulation which is anticipated to be a performance standard setting decibel limits at a fixed distance from a construction site based on the nature of the neighboring property. Since noise limits will be established without regard to the exact type of construction device generating the sound (and, therefore, will not be preempted by EPA product regulations under Section 6 of the Noise Control Act), the State of New York views this as an appropriate technique for control of construction noise at the State level.

Impact on Industry of Existing Regulations (ANPRM #7)

World Construction submitted two editorials stating that conflicting National and International noise standards with varying compliance schedules have created confusion for both portable air compressor manufacturers and users, and arguing that inconsistent environmental requirements replaces tariff barriers with technical barriers.

Gimer commened that existing international regulations on compressor noise emissions have not had a significant impact on the domestic compressor industry, since, with limited exceptions, portable air compressors manufactured in the U.S. are not sold for export. Gimer stated that the industry is concerned with the proliferation of local government regulatory schemes that establish stringent noise emission standards for compressors which cannot be met or which unreasonably increase the costs of new machines (e.g., New York City). Gimer contended that such regulations encourage prolonged use of existing units which will result in a population of compressors with a higher overall noise contribution than could be expected if reasonable uniform standards were adopted. This point was also made by Ingersoll-Rand.

Compliance Methodology

Product Test Methodology for Compliance and Size of Product Sample (ANPRM #20 and #21)

Gimer stated that CAGI strongly recommends that the methodology specified for noise measurement in any Federal mandatory standard for portable air compressors be that contained in ISO 2151. Gimer's arguments for the retention of this measurement methodology byEPA are addressed under General Issues in this appendix.

Gimer advocated that the full range of tests specified in any test code that EPA adopts should not be performed on each and every unit manufactured, but rather an appropriate sampling plan that could vary with the type of unit, the quantity manufactured and the tolerances permitted by the standard.

IF EPA adopts the ISO 2151 basic test methodology, Gimer commented that the costs of imploying this test would vary with the firm as the industry is dispersed throughout the U.S., and therefore, seasons when outdoor testing can be performed would differ. If compliance testing is required at frequenct intervals, then some firms would have to construct covered facilities or hire their own testing staff and purchase equipment to replace their present outside consultant.

Feasibility of Categorizing Product Models or Configurations According to Their Noise Emission Characteristics (ANPRM #22)

Gimer recommended that the current means of classification of compressors by power source and CFM output should be retained. Gimer commented that as noise emission levels and, therefore, cost of compliance vary with each unit and power source type, a regulatory scheme involving several different noise levels might be warranted although confusing. Gimer stated that the industry's position would be dependent on the noise emission standard EPA adopts.

Feasibility of Establishing a Useful Life (ANPRM #23)

The City of New York states that air compressors have an average life of ten years. Gimer estimated that it was approximately eight years, though some compressors have been in use for as much as 20 to 30 years. Gimer stressed the need for proper and regular maintenance to preserve compressor noise emission performance and pointed out that the quality of field maintenance varies widely with the end-users, compressor applications, and operating environment. Gimer commented that many end-users are not overly concerned with the maintenance of sheet metal and enclosure materials nor closing compressor doors. High quality maintenance will be increasingly important with silenced compressors as tight enclosure integrity is essential. Gimer cautioned that the responsibility for normal care and maintenance of EPA regulated products should not be shifted from the user to the manufacturer nor should the manufacturer be penalized initially, in the adoption of noise emission standards, for poor maintenance practices in the field.

GENERAL ISSUES RAISED IN THE DOCKET

Selection of Portable Air Compressors for Regulation

Three docket inputs, (Gimer, P. K. Lindsay and World Construction) questioned the validity of EPA regulating portable air compressors at this time. Objections were raised that (1) portable air compressors had not been identified as a major source of noise in accordance with Section 5(b) of the Noise Control Act and (2) EPA was apparently singling out portable air compressors for regulation prior to alternative product candidates having noise contributions that might be significantly higher.

Identification of Portable Air Compressors as a Major Source of Noise

Gimer contended that the regulatory approach apparently being utilized by EPA (as of March 29, 1974), that of publishing simultaneously the Section 5(b) initial identification document and Section 6 proposed regulations for the identified products, while permissable under the Act was ill-advised for the following reasons:

- Such a procedure leaves affected industries and the public in the dark as to what criteria are being used by EPA to develop proposed standards and all but deprives target industries of any opportunity to show that a particular product or group of products should not be subjected to mandatory emission limits; and
- Such as approach "appears to circumvent the intent of Congress that EPA be required to develop a list of priorities, and to subject that list to public scrutiny" with the advantages of focusing on Agency priorities and helping to avoid arbitrariness in regulatory action.

With respect to portable air compressors, Gimer charged that:

- A vested interest in the regulation of compressors, through the expenditure of funds and manhours prior to formal identification under Section 5(b), has been created.
- There is every evidence that EPA has in fact made a determination that portable air compressors are "major noise sources" on an ad hoc basis.
- It appears that EPA contractors "have neither been requested nor have they accepted the responsibilities for defining the relationship between

proposed emission limits and genuine safety considerations on the part of workers or the general public".

Gimer's critique of EPA's regulatory approach is based on his interpretation of EPA's activities at the time of his docket submittal (March 29, 1974). On June 19, 1974, the identification of medium and heavy duty trucks and portable air compressors as major sources of noise in accordance with Section 5(b) of the Noise Control Act was published in the Federal Register. This initial identification document delineated the approach used by EPA to identify major sources of noise and fulfills Gimer's recommendation that EPA's regulatory priorities and their derivation be available for public scrutiny before publication of proposed noise emission standards under Section 6.

The EPA has continually stressed the importance of affording interested parties an opportunity to participate in all stages of the rule-making process. Gimer's statement that the approach apparently being adopted by EPA "all but deprives target industries of any opportunity to show that a particular product or group of products should not be subjected to mandatory emission limits" is belied by his own response to the ANPRM. The issues and information contained in this docket were considered by EPA prior to publication of the formal identification of portable air compressors as a major source of noise.

The following considerations should be taken into account in assessing Gimer's three criticisms of EPA's approach to regulating portable air compressors:

1. In fulfilling its responsibility to identify those products or classes of products which are major sources of noise, EPA contracted for the preparation of economic and technology studies on a variety of product sources. As in the case of portable air compressors, the background data compiled may be utilized in future regulatory activities. Neither the existence of such product data nor the resource expenditures incurred

in obtaining this information create a vested regulatory interest; rather they reflect EPA's efforts to initiate its regulatory activities from as broad a data base as possible.

2. Both the identification report and Section 2 of this document explain the basis for EPA's determination that portable air compressors are a major source of noise. In the absence of a universally accepted method to determine which noise sources pose the most serious threat to public health and welfare, EPA has made an effort to take into account the many factors affecting public health and welfare in the identification process. As was stated in the initial identification report, "ultimately, however, the identification of major noise sources must be partly subjective". It does not follow from this as Gimer suggests that "EPA has in fact made a determination that portable air compressors are 'major noise sources' on an ad hoc basis. . .".

3. It has never been the intention to shift EPA's responsibility to define the health and welfare basis of regulatory activities to contractors whose function is rather to compile and analyze economic and technological data and submit expert reports to EPA for consideration. The two documents "Public Health and Welfare Criteria" and "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety" comprise the definitive information used in emission standards. An evaluation of the public health and welfare basis for the regulation of portable air compressors is contained in Section 10 of this document.

Advocated Candidates for Prior Regulation

Three docket inputs, those of World Construction, P. K. Lindsay and Gimer questioned the regulation of portable air compressors before the establishment of noise emission standards for other products or components.

One of the editorials submitted by World Construction cited industry objections to compressors being singled out for regulation by countries and municipalities when "the compressor-powered tool may be the greatest offender".

P. K. Lindsay has assumed that EPA would establish maximum noise limits for construction equipment as a class rather than regulate specific items of equipment. P. K. Lindsay maintained that compressor noise reduction is dependent on the availability of quieter engines, and under EPA's separate item approach, an engine used on a compressor which would not meet EPA noise emission standards could continue to be sold for use on other unregulated construction equipment.

Gimer advocated thatnoise emission standards be established for internal combustion engines arguing as follows:

- With many products utilizing internal combustion engines, the noise contribution of the engine itself exceeds that of the other components of the equipment involved as is frequently the case with portable air compressors. The noise emissions from the engine set a practical limit to the amount of quieting which can be obtained on a compressor by various insulating means or redesign approaches.
- Compressor manufacturers generally purchase internal combustion engines from engine manufacturers rather than fabricate the engines themselves. Representing but a small segment of the total consumption of engines, compressor manufacturers are powerless to dictate the noise emission levels of engines. Any attempt to do so would force engine manufacturers to divert their production to other end uses. Other industries, whose products emit noise largely traceable to internal combustion engines and who may be the target of future EPA noise emission standards, also have little market control over engine noise emissions.

- Section 6(a)(1)(c)(iii) of the Noise Control Act clearly contemplates that engines, not just engine powered machines and equipment are to be priority targets of EPA regulatory attention. The noise contribution of internal combustion engines may be the major source of noise for each of the other categories specified in Section 6(a)(1). However, EPA has shifted the focus of attention from the engine to the engine powered device itself - a determination in conflict with the Noise Control Act unless the Administrator finds the regulation of engines themselves is not feasible.

Given the constraints of scarce resources and the desire to assess in depth the health and welfare, cost and technology factors that have a bearing on the feasibility of noise emission controls, EPA has initiated its implementation of Section 6 of the Noise Control Act with the proposed regulation of two products which have been identified as major sources of noise. Other products or classes of products identified as major noise sources and falling into one of the four categories specified in Section 6(a)(c) will be regulated in the future if in the Administrators' judgment noise emission standards are feasible for such products. There is no validity to Gimer's assertion that EPA has chosen to ignore the contribution of engines or motors as sources of noise or that the statutory category "Motor or Engine" has been transformed to "Internal Combustion Engine Devices". It does not follow that as internal combustion engines are not one of the two products for which noise emission standards will be prescribed initially, they are therefore precluded from future regulation. EPA has in the past and continues to collect and analyze cost and technology data on a variety of new products as part of the identification process of major noise sources.

As is delineated in Section 2 of this document, EPA gave first priority to sources that contribute to community noise exposure in its identification of portable air compressors as a major source of noise. Although, as P.K. Lindsay and Gimer state, engines are predominant contributors to air compressor noise, quieting technology is available as is shown in Section 8 and has been used by various manufacturers to significantly reduce the noise emission levels of their products. For EPA to have promulgated regulations incorporating noise emission standards for construction equipment as a class, as P. K. Lindsay advocates, might have placed an unacceptable economic burden on the construction industry.

EPA's Regulatory Approach

Several Docket inputs advocated specific regulatory orientations and suggested provisions to be incorporated into a regulation for portable air compressors which are presented below.

EPA Should Place Primary Emphasis on Safety Factors

Gimer stated that EPA regulations incorporating noise emission standards must have a safety related basis and cited the statutory language of Sections 5(a)(2), 6(b) and 6(c)(1) of the Noise Control Act as evidence of the Congressional intent that noise emission standards be based upon genuine safety considerations. Gimer charged that "notwithstanding these explicit directives in the Act, the approach apparently being adopted (at least by the firm hired by EPA to recommend a noise emission limit) is that the standard to which portable compressors should perform is dictated by the level of noise emission attainable by the 'application of the best available technology'." Gimer contended that such an approach would violate the clear mandate of the Noise Control Act and would be unfair to the industry by shifting the burden of proof of a regulation's safety basis from EPA to the industry. Gimer argued that EPA should consider not only available technology, but the presence or absence of a safety consideration as well as both industry and consumer economic impact prior to publication of a proposed regulation.

EPA is well aware that its statutory authority to establish noise emission standards for porducts distributed in commerce is founded on the Congressional statement of policy contained in Section 2(b) of the Noise Control Act – that of promoting "an environment for all Americans free from noise that jeopardizes their health and welfare". In his legal interpretation of the mandates of the Noise Control Act, Gimer seems to have shifted the statutory emphasis on public health and welfare, counting as it does populations in the aggregate, to safety considerations. Contrary to Gimer's assertion, the Noise Control Act is very explicit in the factors which must be addressed by EPA prior to proposing or promulgating regulations under Section 6. As stated in Section 6(c)(1) any regulation must include a noise emission standard "which in the Administrator's judgment, based on criteria published under Section 5, is requisite to protect the public health and welfare, taking into account the magnitude and conditions of use of such products (alone or in combination with other noise sources), the degree of noise reduction achievable through the application of the best available technology, and the cost of compliance". There is no validity to Gimer's contention that the best available technology will be the sole determinant of the noise emission standards for portable air compressors which EPA will propose. As reflected in this project report, EPA has carefully weighed public health and welfare implication, product use, cost of compliance, best available technology and various other factors in its regulatory process.

Regulation Data Base

Gimer and Ingersoll-Rand questioned the availability and validity of information contained in EPA contractor reports.

Gimer pointed out that while the Compressed Air and Gas Institute could not collect and synthesize data in response to every question raised in the ANPRM for anti-trust reasons, the Institute had encouraged its members to supply EPA and its contractors with sensitive cost and pricing data. He stated that this procedure leaves both industry and the government in a difficult position in dealing with the conclusions reached when the raw data fed into the decision making process is not available. The Institute is deferring any judgment on the accuracy or appropriateness of data compiled or contractor recommendations until the final reports are available for public review.

Ingersoll-Rand contested various aspects of both the draft Bolt, Beranek & Newman Report and the A. T. Kearney Report. Ingersoll-Rand maintained that the Level Three noise level indicated in the draft BBN Report are completely unrealistic as they could be extremely difficult to achieve, very expensive and virtually impossible to check in the market place due to the tremendous influence of ambient noises. Ingersoll-Rand submitted tables in lieu of those contained in the BBM Report which are presented under the information section of this analysis. Ingersoll-Rand also contested specific statements contained in the draft A. T. Kearney Report and questioned its conclusions which were based on levels of noise emission and standards of cost with which Ingersoll-Rand basically disagreed.

EPA appreciates the cooperation of the Institute, its members and other compressor manufacturers in supplying product information to EPA and its contractors. In accordance with EPA's policy of affording interested parties an opportunity to participate in rule-making, the data available to EPA including the final contractor reports will be open for public inspection and comments on these reports will be welcomed.

Ingersoll-Rands' comments on the draft contractor reports have been considered by EPA. However, as these reports were preliminary findings and as little data was provided by Ingersoll-Rand to substantiate their figures, it is felt to be more appropriate to address the points Ingersoll-Rand may choose to raise on the final report used in the rule-making process.

Measurement Methodology

Gimer strongly advocated that the measurement methodology specified in any EPA regulation for portable air compressors be that contained in the CAGI-

PNEUROP test code which has been codified as a national consensus standard and an international standard in ANSI S5.1-1971 and ISO 2151 respectively. Gimer pointed out that the code reflects the considered judgment of the world's leading acousticians and interested government officials in addition to that of U.S. and European compressor manufacturers. Gimer argued that if EPA were to ignore existing internationally recognized standards, the result would be to discourage the massive voluntary effort that has been made to develop these standards and to dry up this source of standard-making activity. In addition, Gimer contended that changes to this methodology with which the domestic industry is accustomed, would add to the cost of testing as many manufacturers would be forced to test with both the EPA and ISO 2151 methodologies.

Gimer stated that a proposal for measuring compressor noise emission has been drafted and was being circulated for comment to the appropriate ISO committees and members. This proposal would require measurement of upward radiated noise in addition to the side measurements currently required by ISO 2151 and would add guidelines for determining sound power as contrasted with the sound pressure measurements currently required. Gimer cautioned that the precise impact on the dBA rating of any given compressor of factoring in a measurement of upward radiated noise cannot be known at this time although tests indicate that the dBA rating for most compressors currently available will differ with the addition of a top level measurement. Gimer also pointed out that virtually all data previously collected do not reflect the effects of upward radiated noise emissions. Gimer urged that if EPA thought revisions to ISO 2151 were needed, the appropriate action would be for EPA to participate in the ongoing revision of that standard.

The measurement methodology EPA is proposing is delineated in Section 6 of this project report. Following data collection using alternative measurement procedures, EPA determined that the measurement methodology specified in

Section 6, which combines the essential features of the CAGI-PNEUROP Test Code with a measurement for upward radiated noise, provides an adequate description of portable air compressor noise. EPA has and will continue to cooperate and participate in the standards setting activities of both national and international professional organizations. The fact that an ISO proposal has been drafted would seem to signify that in at least some segments of the acoustical community a revision of the CAGI-PNEUROP Test Code is considered desirable. Finally, Gimers' contention that EPA's adoption of a measurement methodology other than the CAGI-PNEUROP Test Code would increase testing costs is not in accordance with his statements that, with very limited exceptions, portable air compressors manufactured in the U.S. are not sold for export. In most instances, domestic manufacturers would only be required to test using the EPA procedures.

Sufficient Lead Time for Manufacturer Compliance

P.K. Lindsay urged EPA to establish reasonable noise emission levels and to give compressor manufacturers, and the engine manufacturers upon which all compressor manufacturers are dependant, sufficient time to develop, test, and get into production the quieter units desired.

As is stated in Section 7, the proposed compliance schedule is one year from the date of promulgation of the final regulation. In EPA's judgment, this schedule will enable compressor manufacturers to utilize quieting technology without unacceptable economic consequenses.

Provision for Compressor Use and Compressor Size

World Construction submitted an editorial arguing for consistency in regulations and citing deficiencies in approach and content of existing air compressor noise suppression standards and regulations. Two such criticisms were that no allowance is made for (1) the size of the compressor or (with the exception of West Germany) or (2) the nature of the job site (with the exception of Japan).

Gimer suggested EPA consider whether it is justifiable to impose a single uniform standard on all portable air compressors (or any other product subjected to regulation) for all its uses throughout the entire country. Pointing out that there are different social implications from the noise emitted by a compressor in downtown New York City to that used in an isolated rock quarry, Gimer questioned whether the incremental cost of complying with an EPA regulation should be borne by the product consumer in uses when the requirements were unnecessary. Gimer suggested EPA consider a type of classification scheme being developed in Europe in which two or more classes of silenced units would be required in more populated areas and one or more classes of other units could be used nationally except where municipal governments adopted regulations limiting compressors used in specific areas to the silenced classes. Gimer questioned the statutory language of Section 6 stating that while "the Act does not clearly require a single standard for all products within a category, regardless of intended use", the "statute is clearly product oriented". Gimer stated that the Institute intended to submit further comment on this subject following publication of the NPRM. Gimer also commented that not enough emphasis had been placed by users and government officials upon reducing compressor noise emissions although the use of barriers and selection of compressor location on the job site as is permitted in existing European regulations.

As explained in Section 7 of this project report, EPA's proposed regulation does not make allowance for the size of the compressor, since it has been demonstrated that the noise generation of currently available quieted compressor models is not significantly dependent on the size of the unit.

Section 6 of the Noise Control Act is explicit in defining the division of authority between the Federal government and states or political subdivisions. While, as is stated in Section 2(a)(s) of the Act, "Federal action is essential to deal with major noise sources in commerce control of which requires national uniformity of treatment", States and localities retain jurisdiction to establish and enforce controls on environmental noise "through the licensing, regulation, or restriction of the use, operation, or movement of any product or combination of products". EPA does not have the authority to propose or promulgate any regulation under Section 6 that would establish differing noise emission requirements on the basis of a products intended use. Similarly, EPA does not have the authority to incorporate provisions for barriers or compressor site location in a noise source regulation.

Inclusion of Retrofit Provision

The City of New York advocated that due to the large number of compressors in use with an average life of ten years, EPA should consider a retrofit program and recommended the following noise emission standards for inclusion in a retrofit regulation:

"Air compressors rated at 600 CFM or greater should be reduced to a level of 95 dBA at one meter while air compressors below 600 CFM could be reduced to 90 dBA at one meter."

The Noise Control Act does not authorizeEPA to regulate in-use products, and therefore EPA has no authority to propose a retrofit regulation for compressors.

Suggested Noise Emission Standards

Three docket inputs recommended specific noise emission standard for EPA's consideration.

1. The City of New York, based on its experience, stated that the following standards in their views would not impose an economic burden on either the manufacturer or operator of the equipment;

   "All air compressors manufactured one year after passage of this regulation, and having a rated capacity of 600 CFM or more shall not exceed 85 dBA at one meter. Further, all air compressors having a rated capacity below 600 CFM shall not exceed 75 dBA at one meter".

2. Ingersoll-Rand recommended a maximum silencing of 70 dBA at 7 meters arguing as follows:
   a. This level is feasible and portable air compressors would still be the quietest machine on the construction site;
   b. Other contributing noise sources at a construction site produce levels well over 85 dBA at 7 meters that can only be reduced by 5 to 10 dBA at 7 meters in the future; and
   c. To set a lower level would (i) increase costs of all construction work, (ii) not benefit the environment because of all ambient noises, and (iii) stimulate an extended useful life of existing equipment thereby worsening rather than improving the noise levels associated with compressors.
3. P.K. Lindsay advocated that an overall limitation of 85 dBA at 7 meters is reasonable based on the following considerations:
   a. The operating noise levels of engines currently used to power P.K. Lindsay's compressors approach 85 dBA at 7 meters.
   b. OSHA's standard governing occupational noise exposure sets a maximum permissable level of 90 dBA for eight hours. A workman using a compressor would be 7 or more meters away except for the few minutes required to start or shut down the unit; and
   c. If EPA were to set a standard lower than 85 dBA at 7 meters, P.K. Lindsay would have little alternative other than to close down.

EPA has considered these recommended noise emission standards together with the arguments advanced for their selection in the rule-making process. The background data and findings utilized by EPA in formulating the proposed regulation for portable air compressors are presented in this project report.

Appendix B

METHOD TO EVALUATE THE IMPACT OF PORTABLE AIR COMPRESSOR NOISE ON PUBLIC HEALTH AND WELFARE

LIST OF TABLES

Appendix B

METHOD TO EVALUATE THE IMPACT OF PORTABLE AIR COMPRESSOR NOISE ON PUBLIC HEALTH AND WELFARE

SPECIFICATION OF NOISE ENVIRONMENT

Environmental noise is defined in the Noise Control Act of 1972 as the "intensity, duration, and the character of sounds from all sources". A measure for quantifying environmental noise must evaluate not only these factors, but must also correlate well with the various modes of response of humans to noise and be simple to measure (or estimate).

EPA has chosen the equivalent A-weighted sound pressure level in decibels as its basic measure for environmental noise. The general symbol equivalent level is L_{eq}, and its basic definition is:

$$L_{eq} = 10 \log_{10} \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p^2(t)\, dt}{po^2} \qquad \text{(B-1)}$$

where $t_2 - t_1$ is the interval of time over which the levels are evaulated, p(t) is the time varying sound pressure of the noise, and p_o is a reference pressure, standardized at 20 micropascal.

When expressed in terms of A-weighted sound level, L_a, L_{eq} may be defined as:

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

The primary interval of interest for residential and similar land uses is a twenty-four hour period, with weighting applied to nighttime noise levels to account for the increased sensitivity of people associated with the decrease in background noise levels at night. This twenty-four hour weighted equivalent level is called the Day-Night Equivalent Level, and is symbolized as L_{dn}. The basic definition of L_{dn} in terms of A-weighted sound level is:

$$L_{dn} = 10 \log_{10} \frac{1}{24} \left[15 \int_{0700}^{2200} 10^{\left(\frac{L_A(t)}{10}\right)} dt + 9 \int_{2200}^{0700} 10^{\left(\frac{L_A(t) - 10}{10}\right)} dt \right] \quad \text{(B-3)}$$

or

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

where L_d is the "daytime" equivalent level, obtained between seven a.m. and ten p.m. and L_n is the "nighttime" equivalent level obtained between ten p.m. and seven a.m. of the following day.

ASSESSING IMPACT FROM ENVIRONMENTAL NOISE

The underlying concept for noise impact assessment in the following analysis is to relate the change in expected impact in terms of the number of people involved to the change that will result in the acoustical environment as a result of the proposed action. Three fundamental components are involved in the analysis:

1. Definition of the initial acoustical environment
2. Definition of final acoustical environment
3. Relationship between noise environment and human impact.

The first two components of the assessment are entirely site or system specific, relating to either estimates or measurement of the environmental noise before and after an action is taken. The same approach is used conceptually whether one is examining one house near a highway, a house near a construction site, the transportation system in general, or whatever noise source is involved. The methodology for estimating the noise environment in each case will vary widely, but the concept remains the same.

In contrast to the large number of methodologies that may be utilized to estimate the noise environment, the relationship to human response can be quantified by a single methodology in terms of the number of people in occupied places exposed to noise of a specified magnitude. This is not to say that individuals have the same susceptibility to noise; they do not. Even groups of people may vary in response depending upon previous exposure, age, socio-economic status, political cohesiveness and other social variables. In the aggregate, however, for residential location the average response of groups of people is stable and related to cumulative noise exposure as expressed in measures such as L_{dn} or L_{eq}. The response utilized is the general adverse reaction of people to noise. This response is a combination of such factors as speech interference, sleep interference, desire for a tranquil environment, and the ability to use telephones, radio and TV satisfactorily. The measure itself consists in relating the percent of people in a population that would be expected to indicate a high annoyance to noise for a specified level of noise exposure.

For schools, offices, and similar spaces where criteria for speech communication or a possibility of damage to hearing is of primary concern, a similar averaging process is used to estimate the potential response of people as a group, again ignoring the individual variation of one person as compared to another.

In both instances, then, residential or similar areas and non-residential areas alike, the analysis is performed in terms of the average response of people and its variation with environmental noise exposure.

A detailed discussion of the relationship between noise and human response is provided in several EPA documents[1,28] in which hearing damage, speech and other activity interference and annoyance are related to L_{eq} and L_{dn}. For the purpose of the following analysis, criteria presented in the "EPA Levels Document" are used. Further, it is considered that if the levels identified in the document are met, then no impact exists on the public health and welfare. Thus, arbitrarily we define that if the levels identified in the "Levels Document" are met, a zero percent impact exists. That is, if an L_{dn} of 55 measured outdoor exists, then there is no impact in terms of annoyance and general community response from noise. Similarily, if an L_{dn} of 45 exists indoors, which translates to an L_{dn} of 55 outdoors assuming a 10 dB transmission loss with window partially opened, then no interference exists with respect to speech.

Observation of the data presented in Appendix D of Reference 1 allows the specification of an upper limit, that is a bound corresponding to 100% impact. It may be observed in Figure D-7 of the "Levels Document"[1] that community reaction data show that the expected reaction to an identifiable source of intruding noise changes from "none" to "vigorous" when the day-night sound level increases from 5 dB below the level existing without the presence of the intruding noise to 19.5 dB above the pre-intrusion level. When the combined values of the intruding noise and the pre-intrusion noise levels are considered, the changing community reaction from "none" to "vigorous" occurs when the level increases by 19.7 above the pre-intrusion level. For simplicity sake, it is reasonable to associate 100% impact corresponding to a vigorous community reaction with a change of 20 dB above the L_{dn} value identified as a zero impact level. This conclusion is further validated by the annoyance data presented in the "Levels Document", since this increase in noise level increases the rate of highly annoyed people in the total exposed population by 40%.

Thus, for the purpose of this analysis, $L_{dn} = 75$ is considered to be a 100% impact.

Furthermore, the data in Appendix D of Reference 1 suggest that within those upper and lower bounds the relationship between impact and level varies linearly, that is, a 5 dB excess constitutes a 25% impact, while a 10 dB excess constitutes a 50% impact.

The data presented in the "Levels Document" with respect to activity interference (e.g., speech interference) suggests that if the day-night sound level indoors is 45 dB, no impact exists on speech communication since a noise level intelligibility for all types of speech material and would have a calculated articulation index of 1.0.

The intelligibility of speech is a function of the material presented to the listener as well as the signal to noise ratio. Data on speech intelligibility has recently been reviewed in several of the EPA documents and also by an ANSI committee for the preparation of the ANSI S3.5-1969, and is summarized in Figure 15 of Reference 29.

It may be argued that for most conversation the material the listener normally listens to is in the form of sentences containing a mixture of some known material and some unknown material. Thus, for this analysis it is reasonable to average the data on known and unknown sentences. Observation of Figure 15 of the ANSI Standard[29] reveals that when the noise environment is increased by approximately 19 dB above the level identified in the "Levels Document."[1] Similarily, the intelligibility for known sentences drops to 90% when the level is increased by 22 dB above the level identified by EPA and 50% when the level is increased by approximately 26 dB. Thus, if the values are averaged, it is not unreasonable to assume that a 20 dB increase in the noise level above the level identified by EPA in the "Levels Document" will result in conversational speech deteriorating rapidly with each decibel of increase. For this reason, it is assumed that 100% impact will occur on speech intelligibility when the level of the environmental noise increases 20 dB above the identified level in the "Levels Document". Furthermore, observation of Figure 15 of the ANSI Standard[29] suggests that it is reasonable to assume that speech varies approximately linearly with the level for the range between 0 and 100% impact. That is, with each 5 dB excess of noise above the level identified in Reference 1, a 20% reduction of speech intelligibility occurs while a 10 dB excess results in a 50% degradation.

The previous paragraphs demonstrate that for impact analyses, it is reasonable to consider that annoyance data, community reaction data, and speech interference data, fall within a range of 20 dB corresponding to 0 and 100% impact when 0% impact is defined as being the level identified in the "Levels Document" and 100% impact as being the level which is 20 dB above the levels identified in the "Levels Document".

For convenience of calculation, the percentage between 0 and 100 may be expressed in terms of a Fractional Impact (FI), where FI is calculated in accordance with the following formula:

$$FI = 0.05 \times (L - L_C) \text{ for } L > L_C$$
$$FI = 0 \qquad \text{for } L < L_C$$

where L is the environmental noise level, expressed either in L_{dn} or L_{eq}, and L_c is the level identified in the Levels Document.

It may be observed that for values greater than those corresponding to 100% impact, the FI will be greater than unity. The effect of this will be to maximize the impact weight for those areas in which the impact is only marginal. The appropriate level for the computation of FI is L_{dn} = 55 dB for residential area measured outdoors and for analysis concerned with office buildings and other type of spaces in which speech communication is the principal factor of concern, the identified level is L_{dn} = 45 indoors, which can be translated to an outdoor level by using sound level reduction appropriate to the type of structure.

Data on the reduction of aircraft noise afforded by a range of residential structures are available. These data indicate that houses can be approximately categorized into "warm climate" and "cold climate" types. Additionally, data are available for typical open-window and closed-window conditions. These data indicate that the sound level reduction provided by buildings within a given community has a wide range due to differences in the use of materials, building techniques, and individual building plans. Nevertheless, for planning purposes, the typical reduction in sound level from outside to inside a house can be summarized as follows in Table B-1. The approximate national average "window-open" condition corresponds to an opening of 2 square feet and a room absorption of 300 sabins (typical average of bedrooms and living rooms). This "window-open" condition has been assumed thoughout this chapter in estimating conservative values of the sound levels inside dwelling units that results from outdoor noise.

The final notion to be considered is the manner in which the number of people affected by environmental noise is introduced into the analysis. The magnitude of the total impact associated with a defined level may be assessed by multiplying the numbers of people exposed by the fractional impact associated with the level of the environmental noise as follows:

$$P_{eq} = (FI) \qquad \text{(B-5)}$$

where P_{eq} is the magnitude of the total impact on the population and is numerically equal to the equivalent number of people having a fractional impact equal to unity (100% impacted); FI is the fractional impact for the level and P is the population affected by the noise.

Table B-1

SOUND LEVEL REDUCTION DUE TO HOUSES* IN WARM AND COLD CLIMATES, WITH WINDOWS OPEN AND CLOSED

	Windows Open	Windows Closed
Warm Climate	12 dB	24 dB
Cold Climate	17 dB	27 dB
Approx. National Average	15 dB	25 dB

*(Attenuation of outdoor noise by exterior shell of the house)

Where knowledge of structure indicates a difference in noise reduction from these values, the criterion level may be altered accordingly.

When assessing the total impact of a given noise source, or an assemblage of noise sources, and since the levels of environmental noise associated with the source(s) decrease as the distance between the source and receiver increases, the magnitude of the total impact may be computed by determining the number of people exposed at each level, and summing the resulting impact. The total impact is given by the following formula:

$$P_{eq} = \sum_{i} P_i FI_i \qquad \text{(B-6)}$$

where FI_i is the fractional impact associated with the i^{th} level and P_i is the population associated with the i^{th} level.

The change in impact associated with an action leading to noise reduction, or change in population through a change in land use, may be assessed by comparing the magnitude of the impacts for the "before" and "after" conditions. Another useful measure is the percent expression:

$$\Delta = 100 \; \frac{(P_{eq}\,(\text{before}) - P_{eq}\,(\text{after}))}{P_{eq}\,(\text{before})} \qquad \text{(B-7)}$$

Note that the percentage change may be positive or negative depending upon whether the impact decreases (positive percentage reduction) or the impact increases (negative percentage reduction).

Thus, a 100 percent positive change in impact means that the environmental noise has been reduced such that none of the population is exposed to noise levels in excess of the levels identified in the "Levels Document."

To place this concept in perspective, we consider a simple example. In the recent EPA study on "Population Distribution of the United States as a

Function of Outdoor Noise Level," an estimate is provided for the number of people in the United States exposed to various levels of urban noise. We can use the above concepts to illustrate the current impact of this exposure, and then to assess the change in impact if all noise sources were reduced 5, 10, or 15 dB across the board. In the following computation we take the data from this study defining each P_i as the population between successive 5 dB increments of L_{dn}, assigning this population an exposure level midway betwen successive L_{dn} increments. For this example, the identified level is an L_{dn} of 55 dB measured outdoors.

The results, provided in Table B-2, show that a 5 dB noise reduction results in a 55% reduction in impact, a 10 dB noise reduction results in an 85% reduction in impact, and a 15 dB noise reduction results in a 96% reduction in impact.

The impact assessment procedure may be summarized by the following steps:

1. Estimate the L_{eq} or L_{dn} produced by the noise source system as a function of space over the area of interest.
2. Define subareas of equal L_{eq} or L_{dn}, in increments of 5 dB, for all land use areas.
3. Define the population, P_i, associated with each of the subareas of step 2.
4. Calculate the FI_i values for each L_{dn_i} or L_{eq_i} obtained in step 2.
5. Calculate $FI_i \times P_i$ for each subarea in step 2.
6. Obtain the equivalent impacted population for the condition existing before the change being evaluated,

$$P_{eq_B} = \sum_i (FI_i \times P_i)$$

by summing the individual contributions of step 5.

7. Repeat steps 1-6 for the noise environment existing over the area of interest after the change being evaluated takes place, thus obtaining P_{eq_A}. (Note that the subareas defined here will not in general be congruent with those of step 2 above.)

8. Obtain the percent reduction in impact from

$$\Delta = 100 \frac{(P_{eq_B} - P_{eq_A})}{P_{eq_B}}$$

Table B-2

ESTIMATE OF THE IMPACT OF SUCCESSIVE REDUCTION OF ALL URBAN NOISE SOURCES IN 5 DECIBEL INCREMENTS

Current Conditions — Noise Reduction in Decibels

L_{dn} -dB	Population Exposed to Higher L_{dn} -millions	P_i millions	0: FI_i -millions	0: FI_iP_i -millions	5: FI_i -millions	5: FI_iP_i -millions	10: FI_i -millions	10: FI_iP_i -millions	15: FI_i -millions	15: FI_iP_i -millions
55	93.4	34.4	0.125	4.3	0	0	0	0	0	0
60	59.0	34.7	0.375	13.0	0.125	4.3	0	0	0	0
65	24.3	17.4	0.625	10.9	0.375	6.5	0.125	2.2	0	0
70	6.9	5.6	0.875	4.9	0.625	3.5	0.375	2.1	0.125	0.7
75	1.3	1.2	1.125	1.4	0.875	1.1	0.625	0.8	0.375	0.5
80	0.1	0.1	1.375	0.1	1.125	0.1	0.875	0.1	0.625	0.1
Total Equivalent People Impacted			34.6		15.5		5.2		1.3	
Percent Reduction Impact			0		55		85		96	