N-96-01
II-A-153

United States Environmental
Protection Agency

Office of Noise Abatement and
Control
Washington, D.C. 20460

EPA REPORT NO. 550/9-81-321

AVAILABILITY OF WORKPLACE NOISE CONTROL TECHNOLOGY FOR SELECTED MACHINES

May 1982

N-96-01
II-A-153

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 550/9-81-321	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE AVAILABILITY OF WORKPLACE NOISE CONTROL OF TECHNOLOGY FOR SELECTED MACHINES		5. REPORT DATE September 1982 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) R. Bruce, K. Eldred, C. Jokel, R. Potter, D. Melone		8. PERFORMING ORGANIZATION REPORT NO. BBN Report No. 4330
9. PERFORMING ORGANIZATION NAME AND ADDRESS Bolt Beranek and Newman, Inc. 10 Moulton Street Cambridge, MA 02238		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. EPA Contract No. 68-01-5037
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency Office of Noise Control Washington, D.C.		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

EPA Project Manager: Roger Heymann

16. ABSTRACT

This report reviews the noise control technology available to equipment manufacturers and users of the following machines: automatic screw machines, semi-automatic stamping presses, planes, wood saws, metal saws, crawler tractors, molding machines, spinning frames, and twisters. The study also looks at the reasons for the unavailability of certain control technology. The availability of new quiet machines on the market place is also reviewed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
noise control, planes, saws, tractors, bulldozers, molding machines, frames, spinning machines, twisters, screw machines, presses, punch presses, engineering noise control		

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* unlimited	21. NO. OF PAGES 279
	20. SECURITY CLASS *(This page)* unlimited	22. PRICE

EPA Form 2220-1 (9-73)

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PREFACE

This study was undertaken by the Office of Noise Control at EPA to identify and define the status of industries' compliance with the occupational workplace noise standard. Fundamental to the study was the identification and review of the availability of noise control technology to the equipment manufacturer and user industries.

The study was structured to examine the user industry's ability to comply with the occupational workplace noise standard through the use of control technology. Emphasis was given to those industries and machines for which major problems with respect to compliance were believed to exist. The fundamental thrust of this study was that where technology was not available to the user industry, due either to cost or technical unavailibility, but available to the equipment manufacturer, the potential existed for some benefit from EPA regulatory action. And, this depended upon the availability of control technology to the equipment manufacturer, and the benefits to be gained. The regulatory authority given to EPA by the Noise Control Act applied only to new equipment manufacturers. If EPA was to undertake regulatory initiatives in occupational noise (to assist OSHA in achieving compliance with the occupational noise standard), the regulations could only apply to the machines produced by the new equipment manufacturers.

No decision or plan had been made by the EPA Noise Office to undertake a regulatory program in occupational noise. The study was undertaken only to learn about the occupational workplace noise problem. In addition, no determination had been made on what type of involvement EPA should have in occupational noise in a program complementary to OSHA, if any at all. There was a general feeling at the Noise Office, that developed as a result of the study, that any EPA involvement should be through a coordinated program involving EPA as well as other Agencies in support of OSHA.

The study's results should be of special value and interest because it contains information on noise control technology not readily available in the literature.

The contractor's technical participants were Mr. R. Bruce, Mr. K. Eldred, Mr. C. Jokel, Mr. R. Potter, and Ms. D. Melone. The EPA Project Manager was Mr. R. Heymann.

EXECUTIVE SUMMARY

More American workers are concerned about industrial noise than about any other occupational hazard. The United States Congress has addressed the issue of worker exposure to excessive noise. Congress's concern with noise was expressed in the Occupational Safety and Health Act of 1970 and the Noise Control Act of 1972. The Occupational Safety and Health Administration (OSHA) promulgated a workplace noise standard (29 CFR 1910.95) in 1970 that applies to worker noise *exposures* (not machine noise emissions). Thus, the standard can be satisfied by altering work practices (administrative controls) or by changing the acoustical characteristics of the machine and/or the workplace (*in situ* controls). The responsibility for correcting the unacceptable exposures presently rests entirely with the user, rather than the manufacturer, of the machine. User industries often try to solve noise exposure problems through the use of *in situ* engineering controls. OSHA's initial anticipation was that the users could readily apply *in situ* controls to achieve compliance. However, even after 9½ years of OSHA enforcement, millions of workers are still overexposed according to the OSHA noise standard and are eventually expected to experience noise-induced permanent threshold shifts — permanent hearing loss — caused by long-term exposure to noise.

The Noise Control Act of 1972 empowers the Administrator of the EPA to establish noise regulations dealing with the labeling of new machinery or limiting the noise emissions of such machinery. If this authority were to be applied to industrial noise, the regulatory action would apply to noise emissions of new machines for industrial use. The burden of the regulatory action would chiefly affect the manufacturers of the new machinery. Such an approach could supplement the current OSHA approach to the solution of the industrial noise problem. In situations where *in situ* engineering noise controls are not available because of either technology or cost, source regulations offer the only possibility for a solution to these noise problems.

This study is intended to provide part of the data required to assess whether the application of EPA regulatory authority to the noise emissions of new machines would produce significant benefits to the industrial workforce. When such benefits are expected to occur, the study examines the potential of alternative regulatory approaches.

The study process involved finding example machines that met defined screening criteria for determining impact on worker overexposure to noise, and then applying other screening criteria to determine the potential benefits of regulatory alternatives. The first part of this study was to identify industries in chronic violation of the OSHA noise standard. Then machines causing the overexposure in these industries were identified. The machines were then checked against the following screening criteria:

- 10,000 operators and/or 50,000 peripheral workers had to be impacted
- the users had to experience difficulty in complying with the OSHA noise standard.

Next, for these example machines, the study assessed the availability of noise control to the users. The assessment consisted of:

- Identifying the availability of *in situ* controls for the selected machines
- Determining whether the costs for these controls are acceptable, on the basis of OSHA experience.

Then, for those machines for which *in situ* controls are not available or are available at an unacceptable cost, the study assessed the availability of noise control technology to the original equipment manufacturer (OEM). This analysis consisted of:

- Identifying the existence of noise-reduced machines in the marketplace and, where they represent only a small fraction of machines sold, determining why more of these machines are not sold
- Determining the availability of technology for machine types that do not have noise-reduced machines in the marketplace.

Finally, for the machines that passed all screening criteria, the study assessed the impact of growth and turnover rates on the introduction of new noise-reduced machines into the workplace and used this information to estimate the potential benefits of Section 6 or 8 regulation.

The principal study findings are:

1. OSHA compliance cannot be achieved for 9 of the 18 machines studied because *in situ* controls are unavailable or too expensive. These machines – automatic screw machines, semiautomatic stamping presses, planers, wood and metal saws, crawler tractors (>150 hp), molding machines, spinning frames, and twisters currently cause overexposure

of large numbers of operators in foundries, sawmills and planing mills, broad woven fabric mills, screw machine plants, and metal forgings and stampings plants. These machines control the exposure of the operators. If the noise of these machines were sufficiently controlled, their operators, in most instances, would have noise exposures that comply with the existing OSHA regulations.

2. Noise-reduced versions are available for five of these nine machines: automatic screw machines, planers, wood saws, crawler tractors (>150 hp), and manual molding machines. The OEMs report that the noise-reduced versions do not make up a large percentage of the new machines sold, for the following reasons:

- User industry doesn't know about the availability of the quiet machines
- User industry is often unwilling to pay the premium for noise control (crawler tractor [>150 hp], manual molding machine)
- User industry is planning to install the new machine in an existing facility that is still noisy and concludes that the operator will not receive any benefit from the purchase of a quiet machine (wood saws, automatic screw machines)
- User has no reliable measurement method and prediction procedure to ensure that once the quiet machine is operational, the operator's exposure will be in compliance (planer)
- User industry places a higher priority on production increases, quality control, and reliability than on noise control (planers, crawler tractors [>150 hp], manual molding machines).

3. Technology is available for noise control in the design of the other four of these machines (metal stamping presses, metal saws, spinning frames, and twisters), but the OEMs have not developed such equipment for a variety of reasons including the following:

- There is a limited demand for noise control (metal saws)
- There is sufficient demand for the OEM's machine without noise control (metal stamping presses)
- The OEM has limited capital for machine design and currently gets a better return on investment by improving productivity, reliability, and quality of part produced than by providing noise control. In addition, the OEM does not want to be the first to attempt noise control, since the first OEM will go to great expense to develop concepts that will then be used at much lower cost by other OEMs (saws)
- The OEM is often unaware of the availability of noise control technology (metal stamping presses)
- Users are often loyal to a product line because of the availability of spare parts, and familiarity with the OEM (saws, metal stamping presses)
- The OEM has no confidence that users will buy the noise-reduced machine at the necessary price premium (spinning frames, twisters, metal stamping presses)
- For some machines, neither the user nor the OEM has determined how to specify the noise emission for a noise-reduced machine.

4. Noise-reduced machines are being developed by the OEMs at a very slow rate, and they are being introduced into the workplace at a slow rate. Section 6 and/or Section 8 regulations could accelerate the introduction of new noise-reduced machines into the workplace.

5. If Section 6 emissions regulations were promulgated for the nine machines passing the filters, we estimate that roughly one-half million operators could be removed from overexposure to noise in excess of the limit of the OSHA noise standard between 1986 and 1990.

6. Promulgation of Section 8 labeling requirements on either a voluntary or mandatory basis could result in a reduction of the noise impact. However, there are no scientific methods available for estimating the magnitude of the potential benefits or the certainty of the time period in which they might occur. The existence of meaningful noise emission levels based on standard test procedures would provide the OEM with the information required to define noise reduction requirements and redesign machines to meet these requirements. Such levels would provide the user with information needed for an informed purchase of noise-reduced machines and for the design of new factories.

7. The identification of machines for which the operator's exposure would meet OSHA requirements either by labeling or emission regulation could give OSHA an opportunity to require industries that are in chronic violation of noise standards (and for which engineering controls are not feasible) to confine their future purchases to noise-reduced machinery rather than noisy machinery, so that such industries may eventually meet the standards.

8. An additional benefit of Section 6 regulation may be the development of retrofit noise control kits for many of the machines already in service. If such kits were developed by the OEM, their cost might be low enough to bring down the present cost of noise control to more acceptable levels, enabling OSHA enforcement.

9. Nine machines were found in this study for which new noise-reduced machines appear to be the only alternative to hearing protectors for control of workplace noise. These are probably only a fraction of the total number of such machines. There may be a large number of machine types and wide variation of size and application within each type; these factors could have major implications for the magnitude of the effect needed to regulate new machines for which *in situ* controls are not feasible. For a fixed level of EPA resources, there are probably tradeoffs to consider between the certainty of benefits under Section 6 regulation for a limited number of machines per year and the lower certainty (but possibly more widespread benefits) under a Section 8 mandatory/voluntary regulatory effort that applies to a larger number of machines per year.

10. Complementary actions that may have promise for accelerating the rate of introduction of noise-reduced machines, either with or without Section 6 or 8 regulations, include: OSHA new machine/plant policy, economic incentives, education and training, and research, development, and demonstration.

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1. INTRODUCTION

1.1 Background

Industrial noise has been the subject of much study in many industrial nations in the past decade, because workplace noise is recognized as a hazard to human health and well-being. Research has demonstrated that long-term daily exposure to high-level workplace noise causes both *significant* and *irreparable* harm to human hearing. And, in the United States, high-level noise in the workplace is a pervasive problem, affecting substantial numbers of workers in industrial facilities. To place the problem in perspective, recent estimates of noise conditions in the manufacturing sector of industry show that approximately 19% of the workers in the 19 major manufacturing industries, or *2.5 million individuals*, are exposed – every workday – to sound levels in excess of the maximum permissible limit expressed in the OSHA noise standard [*1*].

Congress, concerned over the effects of industrial noise, has responded with legislation in the form of two acts. The first is the Occupational Safety and Health Act of 1970, which established the Occupational Safety and Health Administration (OSHA) to oversee worker safety and health in specific industries. In exercising its authority, OSHA has promulgated a noise standard that limits worker noise *exposures* (not machine noise emissions) [*2*]. Thus, the standard can be satisfied by altering work practices (administrative controls) or changing the acoustical characteristics of the machine and/or workspace (*in situ* controls). Another important aspect of the OSHA regulation is that the user plant in which the unacceptable condition exists – rather than the manufacturer of the noisy machines – has the responsibility for alleviating the condition.

The second act is the Noise Control Act of 1972, which empowers the Administrator of the EPA to establish noise regulations dealing with the labeling of new industrial machinery or limiting the noise emissions of such machinery. In this case, the regulatory action specifically involves machinery noise emissions, and the regulations are directed toward the manufacturers of the noise-making machinery. Though their approaches differ, the objectives of both OSHA and EPA noise legislation are similar: to reduce the hazard of noise to people. To date, the primary thrust of EPA noise regulations has been directed toward protecting the general public health and welfare from environmental noise resulting from major noise sources, such as transportation and construction machinery. Additionally, the EPA has developed the basis for voluntary noise emissions labeling programs and a mandatory labeling program for hearing protectors.

With respect to noise-induced hearing loss, EPA has developed criteria relating hearing loss to noise exposure [3,4,5], identified levels requisite to protect public health and welfare [6], and sponsored research on noise-induced hearing loss [7,8]. The agency has also studied national patterns in compensation for hearing loss [9], assessed the state of research and research needs for noise control of industrial machinery [10,11], and participated in the process of developing federal policies and revisions in the current OSHA regulations. However, EPA has yet to assess the potential benefits of applying its regulatory authority to the noise of new machines purchased for use in the workplace.

1.2 Objectives

This study was undertaken to provide data that can be used as an input to EPA in its examination of a full range of alternative federal strategies, that, together with the OSHA program, would make a major contribution to reducing noise exposures of workers in the workplace. An objective of this study was to find examples of industrial machinery that currently cause chronic overexposure of workers to noise and for which the only engineering solution for meeting OSHA requirements is the introduction of new noise-reduced machines* supplied by the original equipment manufacturer (OEM). Then, for these examples, the following factors were considered:

- The rate at which these new noise-reduced machines are being introduced into industry
- Why the rate of introduction is not higher
- Where technology for noise reduction is available, why some OEMs do not manufacture noise-reduced versions for the machines studied.

Then, the study focused on the applicability and potential effectiveness of using appropriate noise emissions standards under Section 6 and noise labeling regulations under Section 8 of the Noise Control Act to reduce the overall noise exposure of workers in the workplace.

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*Noise-reduced machines are ones in which the OEM has incorporated noise control into the design of the machines. Under normal operating conditions, the exposure of the operator is in compliance with the OSHA noise standard.

1.3 Content

Section 2 of this report discusses the methodology used to achieve the stated objectives. In Sec. 3, findings and conclusions are presented. The appendices present detailed information on the study criteria (Appendix A), industries with chronic OSHA violations (Appendix B), the studied machines (Appendices C.1 - C.19), and Research Triangle Institute's Industrial Machine Trends (Appendix D).

2. METHODOLOGY

In this section, we outline the methodology and principal data sources that were used to select examples of machines for consideration in the study and to evaluate the potential benefits of regulatory alternatives for new machines. The principal data sources were identified through extensive literature searches and discussions with users, OEMs, the noise staff of the regulatory agencies (OSHA, MSHA, and EPA), and their consultants.

2.1 Overall Logic

The first part of this study was to select machines in industries in chronic violation of the OSHA noise standard. These machines were then subjected to a series of screening criteria, or filters, which are detailed in Appendix A. Basically, these filters focused on four major themes: selection of the machines, assessment of noise control technology to the user industries and to the original equipment manufacturer industries, growth and turnover of machines, and assessment of benefits of regulatory alternatives.

2.2 Selection of Machines

The selection of machines was based on the following criteria (filters): that the machines were used in industries in chronic violation of the OSHA noise standard, that the machines caused the overexposure, that there were at least 10,000 operators and/or 50,000 peripheral workers, and that users experienced difficulty in meeting the OSHA noise standard.

2.2.1 Industries with chronic noise violations

The Occupational Safety and Health Administration provided detailed inspection information for the period from July 1972 to April 1979. These data were presented at the 4-digit Standard Industrial Classification (SIC) code level [*12*]. The number of inspections, the number of violations, and the violation rate were given. Using this information, we aggregated the data to the 2-digit SIC code level and selected the industries with the highest violation rates.

2.2.2 Machines causing chronic violation of OSHA noise standard

The OSHA violation records are not in themselves sufficient to identify the specific machines responsible for the violations of the noise standard. To determine probable candidate machines, we developed an extensive list of machinery in each of the selected industries and conducted a broad literature search of all journals known to have published papers on industrial noise. In addition, we conducted computerized searches using the EPA library, NIOSH's data base, NTIS, and Compendex (Engineering Index data base). For each of the machines under investigation, we developed reference files containing information about noise emissions, generation, and control for each machine. A review of these data coupled with our field experience led to the identification of machines in each of the selected industries that were most likely to cause overexposures.

2.2.3 Number of operators and peripheral workers

Filter f required that more than 10,000 operators and/or 50,000 peripheral workers be exposed to the noise of the machine. One of the more difficult tasks in this study was to develop reliable estimates of the number of operators exposed to the noise of a particular machine. Estimating the number of peripheral workers was even more difficult. *Occupation by*

Industry [*13*] presents information on the number of operators in each industry. This data source was useful in some instances (for example, planers, Appendix C.17). More often the data were aggregated so that the operators of the machine under investigation were included in a more general category (for example, saws, Appendix C.18).

We found other sources that presented inventories of the machinery used in the industries. Using these machinery inventories, the number of machines tended by each operator, the number of shifts, and the percent utilization of the machinery, we developed estimates of the number of operators. Since we identified a sufficient number of machines with more than 10,000 operators and since developing estimates of the number of peripheral workers was fraught with uncertainties, these estimates were not developed for all machines.

Major sources of information on the number of machines include:

- *12th American Machinist Inventory* [*14*]
- *Woodworking and Furniture Digest* [*15*]
- Textile Machinery in Place [*16*]
- BBN files on sawmills (approximately 280 case histories)
- BBN files on foundries (approximately 300 case histories).

Information on the number of machines tended by each operator, the number of shifts, and the percent utilization of the machinery was estimated by BBN after reviewing the available data on each of the machines.

2.2.4 Degree of difficulty

Filter b was designed to determine whether the user industry was having difficulty in obtaining and applying noise control technology in complying with the OSHA noise standard. In general, the literature reviews, discussions with users, and our field experience provided evidence to establish that industry *is* having difficulty in complying with the noise standard for the selected machines.

2.2.5 Commonality of machines to more than one industry

Filter d was included to evaluate the possibility that some of the machines in chronic violation are used across various industries or production processes. Using the sources on the number of machines mentioned in Sec. 2.2.3, we were able to determine whether a particular machine was used across more than one industry, or whether it was industry-specific.

2.2.6 Summary

At the conclusion of this selection process, a list of machines was developed. These machines cause chronic noise violations in their industry, are difficult for the user industry to control, impact at least 10,000 operators, and may be common to more than one industry.

2.3 Assessment of Noise Control Technology Available to the User Industries and to the Original Equipment Manufacturers' Industries

Our assessment of the availability of noise control to the users and to the original equipment manufacturers consisted of:

- Identifying available *in situ** controls for the selected machines, determining whether costs for those controls are acceptable, and retaining for further analysis only those machines for which *in situ* controls are not available or are available at extraordinary expense (Filter c)
- Identifying new noise-reduced machines and determining why more of these machines are not sold (Filter i)
- Determining the availability of technology for machine types without noise-reduced versions (Filter j).

2.3.1 *In situ* controls

Filter c required *in situ* controls to be either unavailable or too expensive. BBN's experience, discussions with users and OSHA staff, and a review of the literature on each of the machines enabled us to identify the *in situ* controls that are available for each machine. A review of more than 240 Occupational Safety and Health Review Commission (OSHRC) cases dealing with noise sometimes established whether the available noise control treatments for a particular machine could be installed for a cost ruled by OSHRC as acceptable for that particular instance. In addition, OSHA established a limit in terms of a maximum dollars-per-person limit, above with OSHA will not press for installation of engineering controls.

**In situ* controls include changing the acoustical characteristics of the workplace with the use of facility treatments (such as barriers and room absorption), custom designed noise control treatments for the machine (such as partial enclosures, mufflers, damping, and vibration isolation), and retrofit kits from the OEM.

2.3.2 New noise-reduced machines

In response to Filter i, we discussed the availability of quieter machines with original equipment manufacturers. Information from these discussions and the literature search enabled us to identify which machines have noise-reduced versions and why these machines do or do not sell well.

2.3.3 Availability of technology

Filter j addressed the availability of technology for machines for which no manufacturer produced a noise-reduced version. Our assessment of the availability of technology and the reasons why this technology is not integrated into the design of many machines is based on the literature on each machine and on our discussions with both users and original equipment manufacturers.

2.4 Growth and Turnover of Machines

Filter h addressed the first-owner life of the machines and the growth of the user industries. Both of these economic indicators play major roles in determining the rate at which new machines are introduced into the workplace. If the first-owner life (turnover rate) is short and the growth of the user industries is high, larger numbers of new machines will be introduced into the workplace than if the turnover rate is slow (machines last a long time) or the growth rate is small.

Research Triangle Institute, working under separate contract to EPA, provided estimates of the U.S. production, exports, imports, U.S. consumption, stock of machines in place, and retirements of machinery from 1986 to 1990, the period over which we would evaluate benefits. These data are presented in Appendix D.

2.5 Development of Benefits of Regulation

2.5.1 Degree of reduction

Filter e required the noise exposure of the operator of a particular machine to be brought into compliance with the OSHA noise standard when the noise of that machine was reduced. In other words, the peripheral machines should not make major contributions to the noise in the vicinity of the machine. We were able to evaluate this criterion using the literature on each of the sources and our experience with each of the sources.

2.5.2 Benefits of Section 6 regulation

Filter k required that regulation bring relief to the worker population within five years. Using the data developed by Research Triangle Institute, we estimated the increase in the number of operators from 1986 to 1990 and the maximum number of operators who will benefit from the introduction of noise-reduced machines into the workplace.

2.5.3 Benefits of Section 8 regulation

Filters l and m focused on the benefits of Section 8 regulation. Filter l asked if users would benefit from labeling information in selecting quieter machines and in arranging the plant layouts to reduce noise. In addition, the reasons why detailed information is not now available from the OEM were to be determined. Filter m focused on the worker and labeling and asked if labeling would inform the worker and encourage diligent use of hearing protectors. In responding to these filters, we used information previously developed by EPA for other labeling efforts, information from users and OEMs, and the literature on each machine.

3. FINDINGS AND CONCLUSIONS

3.1 Selection of Machine for Study

Since the Occupational Safety and Health Act was signed into law in December of 1970, the manufacturing industry has been faced with the requirement to comply with 29 CFR 1910.95. Although industry has been attempting to comply with the standard for the past 9½ years, many workers in the manufacturing industry are still overexposed according to the standard. Examination of the OSHA inspection data for the period July 1972 to April 1979 indicates that four industries (Primary Metal, Lumber and Wood Products, Textile, and Fabricated Metal) account for about 47% of the total number of violations issued by the agency (even though they account for only 27% of the total number of inspections). Appendix B presents a summary of OSHA's noise-related inspections for this time period, aggregated by 2-digit SIC code.

Within these four 2-digit industries, we selected for further analysis the following 3-digit industries, which have particularly high violation rates within their 2-digit industry: Foundries, Sawmills and Planing Mills, Broad Woven Fabric Mills, Screw Machine Products and Metal Forgings and Stampings. The following 18 machines were selected from among all of the machines in these industries as the ones with potentially the greatest impact and the greatest likelihood of meeting all the criteria:

Foundries	Sawmills and Planing Mills	Broad Woven Fabric Mills
Furnaces	Wood Saws	Draw Frames
Shakeouts	Planers	Looms
Molding Machines	Chippers and Hogs	Spinning Frames
Pneumatic Hand Tools		Twisters
		Knitting Machines

Screw Machine Products and Metal Forging and Stampings

Pedestal Grinders

Tumblers

Automatic Screw Machines

Metal Stamping Presses

Metal Saws

Miscellaneous

Crawler-Tractors (>150 hp)

Upon examination of these machines, we found that nine of them cause chronic violations of the noise standard, *in situ* controls are unavailable or too expensive for them, there are more than 10,000 operators for each type, and noise-reduced versions of the machines can be or already are offered by the OEM.

The machine meeting the study criteria are: automatic screw machines, semiautomatic metal stamping presses, planers, wood and metal saws, crawler tractors (>150 hp), molding machines, spinning frames, and twisters. The remaining nine failed one or more of the criteria.

The following sections will discuss in detail:

- *In situ* controls — the availability of technology to the user industry
- Noise-reduced machines — The OEM has incorporated noise control into the design of the machines. Under normal operating conditions, the exposure of the operator is in compliance with the OSHA noise standard
- Availability of noise control technology for use by the OEM.

The findings are based on the investigation of the 18 selected machines. In general, these findings may be extended to all machines that meet the selection criteria. However, because the selection process was designed to find examples of machines that would be useful for the study, it is not possible to draw any conclusion about the proportion of machines in industry that would meet any or all of these criteria.

3.2 Availability and Cost of *In Situ* Controls

We found that the noise exposure of the operators of 9 of these 18 machines could not be brought into compliance because *in situ* controls were unavailable or too expensive. Of the machines studied, only automatic screw machines can be treated with an OEM-supplied retrofit kit that brings the operator's exposure into compliance with OSHA requirements. In order to quiet the other machines that we studied, the user must design noise control treatments for each machine or must have them designed. Although *in situ* controls can be developed and installed for 5 of these 9 machines, the cost of such controls is probably unacceptable. In this study, the cost is considered unacceptable for machines identified in contested citations when the Occupational Safety and Health Review Commission (OSHRC) has ruled that the user does not have to use engineering controls to comply with the standard, because such controls are excessively expensive. The Commission has not established an explicit maximum cost per worker for the acceptability of such expenditures. A review of the more than 240 OSHRC cases involving noise reveals that the maximum cost per worker varies from several thousand to more than ten thousand dollars, depending on the specifics of the case. However, OSHA's Office of the Solicitor has indicated that the current policy is not to cite until the daily noise dose is 1.32 and not to require *in situ* engineering controls when the cost is more than $8,000 per worker. This figure is within the range established by the OSHA Review Commission.

Table 1 summarizes the availability and cost of *in situ* controls for all of the machines studied. Even though *in situ* controls are available for all of the machines except manual molding machines, pneumatic hand tools, most drawframes, looms, manual shakeouts, and induction furnaces, the operators of these machines are not likely to be protected with *in situ* controls, because of the high cost of such controls. We think that *in situ* controls for most applications for the following machines will be in excess of $8,000 per worker and won't be installed: automatic screw machines, semiautomatic metal stamping presses, planers, wood and metal saws, crawler tractors (>150 hp), spinning frames, twisters, some draw frames, and large chippers and hogs. *In situ* controls are available at acceptable costs for large and small hand-fed presses, automatic molding machines, automatic shakeouts, furnaces (crucible, cupola, and electric arc), small chippers and hogs, pedestal grinders, tumblers, and knitting machines.

3.3 New Noise-Reduced Machines

With respect to noise, the population of new machines offered for sale by the OEM can be divided into three basic categories:

- All new machines of a particular type are quite enough to meet OSHA requirements.

TABLE 1. AVAILABILITY OF *IN SITU** CONTROLS.

In Situ Controls Available at Acceptable Cost	*In Situ* Controls Available but at Unacceptable Cost†	No *In Situ* Controls Available
	Automatic screw machine	
Large and small hand-fed presses	Semi-automatic presses	
	Large roughing planers Small finishing planers	
	Saws (wood and metal)	
	Crawler tractors (>150 hp)	
Automatic molding machine		Manual molding machine
	Spinning frames	
	Twisters	
		Some pneumatic hand tools
	Some draw frames	Most draw frames
		Looms
Automatic shakeouts		Manual shakeouts
Furnaces: crucible cupola electric arc		Induction furnace
Small chippers and hogs	Large chippers and hogs	
Pedestral grinders		
Tumblers		
Knitting machines		

**In situ* controls include changing the acoustical characteristics of the workplace with the use of facility treatments (such as barriers and room absorption), custom designed noise control treatments for the machine (such as partial enclosures, mufflers, damping, and vibration isolation) and retrofit kits from the OEM.

†In a few instances, these machines can be quieted at acceptable costs.

- Some new machines are quiet enough to meet OSHA requirements
- No new machines are quiet enough to meet OSHA requirements.

The category "no new machines are quiet enough to meet OSHA requirements," can be divided into two subcategories with regard to the availability of noise control technology: Noise control technology is available, or it is not available. Table 2 lists new machines in the following categories: all noise-reduced machines, some noise-reduced machines, or no noise-reduced machines. This table contains only those machines for which *in situ* controls are not available or for which they are too expensive. Because we selected for study noisy machines in industries that have chronic noise problems, it is not surprising to find that none of the machine types have been quieted sufficiently that all of the OEMs offer noise-reduced machines. In five of the machine types, one or more of the OEMs provide some versions of their machines that will meet the OSHA standard when operated. Another seven machine types could be quieted to meet OSHA requirements with available technology. Three cannot be quieted with available technology.

We also find that the market demand for new noise-reduced machines is relatively slight in the category where some of these machines are available for purchase. In discussions with both user industries and OEMs, the following reasons have been given for not purchasing noise-reduced machines from the OEM:

- User industry doesn't know about availability of noise-reduced machines.

TABLE 2. AVAILABILITY OF NEW NOISE-REDUCED MACHINES.

All Noise-Reduced* Machines	Some Noise-Reduced* Machines	No Noise-Reduced* Machines: Technology Available	No Noise-Reduced* Machines: Technology Unavailable†
	Automatic screw machines		
		Semi-automatic presses	
	Large roughing and small finishing planers		
	Wood saws	Metal saws	
	Crawler-tractors (>150 hp)		
	Manual (jolt squeeze) molding machine		
		Spinning frames	
		Twisters	
			Some pneumatic hand tools
			Looms
		Draw frames	
		Induction furnaces	
			Manual shakeouts
		Large chippers and hogs	

*The OEM has reduced the noise enough to meet OSHA requirements under normal operations.

†For the machine to be quieted. Some noise reduction is possible through the use of *in situ* controls.

- User industry knows about these machines, but is unwilling to pay additional costs for noise control (crawler tractor [>150 hp], manual [jolt-squeeze] molding machine).
- User industry knows about these machines, is willing to pay, but is unsure of the acoustical results because:
  - User is planning to install the new machine in an existing facility where other noisy machines will continue to cause overexposure (wood saws, automatic screw machines).
  - User has no reliable measurement method and prediction procedure to ensure that once the new machine is operational, the operator's exposure will be in compliance (planers).
- User industry is more interested in production increases, quality control, and reliability than in noise control; thus, when the choice must be made between two machines (one with noise control and one without) industry is most likely to pick the machine with the better production capacity, quality control, and reliability, including the availability of spare parts to the plant (planers, crawler tractors [>150 hp], manual [jolt-squeeze] molding machine).

For those machines where technology is available for quieting machines to meet the OSHA standard, the following reasons have been given to explain why original equipment manufacturers do not design and build quiet machines:

- There is a limited demand for noise control by the user (saws, chippers and hogs).
- There is sufficient demand for the OEM's machines without noise control. New orders for much industrial machinery cannot be filled for 6 to 18 months (planers, metal stamping presses).
- The OEM has limited capital for research, development, and design and currently gets a better return on investment by improving production, reliability, and quality of part produced than by providing noise control. In addition, the OEM does not want to be the first to attempt noise control, since that OEM will go to great expense to develop concepts that will then be used at much less cost by other OEMs (saws, automatic molding machines, draw frames).
- The OEM is often unaware of the availability of the technology, because the technical staff are often not experienced in noise control engineering (metal stamping presses).
- Users are often loyal to a product line because of the availability of spare parts, familiarity with the OEM, and confidence in the OEM; the OEM recognizes that the customer will probably continue to buy from the OEM even if their products are the last to incorporate noise control features (planers, saws, metal stamping presses).
- OEMs are reluctant to invest in noise control because there are no market forecasts indicating that users will buy that feature (automatic molding machines, spinning frames, twisters, metal stamping presses).

- For some machines, neither the user nor the OEM has determined how to specify the noise requirements for a noise-reduced machine.

Table 3 lists the machines meeting the study criteria, presents an estimate of the number of operators who are currently overexposed, and summarizes information on the availability of *in situ* controls, the acceptability of the costs, availability of OEM noise-reduced machines, and availability of technology to the OEM.

3.4 New Machine Regulatory Alternatives

Any estimate of the benefits of regulatory action are directly dependent upon estimates of the turnover rate and the growth rate of the user industries. Research Triangle Institute estimated the stock of machines in place and the U.S. consumption of machines for each of the machines in our study for the years 1986 to 1990. This information is presented in Appendix D as "Industrial Machine Trends". Using the stock of machines in place, the number of machines per operator, and the number of shifts, BBN developed an estimate of the increase in the number of operators from 1986 to 1990; this represents expansion of the user industries. Using the sum of the consumption of machines for the years 1986, 1987, 1988, 1989, and 1990, the number of machines per operator, and the number of shifts, BBN estimated the maximum number of operators that could be impacted if all of the new machines were noise-reduced. This information is summarized in Table 4.

The maximum number of operators that could benefit from new noise-reduced machines was developed, assuming that all new machines will be utilized in new facilities and the operators

TABLE 3. MACHINES MEETING STUDY SCREENING CRITERIA (FILTERS A THROUGH J).

Machine	Current Estimate of Total Operators Overexposed*	Comments
Automatic Screw Machine	21,000	*In situ* controls are too expensive. Noise-reduced machines are available but generally are not sold because of cost.
Semiautomatic Metal Stamping Presses	68,000	*In situ* controls are usually too expensive. Noise-reduced machines are not available but technology is.
Planers	20,000	*In situ* controls are seldom fully utilized because of cost. Noise-reduced versions are available for some applications. Technology is available for most applications.
Wood Saws	183,000	*In situ* controls are too expensive and sometimes interfere with operation of machine. A few quieted saws are available; technology is available.
Metal Saws	70,000	*In situ* controls are too expensive. A few noise reduced saws for limited applications are available; technology is available.
Crawler Tractors (>150 hp)	23,000	No *in situ* controls. Noise-reduced machines are available but large quantities are not sold because of cost, reliability of air conditioning, and industry's reluctance.
Molding Machines	50,000	Single industry; *in situ* controls are not available for manual machines; quieter versions of manual machines are available; no quiet versions of automatic machines, but technology is available.
Spinning Frames	44,000	Single industry; *in situ* controls are not available; no quieted machines, but technology is available.
Twisters	16,000	Single industry; *in situ* controls are not available; no quieted machine but technology is available.

*BBN Estimates based on machinery data and literature survey. Rounded to nearest thousand.

TABLE 4. ESTIMATES OF IMPACT OF GROWTH AND TURNOVER OF NEW MACHINES ON THE NUMBER OF OPERATORS OVEREXPOSED TO NOISE.

Machine	No. of Machines/ Operator[1]	Typical No. of Shifts[1]	Stock of Machines In Place[2]		Increase in No. of Operators 1986 to 1990[3]	Total No. of Machines Purchased For Use in U.S. 1986 to 1990[4]	Potential Maximum No. of Operators Impacted by New Machines[5]
			1986	1990			
Automatic Screw Machine	3	2	33,730	38,256	3,017	14,005	9,337
Metal Stamping Presses	2.5	2	117,900	126,201	6,640	55,665	44,532
Planers	0.67	1	33,924	49,487	23,228	39,067	58,309
Wood Saws	1.3	1	494,500	703,165	160,512	185,111	142,393
Metal Saws	1.6	2	135,048	213,738	98,363	160,246	200,308
Crawler Tractors (>150 hp)	1	1.5	55,658[6]	84,493[6]	43,253	37,677[6]	56,516
Molding Machines	1	2	41,750	57,647	31,794	28,404	56,808
Spinning Frames	4	4	63,208	75,089	11,881	29,014	29,014
Twisters	4	4	44,210	66,921	22,711	23,213	23,213

[1]BBN estimates based on machinery data and literature survey.

[2]RTI estimates from Appendix D, Industrial Machine Trends.

[3] $\left|\frac{\text{Stock of Machines in Place 1990} - \text{Stock of machines in Place 1986}}{\text{No. of Machines/Operator}} \times \text{No. of shifts}\right|$

[4]Sum of U.S. consumption for years 1986, 1987, 1988, 1989, and 1990 from Appendix D.

[5] $\left|\frac{\text{Total U.S. Consumption}}{\text{No. Machines/Operator}} \times \text{No. of shifts}\right|$

[6]BBN estimates for crawler tractors (>150 hp) using RTI's estimates of growth and turnover.

will not be exposed to noise from other more noisy machines. Although some of the machines will go into such new facilities, some will also go into existing (noisier) facilities. We have no precise way to estimate the percentage of new quiet machines that will go into new facilities or into older facilities where noise has been controlled. The column "Increase in Number of Operators" in Table 4 represents expansion of the industry. These operators are likely to be operating new noise-reduced machines. Thus, this figure represents a minimum estimate of the number of operators that will be operating noise-reduced machines, except for the instance where the "Increase" figure is greater than the "Maximum" figure. This occurs for wood saws. One explanation of this inconsistency is that the user industries have excess capacity, and some of the new operators will be operating older machinery. A more likely explanation is that the differences are due to the large confidence intervals of the input data for the lumber and wood industry. For this case the "Maximum" figure would appear to be the best estimate of the number of operators that could benefit. Table 5 summarizes the number of operators that could benefit from the introduction of quiet machines into the workplace. Minimum, maximum, and best-guess estimates are presented. The best-guess estimates are made recognizing that some of the new machines will go into noisy enviornments. As noted in Appendix D, the estimates are most reliable for the metalworking industry, less reliable for the textile industry, and least reliable for the lumber and wood industry.

Another consideration with regard to growth rate and turnover rate is that much of the U.S. capital stock is older than that of other nations. With the current political, economic, and military climates, it is likely that many segments of

TABLE 5. ESTIMATES OF THE NUMBER OF OPERATORS THAT CAN BENEFIT FROM THE INTRODUCTION OF NOISE-REDUCED MACHINES INTO THE WORKPLACE.

Machine	Minimum*	Maximum*	Best Guess
Automatic Screw Machine	3,000	9,300	7,000
Metal Stamping Presses	6,600	44,500	20,000
Planers	23,200	58,300	35,000
Saws, wood	142,400	142,400	142,400
Saws, metal	98,400	200,300	140,000
Crawler Tractors (>150 hp)	43,300	56,500	50,000
Molding Machines	31,800	56,800	38,000
Spinning Frames	11,900	29,000	20,000
Twisters	22,700	23,200	23,000
Total	362,800	620,400	475,400

*Rounded

American industry will go through a major rebuilding and renewal process within the next two decades. The end result of such actions would be to increase significantly the turnover rate of old machines, replacing them with more modern, efficient machines. If a regulatory program for industrial machine noise emissions were in effect at that time, significant benefits could be derived from such action, assuming that the cost associated with complying with the regulation did not significantly alter the purchasing plans.

3.4.1 Potential benefits of Section 6 regulation

On the basis of the analysis presented in the previous section, we find that the promulgation of not-to-exceed noise emissions regulations for these machines could bring relief to roughly one-half million of the operators of the machines in the time frame from 1986 to 1990. Because industrial machinery lasts for many years, not all of the operators of this type of machinery will be benefited before two to three decades, depending on the growth rate.

In addition to providing benefit to the operators of new machines, the development of noise-reduced machines by the OEM will introduce the OEM to the concepts of noise control. As a result of having staff with skills in noise control engineering, we think the OEM will develop retrofit kits for many of their machines already in service. If the OEM were to develop such retrofit kits, it is likely that their cost could be low enough to bring down the total cost of noise control per worker to more acceptable values so that OSHA could enforce retrofit. Under these circumstances, the operators of existing machines could be benefited in a time period shorter than otherwise possible.

3.4.2 Potential benefits of Section 8 regulation

The promulgation of labeling requirements (either mandatory or voluntary) pursuant to Section 8 may result in a reduction of noise impact. However, there are no scientific methods available for estimating the benefits. This reduction could occur as a result of the user purchasing the quietest machine offered for sale. In addition, the user could use the noise emissions information to predict the noise levels in the plant and, as a result, the user could design noise control features into the new facility. Additionally, OSHA could make use of labeled machinery both in assessing the degree of compliance within a plant and in developing agreements with companies or industries on the solution of noise problems by the time-phased replacement of noisy machines with quiet machines.

In discussions with users, we have learned that many would like to have such information available. However, in most cases there has not been sufficient incentive for the users or the OEM to develop measurement standards that enable the OEM to measure the noise of the machine and the exposure of the worker under some "standard" operating conditions. In addition, no supporting documentation exists to enable the user to use the reported measurements to estimate the noise that will be generated when the machine is operated in his plant under different operating conditions. The development of adequate measurement standards will require extensive effort and cooperative interaction between both OEM and industries, government, and experienced noise control engineers.

If machines were labeled according to Section 8, would such labeling provide workers with greater awareness of the adverse effects of noise and thus encourage more diligent use of personal hearing protection devices? There is little scientific evidence to substantiate a position on whether or not such labeling would be effective. In general, labels warning of imminent dangers seem to be more effective than labels warning of potential or future hazards. For example, a label warning the punch press operator not to put his hands in the die would probably be heeded more than a label warning that the noise generated by the punch press could have specific adverse effects on the operator if he did not wear hearing protection.

Theoretically, the availability of noise emission information to the worker should be of some benefit. Whether an EPA label would result in a higher degree of awareness on the part of the worker depends upon whether the workers are already aware of the hazard and whether they believe, and understand, what they are told. We think that, by now, most workers are aware that there is a concern about workplace noise exposure. Douglas Frazier, President of the UAW, testified that more complaints are received about noise in the workplace than about any other occupational hazard [17]. Signs are posted in many noisy areas requiring workers to wear hearing protection while in the area. To the extent that noisy areas are not labeled and workers are otherwise unaware of the hazard, an EPA label can benefit. Although no definitive information exists, we think noisy areas are generally posted.

Do workers believe and understand the nature of the hazard? On the basis of our observations of workers' use of hearing protectors, we suspect that few workers either believe what they are told or fully understand the hazards involved, since many workers either do not wear hearing protectors or wear them improperly. Hearing protectors seem to be worn more frequently in plants with strict enforcement policies than in plants without such policies. A strict enforcement policy is a form of educating the employee about the hazards of noise. Other forms of training and education might also accomplish this same objective. An EPA label could be one element of this training and education and could result in a higher degree of awareness by the worker.

Would this higher degree of awareness result in more diligent use of hearing protectors? If the label contained information about the need to wear hearing protectors (as well as information about the noise emissions of the machine), we think workers would be more likely to wear protectors than without such information. Clearly, training and education about the hazards of noise and incentives to wear the protectors will be useful additions to such a label. Disincentives, such as uncomfortable protectors, should be removed.

If machinery were labeled by the OEM, users would probably take additional steps to ensure that the company's liability with regard to future compensation claims is minimized. Such steps might include a stricter enforcement policy and periodical screening of workers by means of audiometric testing.

3.4.3 Consideration of alternative types of source emission regulations

The certainty of benefits is greatest with a Section 6 regulation, less with a mandatory labeling regulation, and least with a voluntary labeling program. However, it is not clear that the rate at which total benefits are achieved is proportional to this order, because of finite limitations on regulatory resources.

The nine machines that met the criteria in this study for potential source regulation probably represent only a small fraction of the total number of machines for which noise control is possible only through new machines or retrofit kits. The majority of these machine types vary significantly in size and application, factors that must be considered in developing meaningful measurement procedures for any of these three regulatory alternatives. These same factors further confound the determination of compliance with a Section 6 emission limit regulation. Thus, for a specified dedication of regulatory effort, we can anticipate that more machines could be covered per year by a Section 8 labeling approach than by a Section 6 emission limit approach.

Table 6 summarizes the necessary steps in developing Section 6 and Section 8 regulations. We observe that one of the alternatives open to EPA is to begin the regulation with a voluntary Section 8 labeling program, alerting industry to the possibility that a Section 8 mandatory labeling or a Section 6 not-to-exceed emissions regulation will follow unless industry is responsive to the voluntary program. This program could be coupled with some of the alternatives discussed in the following section.

3.5 Alternative Options

In addition to or instead of Section 6 or Section 8 regulations, there are other alternative options for reducing the

TABLE 6. PROCESSES NECESSARY FOR REGULATING INDUSTRIAL MACHINERY.

Item	Section 6	Section 8	
		Mandatory	Voluntary
Measurement criteria and procedures	✓	✓	✓
Technology studies	✓		
Economic studies	✓		
Regulatory analyses	✓		

exposure of workers to hazardous levels of noise when *in situ* controls are inapplicable. The following concepts will be discussed in this section:

- OSHA New Machine/Plant Policy
- Economic Incentives
- Education and Training
- Demonstrations
- Research and Development.

3.5.1 OSHA new machine/plant policy

In some of the OSHA investigations of the noise exposures of workers in industries that we studied in this program, the cost of *in situ* controls was found to be above the $8,000-per-worker-protected limit used by OSHA to determine the acceptability of cost. In most of these situations, the solution was to require a hearing conservation program in lieu of engineering controls. Usually, no further action is required on the part of the local plant or the corporation. Thus, for example, when a screw machine plant expands or when the corporation builds a new plant, there is no requirement to purchase automatic screw machines that meet the OSHA noise standard. The opportunity presented by the citation and possible OSHRC hearing could be an ideal time to work out an agreement with the local plant and the corporation that the next time a new automatic screw machine is purchased for the local plant or a new facility is planned, the plant will purchase noise-reduced machines – paying the necessary premiums for the machines. Such a policy would enhance the market for noise-reduced machines, probably lowering their relative cost, and accelerate the rate of compliance and its protection of the workers.

3.5.2 Economic incentives

One of the major reasons workers are still overexposed to noise in industry was found to be cost. The industries using the nine machines meeting the study criteria could be encouraged to comply with the standard and/or to introduce new machines into the workplace through economic incentives or penalties. The following economic penalties could be modified to accelerate the introduction of these machines into the workplace.

- Unions sometimes demand higher pay for hazardous exposure to noise. A measure similar to the minimum-wage requirement, but designed for hazardous work, could be established.
- Hearing loss claims are likely to continue to increase in size and total dollars expended. Federal and state governments could develop consistent legislation for compensation.
- OSHA fines could be increased and made equal to the cost of the noise control treatments, and then the plant could be required to comply in addition to paying the fine. It is unlikely that the OSHRC would support this approach.

Economic incentives could include:

- Accelerated depreciation schedules that would enable the industry to write off the costs more quickly than is currently allowed. The limit in this approach would be to allow the corporation to write off the total cost of OSHA compliance as an expense during the year the expenditures occur.
- Tax credits that would be applied against the income tax of the corporation. Such tax credits appear to be possible in the area of environmental pollution control.

- Innovation and productivity and noise control. During our discussions with both OEMs and users of automatic screw machines, productivity increases as a result of noise control treatments have been reported. Innovation centers to be funded by the Department of Commerce and the National Academy of Science should be encouraged to investigate the potential of productivity increases through noise control.

Clearly, incentives, rather than penalties, are more likely to produce the desired result of more quiet machines in the workplace.

3.5.3 Education and training

Many employees and employers do not understand the hazards of exposure to noise or the means available to control worker exposure through engineering controls or hearing conservation. OSHA has made some progress with consultation programs [*18*]. In these programs, industrial plants can receive a free consultation from an OSHA contractor. The contractor issues a report identifying the occupational safety and health hazards found during the consultation visit. In addition, suggestions are made for controlling the hazards. Contractors make follow-up visits to ensure that the employer has made the necessary modifications. No evaluation of the effectiveness of these programs has been made to date.

OSHA has also attempted to communicate with workers through various OSHA-sponsored programs. As with the consultation programs, emphasis is placed on all of the occupational safety and health hazards. As a result, noise control and hearing conservation are often not given much emphasis.

3.5.4 Research, development, and demonstration projects

When technology is not available to quiet new machines to meet the OSHA noise standard, additional effort is required, either to develop new ways to apply noise control engineering principles to conventional machine designs, or to develop unconventional machine designs, including application of entirely new processes. In either event, it is unlikely that fundamental research in acoustics is required to obtain an engineering understanding of noise source mechanisms, radiation, and interactions.

To quiet the conventional machine (for example, semiautomatic presses), redesigns of various noisy parts or functions of the machine may be required, based on sophisticated technical analysis coupled with practical engineering know-how, so that the new design can accomplish its function and incorporate the required noise control. In instances requiring the development of new unconventional machines (for example, looms), the noise control requirement should be made one of the objectives of an R and D program for a significant productivity breakthrough. Both of these situations offer opportunities for innovative federal R and D programs to lead to a more productive and "quiet" industry in the United States.

In earlier sections of this report, we have discussed situations where technology is available for designing quiet machines but where, for various reasons, OEMs have not developed such machines and are unlikely to develop them without outside motivation and assistance. Examples of outside assistance to an industry experiencing difficulty in complying with a noise standard are the Bureau of Mines demonstration programs. Although focused on developing retrofit techniques to control the noise, the programs illustrate the necessary ingredients for a successful program. The Bureau contracts with a noise control engineering firm and the OEM and helps to arrange for close cooperation between the manufacturers and the coal mines. This partnership in a cooperative relationship among the machine designers, the noise control engineers, and the users can be most effective. As concepts for noise control are developed, the manufacturers and coal mines can comment immediately upon the impact of such ideas. To the extent that lack of funds and motivation prevent development of quiet machines, an EPA demonstration program showing how available technology can be incorporated into a machine will be useful.

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APPENDIX A

STUDY CRITERIA TAKEN FROM EPA RFP WA 78-C297 (FILTERS)

a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

b. The degree of difficulty user industries presently encounter in meeting an eight (8) hour 90 dBA* environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit to continued production of their products without correction of the noise violation.

c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which insitu retrofit noise control is not possible or can only be achieved at extraordinary expense.

d. The commonality of a major noise producing piece of equipment to multiple industries or production processes.

e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed by the OSHA formula.

f. On a national basis a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type of class and thus would realize direct benefit from noise reduction actions on this specific device.

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*The level of 90 dBA is intended as a screening tool in this program to ascertain the worse cases of worker exposures. It is not to be interpreted as an EPA endorsement of this level for the future OSHA worker standard nor a prediction by EPA of OSHA's final decision on an appropriate level.

g. The extent to which hearing protective devices are required while operating or working in proximity to the selected machines and the general worker response to this protective measure. Of particular note should be those factors which would lead to employee nonuse, or intermittent use of hearing protective devices because of the need to verbally communicate with one another, discern audible signals in the performance of their jobs, or the fact that nonnoise environmental conditions i.e. dust, temperatures, moisture content, etc., result in physical discomfort from continued use of hearing protective devices.

h. The first owner life of the identified machining is relatively short, machine designs do not reflect currently available noise control features, existing industry/ manufacturing process plans indicate an increase in demand for the selected machines or other factors which might be used as indicators of increased noise impact in terms of severity and/or extensiveness through increases in machine population.

i. There are currently available quieted versions of the selected machine which are capable of meeting an eight (8) hour 90 dBA noise level requirement but for specific reasons (to be determined) by contractor do not make up a large percentage of machines currently in use or being sold.

j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

k. The promulgation of a not-to-exceed noise emission regulation pursuant to Section 6 of the Noise Control Act would in all likelihood bring relief to the exposed worker population within a period of five years.

l. The promulgation of noise labeling requirements pursuant to Section 8 of the Act, would, for the selected machines result in a reduction of noise impact on a portion of the presently exposed work force either as a result of consideration of the noise emission properties in the selection of the particular machines or in the choice of its location within a given plant layout. The Contractor should determine in detail why this information is not now available to purchasers and plant layout planners.

m. The availability of noise level information to the operator and peripheral workers in the form of noise emission labels, would result in a higher degree of awareness to the adverse effects of noise and thus encourage diligent use of personal hearing protection devices.

APPENDIX B
SUMMARY OF NOISE-RELATED INSPECTIONS BY OSHA

SUMMARY OF NOISE RELATED INSPECTIONS BY OSHA (July 1972 – April 1979).

No.	SIC	No. Inspections	Violation Rate	Industry
1	3300-3399	3,992	41 %	Primary Metal
2	2400-2499	4,727	36	Lumber & Wood
3	2211-2299	1,456	25	Textile
4	3400-3499	8,378	25	Fabricated Metal
5	3000-3079	2,633	25	Rubber
6	3110-3199	677	24	Leather
7	2600-2661	2,135	24	Paper & Allied Products
8	3200-3299	2,658	23	Stone, Clay, Glass & Conc.
9	2010-2099	4,415	22	Food & Kindred Products
10	3710-3799	2,860	20	Transportation Equipment
11	3612-3699	2,763	18	Electrical & Electronic Equip.
12	2911-2999	351	17	Petroleum
13	3911-3999	1,708	16	Misc. Manufacturers Industry
14	2500-2599	2,123	16	Furniture
15	2800-2899	2,032	14	Chemicals & Allied Products
16	2710-2795	1,337	13	Printing, Publishing
17	3511-3599	5,773	13	Machinery, Except Electrical
18	1011-1499	334	11	Metal Mining
19	3811-3873	712	10	Instruments
20	4910-4961	262	9	Electric, Gas & Sanitary
21	9199-9999	14	7	Exec. Legislature & Gen. Govt.
22	7620-7699	454	7	Misc. Repair Services
23	6311-6331	16	6	Insurance
24	5910-5999	168	5	Misc. Retail
25	5611-5699	43	5	Apparel & Accessory Stores
26	6510-6553	44	4	Real Estate
27	5110-5199	1,139	4	Wholesale Trade (Durable)
28	5010-5099	1,781	4	Wholesale Trade (Non-Durable)

SUMMARY OF NOISE RELATED INSPECTIONS BY OSHA (July 1972 – April 1979) *(Cont.)*

No.	SIC	No. Inspections	Violation Rate	Industry
29	7300-7399	324	3 %	Business Services
30	4000-4899	2,099	3	Railroad Transportation
31	1500-1799	4,166	3	Construction
32	7510-7549	768	3	Auto Repair Service & Garage
33	2311-2399	989	3	Apparel
34	0000-0913	436	3	Agriculture, Forestry & Fishing
35	5210-5271	647	2	Building Materials (Retail Trade)
36	8010-8999	376	2	Health Serv., Legal Serv., etc.
37	7920-7999	106	1	Amusement & Recreation Serv.
38	5800-5813	131	1	Eating & Drinking
39	5410-5499	572	1	Food stores
40	5510-5590	1,738	< .5	Auto Dealers & Gas. Serv. Sta.
41	7210-7299	311	< .5	Personal Services
42	5310-5399	364	< .5	General Merchandise Stores
43	2111-2141	30	0	Tobacco
44	5710-5733	111	0	Furniture, Home Furnishings, and Equipment Stores
45	6011-6794	43	0	Finance, Insurance, and Real Estate
46	7010-8111	168	0	Services
	Total	68,907	18	

APPENDIX C

Appendices C.1 through C.19 summarize the information about each of the studied machines, in response to Filters a, b, c, d, e, f, i, and j.

APPENDIX C.1
ANALYSIS OF AUTOMATIC SCREW MACHINES

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- Articles on screw machine noise date back to 1955; vendors have been selling noise controls ("quiet stock tubes") since the 1950s (see attached bibliography).
- OSHA violation rate in principal user industry (SIC 345, Screw Machine Products) is 38%, based on 555 inspections.
- Manufacturers have been working on problem since the early 1970s.

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- Although the user industry and the OEMs have been working on the problems, the user industry still experiences difficulty in complying with the standard.

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE

- These machines are typically lined up in rows; however, in some smaller user companies they may be interspersed or located in the midst of other noisy equipment such as grinders, presses, etc.
- Individual machine noise emissions usually dominate local noise environments, but reverberant levels are also important.
- Operators generally tend several machines simultaneously (average is about 3 mach/worker, but single worker may tend up to 8 machines on occasion).
- Machine noise sources are (1) stock rattling inside stock carrier, (2) cutting noise, (3) drive train (including gearing).
- Davenport, National Acme both sell retrofit kits which reduce noise to below 90 dB(A).
- Davenport has sold 1000 kits (to 4/79) at cost of $4000/machine ($5721 with oil control conversion – present cost is $6044).

- Only two cases of the more than 200 OSHRC decisions concerned screw machines: 13490 (KLI, Inc.) which was contested on economic feasibility grounds ($11,200/employee to quiet 14 machines), awaiting final ruling; 78-5910-E (IBEW Local 1031 — Stewart Warner), for which economic and technical feasibility for controls were established.
- The cost per worker can exceed the $8000/worker OSHA limit and thus these treatments can be considered extraordinarily expensive.

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries of production processes.

RESPONSE

The 12th Annual *American Machinist Inventory* (AMI) reports that the automatic screw machines are used in the following industries:

SIC Code		No. of Machines
25		40
33		856
34		25,641
35		17,573
36		4,778
37		7,060
38		6,186
39		598
	Total	62,732

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 DBA* as computed by the OSHA formula.

RESPONSE

- The noise exposure of automatic screw machine operators is caused entirely by screw machines in most environments, particularly for large companies.
- If the noise levels of the automatic screw machine were reduced, the exposure of these operators would be brought into compliance.

FILTER f. On a national basis a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE

- The Department of Commerce, Bureau of the Census, Occupation by Industry for 1970 includes screw machine operators under category of precision machinery operatives, for which there are 4872 workers.
- According to 12th AMI, there are 62,732 screw machines in the metalworking industry. Assuming three machines per worker, there should be at least 20,900 screw machine operators.

- Few peripheral workers should be impacted.

FILTER g. Not considered for each machine.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE

- Large companies specify noise emissions for new equipment; small companies generally do not, but OEMs report that more small companies seem to be specifying not-to-exceed limits.
- Brown and Sharp and Cone/Blanchard sell machines with noise reduction incorporated into the machine.
- Roughly 25 to 35% of Davenport's sales are for versions with noise control incorporated.
- More of these machines are not purchased because the user company installs the new machine in a noisy area; the workers cannot "hear" the new machine and thus they leave noise control panels open. OEMs also report that users' management is generally lax about enforcing operation with noise controls in place.

- OEMs also report that some users have indicated that they accomplish a small productivity increase as a result of using quieter machinery.

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE

- Currently available technology has been applied by the OEM.

BIBLIOGRAPHY FOR AUTOMATIC SCREW MACHINES

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Sandford, J.E., "Industry's Quiet Rush to Silence," Iron Age 12/16/71, pp. 78-78 (mentions enclosure produces 18 dBA noise reduction from 108 to 80 dBA — no specifics).

Hall, A., "Plastics put the Damper on Noise," *Modern Plastics*, Vol. 49, No. 7, 7/72, pp. 42-45 (mentions stock tubes replaced with proprietary plastic bought from Commercial Plastics and Supply Co., Baltimore — reduces noise 6-16 dB).

Schweitzer, B.J., "A Silent Stock Tube for Automatic Screw Machines," *Noise Control*, March 1956, pp. 14-17 (describes lab and field noise reduction obtainable for single spindle machines by using Corlett-Turner Co., Chicago, CT Silent Stock Tubes; field-obtained noise reductions restricted to 1000 Hz and above because of noise from other machine sources).

Lee, G.L. *et al.*, "The Control of Noise Produced by Bar Automatic Lathe," *Ann. Occupational Hygiene*, Vol. 14 (1971), pp. 337-343 (describes exposure with and noise reduction from 96-110 dBA to 87-92 dBA by using nylon liners. Undefined octave band noise reduction for nylon lined tubes compared with commercially available quiet feed stock tubes.

Bourne, J.C., "Noise Control Hood for the Davenport Automatic," *Sound and Vibration*, Nov. 1974, pp. 22-27 (describes development and features of integral machine enclosure and its effectiveness in quieting the machine).

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Hart, F.D., "Industrial Noise Control: Some Case Histories," Vol. 1, NTIS N75 19472, 1974.

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Meteer, C.L., "Workable Solutions to Common Machinery Noise Problems," *Pol. Eng.*, January 1974, pp. 43-45 (approaches for noise due to turret lathes. Suggests 80-90% of screw machine problems can be solved via 5 approaches: partial enclosure of cutting area and/or stock tubes, damp gear housing and machine panels, damp stock tubes, vibrationally isolate lathe).

Not reviewed:

"Noise Reduction of an Acoustical Stock Tube for Screw Machine," Report No. 1, Chicago Illinois Institute of Tech., 1955 (no copy is available).

APPENDIX C.2

ANALYSIS OF METAL STAMPING PRESSES

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE All available information on mechanical stamping presses indicates that such machines create worker exposures that are in chronic violation of present OSHA standards. At least 50% of the presses in the metalworking industries, about 135,000 presses, are responsible for causing OSHA violations. Most of these machines are semiautomatic presses for mechanical stamping.

OSHA has quantitative data on chronic violation of the OSHA noise standard. The data are in the form of violation rates of different manufacturing industries. These rates are based on the number of inspection visits and noise citations issued for each industry, listed by SIC code, during the past seven years. Table 1 summarizes the data for eight metalworking industries, which together use about 78.2% of the total of mechanical presses.* The table shows a comparison of the violation rates in those industries to the range and mean violation rates for industry as a whole.

*The figure of 78.2% is for all metalforming tools estimated in the *12th American Machinist Inventory*, McGraw-Hill Inc., 1978, to be in the metalworking industry. We assume the same percentage applies to presses as a category of metalforming tool.

TABLE 1. NOISE STANDARD VIOLATION RATES FOR EIGHT METALWORKING INDUSTRIES.

SIC	No. of Mechanical Presses*	Violation Rate (%)†
Range for all Manufacturing Industries		0 – 41
Mean of Range		18
25 (Metal furniture)	8,804	16
33 (Primary metals)	6,851	41
34 (Metal fabrication)	103,961	25
346 (Forgings and Stampings)	39,000	31
35 (Machinery, except electrical)	29,100	13
36 (Electrical machinery)	43,115	18
37 (Transportation equipment)	24,000	20
38 (Measuring equipment)	6,407	10
39 (Misc. mfg. industries)	8,423	16
Total for Metalworking Industries	230,661	

**12th American Machinist Inventory*, McGraw-Hill, Inc., 1978, not including presses in plants employing under 20 workers (roughly 5% of the total plants and 5% of the total employees).

†Noise-Related Inspections, July 1972 – April 1979, OSHA. The violation rate is the number of citations divided by the number of inspections. These data are only for industries with more than 100 inspections.

These data suggest that press user industries, especially SICs 33, 34, and 37, do have problems in complying with the OSHA standard. However, the data do not give us a complete picture of the problems in these industries. For example, the information tells us neither which machines in the industries cause the noise problem (because there are many categories of noisy equipment used in these industries in addition to presses), nor the real incidence of noise problems (OSHA inspectors do not always investigate entire plants). Nevertheless, the consensus among all consultants and industry members familiar with presses is that the noise problem associated with mechanical stamping presses is pervasive and long-standing. This conclusion is based on expert opinion of noise consultants (BBN and others) and the opinion of industry experts expressed at regulatory hearings, in articles, and in private communications. In addition, there is a much visible activity concerning press noise, including:

- Widespread recognition that the punch press causes workplace noise problems, demonstrated by the fact that research programs specifically addressing press noise have been supported worldwide (nine foreign programs, one in the U.S.)
- Industry-sponsored research programs (ORC plus others not made public)
- Articles on the topic (more articles are written about presses that about any other single category of tended equipment)
- Attempts by noise control product vendors and press manufacturers to market devices specifically to control press noise.

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour (8) 90-dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- Industries that use mechanical stamping presses encounter serious difficulties in meeting the 8-hr, 90-dB(A) OSHA noise standard. The major difficulties are the high implementation costs of available treatments and the complexity of the treatments needed to correct noise problems. Assuming that no change occurs in the conditions that might influence the installation of engineered controls, we estimate users will quiet only small numbers of presses to meet OSHA requirements.
- In public statements, private sector industries express difficulty in bringing stamping presses into compliance with OSHA standards. Many of these difficulties have been expressed at DOL hearings. The claims range from complaints that the advice from noise control experts doesn't work to statements that implementing controls would be so expensive it would put firms out of business. Although not all the claims are equally valid, we conclude that many of the industry's fears about the effects of these costs on their operations are well founded, and that they often cannot afford the costs associated with reducing noise.

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE To analyze press noise problems, we have established three categories of press types: These are:

- Large hand-fed presses (300 tons and over), which usually do not cause a violation of OSHA noise standards, but can cause a violation if they are in disrepair and can contribute to a violation if they are used in conjunction with other presses or noisy auxiliary operations
- Small hand-fed presses (under 300 tons), which usually do not cause a violation of OSHA noise standards, but can contribute to a violation if they are used in conjunction with other presses or noisy auxiliary operations
- Semiautomatic presses (of all capacities), which often cause OSHA problems.

None of the published statistical data on number of presses breaks down the numbers by these press categories. We do not have published data, for example, on how many "gap" presses fall into the small hand-fed class or into the semiautomatic class. On the basis of a general review of about 50 separate studies performed by BBN involving mechanical stamping presses in all kinds of plants, we estimate that the distribution of press classes is as follows:

large hand-fed presses	10%
small hand-fed presses	30%
semiautomatic presses	60%

Until further analysis is performed, we will assume that this distribution applies throughout the user industries. In Table 2, we combine the assumed distribution of press types with other information to produce an estimate of the total number of presses capable of causing an OSHA noise violation.

TABLE 2. ESTIMATES OF PRESSES CAUSING OSHA NOISE PROBLEMS.

Press Category	% of Total[1]	Number of Press Type[2]	Estimated Likelihood of Violating OSHA Standard	Estimated Number of Presses Capable of Causing OSHA Noise Problems[5]
Large hand-fed[5]	10	23,066	50%[3]	11,533
Small hand-fed[5]	30	69,198	25%[3]	17,300
Semiautomatic[5]	60	138,397	76.8%[4]	106,288
Total	100	230,661	135,121 of 230,661 = 58.6%	

[1] BBN estimate.

[2] Total is from the *12th American Machinist Inventory*, McGraw-Hill, Inc., 1978, and is only for the metalworking industry sector; it does not include small facilities in that sector.

[3] Includes either exposure to continuous noise or to impulsive noise.

[4] Developed from data in "Noise in Press Shops," A.G. Herbert, *Inter-Noise 79*, pp. 309-313.

[5] In metalworking industries.

Noise levels attributable to semiautomatic press operations range from 90 to 110 dB(A). Both kinds of hand-fed presses are quieter than semiautomatic presses, usually ranging from 85 to 95 dB(A) when measured isolated from the noise of surrounding equipment.*

The best published source of data on the noise of presses is a recent British survey† of press noise in 25 different large-press facilities. This paper presents the distribution of sound level by the number of presses. The energy mean of the distribution is 99 dB(A) and the arithmetic mean is 96 dB(A) (see Fig. 1). The article does not identify the press types investigated. The results reported, however, are consistent with our experience if we assume that the lower levels reported are measures of hand-fed press noise and the higher levels measures of semi-automatic press noise.

There is little other published information on worker exposure to punch press noise, and the available data do not include all types of semiautomatic presses.

Approximately 78% of all stamping presses are used in plants employing more than 50 people. In these large operations, presses are usually segregated from other kinds of operations and machines, so that the only noise present is from the presses and from

*These ranges are in terms of L_{OSHA} values. L_{eq} values for press noises will be higher than when measured in accordance with OSHA, by 0 to 3 dB for semiautomatic presses (which emit essentially continuous noise), and by more than 3 dB for hand-fed presses (which emit more impulsive noises).

†Herbert, A.G., "Noise in Press Shops," *Inter-Noise 79*, pp. 309-313.

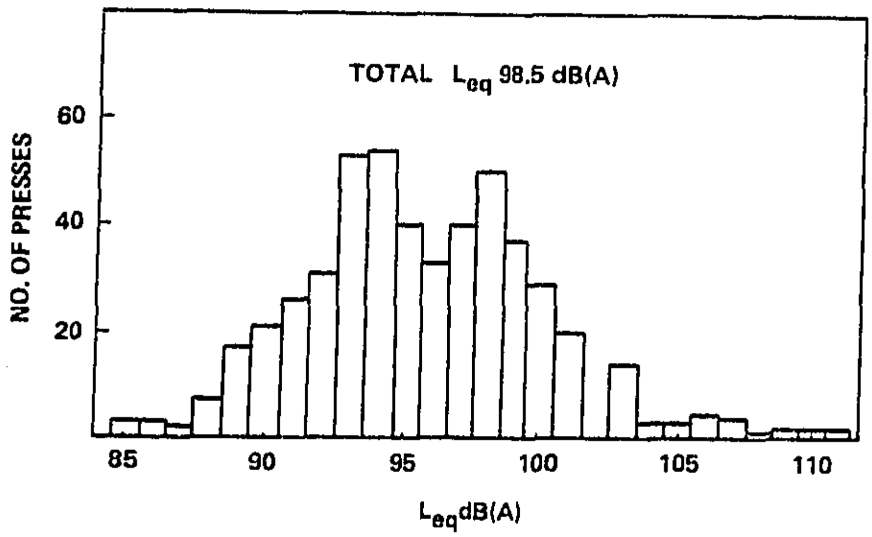

FIG. 1. DISTRIBUTION OF PRESS NOISE LEVELS.

peripheral support equipment, primarily conveyors and occasionally HVAC equipment. In most cases, only the press noise is significant. Thus, we can conclude that presses, as a single type of class of machines, are the principal cause of the OSHA noise violations in large operations. The 22% of presses in smaller plants are in situations ranging from those in which press noise is the only important noise to those in which it is only one of many noises.

As discussed below, we estimate that only 20,295 of the total of 135,121 presses can be controlled with *in situ* controls. The remaining 114,826 can be controlled only at extraordinary expense.

Following is a detailed analysis, for each press type, of (1) the kinds of noise controls available to the user to bring his plant into compliance with OSHA standards, and (2) the feasibility of implementing these controls. Cost is a key factor in determining feasibility of implementation of controls. In this analysis, over 240 OSHRC decisions about contested noise vibrations were examined. Of these, 14 are press noise violations. According to the record, economic feasibility is apparently determined on a case-by-casis basis. The cases studied indicate that controls costing between $3000 and $8000* per benefited production worker will probably be considered economically feasible in most instances.

*Recent discussions with OSHA personnel indicate that the OSHA solicitor will drop the citation in any case where the cost is greater than $8000 per benefited production worker.

Semiautomatic Presses

Semiautomatic presses *in the metalworking industry* have noise problems because of sounds in the immediate vicinity of the die/workpiece point of interaction. Other parts of the press or ancillary equipment contribute less noise to press operations. To solve the noise problem, users must first control die-area noise. However, control of the die area alone will provide only small amounts of noise reduction, approaching an average of 4 dB for typical user-designed and installed die-bed enclosures.* Only 35,423† semiautomatic presses have a noise level of 94 dB(A) or less, and therefore, only these could be brought into compliance by die-bed enclosures alone.

Regarding the presses for which die-bed enclosures might solve the noise problem, the following analysis applies. The die-bed enclosure is a treatment that surrounds the die area and is attached to the press. Effective die-bed enclosures have cost around $3,000 each.** We estimate they could solve the problem

*6 dB or more if fully integrated with the basic press design. Because the user must deal with the press as furnished by the supplier, he must usually compromise some noise control feature in order to fit it to the press or get the press to function with the noise control feature in place.

†Developed from data in "Noise in Press Shops," A.G. Herbert, *Inter-Noise 79*, pp. 309-313.

**This is a typical installed-cost figure for our clients that have built them, and the cost includes the design work done by the user and supervised by us. Somewhat higher costs would be incurred by users who do not have the in-house capacity to do the design work. The cost does not include prototype development which might be needed by facilities unfamiliar with retrofitting acoustic designs.

for close to 100% of the cases marginally in violation. We also estimate that only about 10% of press noise problems will be solved in this way. Most press users will not install die-bed enclosures for the following reasons:

- The treatment must be custom-designed to each model of the press line. Many users, especially smaller facilities, will probably be unable to transfer the concept effectively from available case histories to hardware design. They will have to incur the costs and uncertainties of a treatment development program in addition to the costs of implementation.
- Current published data are insufficient to provide adequate information about the effectiveness of such controls. Therefore, plant engineers cannot convince their managers that expenditures for these controls are worthwhile.
- Because of limited publicity about the availability of noise controls, small plants, and even some larger ones, may be unaware that this technology exists.
- Since the die-bed enclosure treatment is usually not sufficient to reduce the exposure to an OSHA-acceptable level, users may be unwilling to consider it.

Regarding the presses for which a die-bed enclosure is an inadequate noise control, the following analysis applies. In addition to the die-bed area noise, there will be excessive noise caused chiefly by vibrations of the entire press structure, imparted to the press frame by impacts in the die area and along other parts of the ram drive train. Noise of the pneumatic exhausts or parts ejectors, or of the feed mechanism or clutch/brake assembly might also cause excessive noise. Sufficient control of remaining noise can only be achieved by modifying the basic press components or by enclosing the entire press. Ruling out modifications as a form of control to be attempted by the press user, estimating the difficulty of meeting noise standards for semiautomatic presses entails an evaluation of the feasibility of total enclosure.

Most users, we believe, would admit to the technical feasibility of total enclosures, but the available data suggest that few would be willing to admit to the economic feasibility of such a treatment.

Assuming that additional plant space is not needed, total enclosures initially cost between $2,600 and $19,000, depending on press size, and they average about $10,000 each. There are additional, lesser, recurring costs from reduced productivity caused by the presence of the enclosure. Assuming that presses usually operate over two shifts and one worker runs about 2.5 presses on average,* this works out to about $12,500 per benefited worker. This figure is greater than typical figures that the courts have decided are economically feasible.

*Based on BBN data.

On the basis of this analysis of possible treatments for semiautomatic presses, we conclude that no more than 10% (10,629) of the semiautomatic presses will be quieted with total enclosures. Of the 35,423 semiautomatic presses with marginal [94 dB(A)or lower] noise problems, no more than 10% will be quieted with die-bed enclosures. Thus, a total of 14,171 semi-automatic presses will be quieted, leaving 92,117 unquieted. Table 3 summarizes our estimates for the number of presses that will be quieted.

TABLE 3. ESTIMATE OF NUMBER OF PRESSES TO BE BROUGHT INTO COMPLIANCE.

	Number Causing Problem	Number Likely to be Brought into Compliance
Semiautomatic presses	106,288	14,171
Small hand-fed presses	17,300	5,124
Large hand-fed presses	11,533	1,000
Total	135,121	20,295

Small Hand-fed Presses

Small hand-fed presses cause OSHA noise problems when: (1) They are used in a mass-production operation in which the cyclic noise of the press occurs often, and (2) the cyclic noise is at a relatively high level. We estimate that these two factors combine in 25% of the instances of small hand-fed press use for about 17,300 presses. The high noise levels of these presses may be due to clutch and brake impacts, die impacts, pneumatic exhausts, or parts ejectors.

If the press is small, the operator is usually seated in front of the machine. Exposure to die noise from the worker's own press can be reduced by transparent noise barriers inserted in front of the operator's face. If the press is larger, the operator usually stands in front of the machine. In this case, a shielding system is available that opens the die area during the feeding part of the press cycle and closes the area before and during the press ram descent. Various combinations of partitions and room treatments may be needed if many presses in close quarters are involved.

Pneumatic exhaust noise can be quieted with commercially available mufflers.

Parts ejection noise can be attenuated by using commercially available air-release timing mechanisms or by using mechanical knockouts.

Clutch/brake mechanism noise can be quieted by installing barriers or partial enclosures around those mechanisms. Here, also, various combinations of partitions and room treatments may be needed if many presses in close quarters are involved.

The difficulties in meeting OSHA requirements for these presses lie in (1) analyzing the problem, (2) accepting the changes in procedures or physical presence of treatments, and (3) the costs.

We think the cost is the most significant problem. On the basis of the above analysis, total costs should not be more than $3,000 per benefited worker — a cost we would expect the courts to view as economically feasible.

Note, however, that a portion of these hand-fed presses are located in areas where there are other noisy machines (including banks of semiautomatic presses, for example). These other machines would also have to be treated to achieve the potential benefit of the hand-fed press treatments. According the the American Machinist Inventory, 78.2% of the total number of presses are in plants employing 50 or more workers, where press areas are likely to be segregated from other plant areas. Since data do not exist for the distribution of types of presses across plants by employment size, we assume that small hand-fed presses will be distributed as are all presses: 78.2% in areas where other equipment – principally semiautomatic presses – are also used, and 21.8% in areas where only small hand-fed presses are used.

Thus, in areas where only small hand-fed presses are used, 3,771 presses (21.8% of 17,300) can be quieted. The remaining 13,528 small hand-fed presses are located in areas with other presses. Since sound levels around these presses are influenced by other sources 90% of the time (10% could be quieted with total enclosures), only 10% (1,353) of these 13,528 small hand-fed presses can be quieted with the mechanisms previously described. In summary, there are 5,124 (3,771+1,353) instances where small hand-fed presses can be quieted, leaving 12,175 in violation of OSHA regulations. If all semiautomatic presses that could be quieted were quieted, 90% (12,175) of the 13,528 small hand-fed presses could also be quieted.

Under these circumstances, 15,946 (3,771 + 90% of 13,528) could be quieted, leaving 1,353 in violation of OSHA regulations.

Large Hand-fed Presses

Large hand-fed presses individually cause OSHA noise problems when they wear or when material-handling noise is significant. When worn parts are responsible for the noise, the solution is usually straightforward, requiring component or machine replacement. However, this solution is not always feasible, because the part may be unavailable or the costs unjustifiable, considering the age of the machine. Occasionally, it may be cost-effective and technically feasible to encase the offending part. Material-handling noise is a more difficult problem to solve. Possible solutions include automating the operation or redesigning the material flow so that material-handling noise can be segregated from the workers. Either solution is viewed as usually being a significant process change (especially for existing plants, where labor would object to automation and where the likelihood of changing equipment layout is small).

When the problem is due to the noise impulse alone, it may be possible to shield workers with a noise barrier. We see this as the only instance where the OSHA noise problem for large hand-fed presses has a realistic chance of being solved. Also, since large hand-fed presses may be used in areas where semi-automatic units are found, the number of large presses that can be made to meet OSHA requirements will be a small portion of the 11,533 total of this class of press – probably no more than 1,000 individual units.

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries or production processes.

RESPONSE Mechanical stamping presses are used throughout industry, and the noise problems caused by these machines are similar in each industry.

The latest inventory* presents the 1978 distribution of mechanical stamping presses across major two-digit SIC industry groupings that manufacture items made of or with sheet metal components. These data are summarized in Table 4. They are based on an extensive survey of those industries, except for small plants, employing fewer than 20 people.

In addition, Department of Commerce census† data indicate that mechanical stamping press workers are found in lesser numbers in 19 other two-digit SIC industries. These workers operate the same press models and have roughly similar noise exposures, but they process plastics, linoleum, or other materials instead of sheet metal.

**12th American Machinist Inventory*, McGraw-Hill, Inc., 1978.

†U.S. Bureau of Census, Census of Population: 1970 Occupation by Industry, Final Report, p. c(2)-7c.

TABLE 4. NUMBERS (AND PERCENTAGES) OF PRESSES IN METALWORKING INDUSTRY BY PRESS TYPE AND INDUSTRY.

Industry (By SIC Code)	OBI	Gap or C-Frame	St. Side Single Action	St. Side Double or Triple Action	Knuckle Joint	Adj. Bed and Horning	Pulldown	Multiple Transfer Press Auto.	Multiple Plunger	Horizontal	Total
25 Furniture and Fixtures	5,308 (4.5)	1,859 (4.1)	1,078 (2.5)	89 (2.0)	7 (0.3)	247 (6.1)	127 (2.6)	1 0	0 0	88 (3.5)	8,804 (3.8)
33 Primary Metal	3,304 (2.8)	1,438 (3.2)	734 (1.7)	125 (2.8)	462 (20.5)	185 (4.5)	76 (1.6)	93 (2.6)	19 (0.9)	415 (16.4)	6,851 (3.0)
34 Metal Fabrication	54,843 (46.3)	19,571 (42.9)	18,372 (43.0)	2,264 (50.3)	600 (26.6)	2,035 (49.9)	2,058 (42.7)	1,933 (53.0)	896 (43.2)	1,389 (55.0)	103,961 (45.1)
35 Machinery Exc. El.	17,014 (14.4)	5,033 (11.0)	4,287 (10.0)	516 (11.5)	204 (9.0)	320 (7.8)	725 (15.0)	531 (14.6)	130 (6.3)	340 (13.5)	29,100 (12.6)
36 Electrical Machinery	23,732 (20.0)	8,070 (17.7)	7,559 (17.7)	440 (9.8)	617 (27.3)	494 (12.1)	1,193 (24.7)	496 (13.6)	354 (17.1)	160 (6.4)	43,115 (18.7)
37 Transportation Equip.	4,952 (4.2)	7,631 (16.7)	8,797 (20.6)	963 (21.4)	63 (2.8)	651 (16.0)	325 (6.7)	419 (11.5)	86 (4.1)	113 (4.5)	24,000 (10.4)
38 Meas. Equipment	4,563 (3.9)	322 (1.8)	535 (1.3)	20 (0.4)	108 (4.8)	45 (1.1)	167 (3.5)	43 (1.2)	104 (5.0)	0 0	6,407 (2.8)
39 Miscellaneous	4,718 (4.0)	1,161 (2.5)	1,375 (3.2)	84 (1.9)	198 (8.8)	103 (2.5)	150 (3.1)	131 (3.6)	484 (23.3)	19 (0.8)	8,423 (3.7)
TOTAL	118,434	45,585	42,737	4,501	2,259	4,080	4,821	3,647	2,073	2,524	230,661

The major difference in the problems among the user industries is in the number of presses per plant. Typical plants in the metalworking industries use many presses, and one operator may tend up to four or five individual presses, each of which would have to be quieted to benefit that operator. Fewer presses are used per plant in other industries, and the ratio of operators to presses approaches one to one. Differences also occur in the noise output of typical presses: less noise is associated with processing softer materials, and less high-frequency noise is associated with pneumatic parts ejection and material-handling found in metalworking plants. However, sound levels remain dominated by the "process sound" caused by press parts banging together. This noise occurs even if the the press operates without a product being passed through it. As long as the press operates at about 100 strokes per minute (spm), noise usually exceeds 90 dB(A). Highest exposures, though, are found mainly in metalworking industries.

FILTER e. The degree to which reduction of the noise level of the identified type of class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed by the OSHA formula.

RESPONSE Noise controls applied to new machines can reduce present noise exposures by a minimum of 6 dB (die-bed enclosures).* A realistic upper limit of the

*This is a few dB better than the user can typically obtain with the same conceptual noise control design, mainly because there is an opportunity to integrate more fully the noise control with the press structure.

potential noise exposure reduction is 10 dB (die-bed enclosures plus additional assorted controls). The reductions should be applicable to all common press types that can be run in a semiautomatic mode, presses that we think represent 60% of the in-place presses. If we consider only the degree to which application of these machine controls is made on new presses, the potential benefit of such controls is small. The full potential of the noise reductions will be realized only for completely new facilities where only new presses are installed, and for existing facilities where virtually all noisier old presses are replaced with the quieted equivalent or retrofitted.

If we consider the benefit that could be obtained from the creation of an essentially new noise control treatment (a die-bed enclosure developed by a manufacturer) as it affects existing presses, the benefit for retrofit treatment analyzed in the response to Filters b and c increases dramatically. Of the 106,288 presses that currently exceed 90 dB(A), 44,984 can be reduced to 90 dB(A) or less, and the balance of these levels can be reduced by 6 dB. In addition, the quieting of existing semiautomatic presses will quiet noise environments around hand-fed presses. If these hand-fed presses were also treated, noise exposures of operators of those machines could be acceptable.

FILTER f. On a national basis a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device, within a period of five years.

RESPONSE The latest Department of Commerce (DOC) census data* indicate that there were about 160,000 punch and stamping press operators, throughout industry, in 1970. About 145,000 of these operators worked in the whole of the metalworking industry, which includes SICs 25 and 33 to 39. The number of production workers in the metalworking industries has grown during the past eight years by a weighted average of about 12%.† If the gain in numbers of punch and stamping press operators in the metalworking industry was the same as the gain in production workers, there would be about 162,000 operators in 1978 in the metalworking industry.

The punch and stamping press category includes other operators in addition to operators of metal stamping presses. About 20 of the 38 operator classifications are unrelated to stamping press operations. Thus, there are fewer than 162,000 mechanical stamping press operators, but the DOC has no way to identify the actual number.

*U.S. Bureau of Census, Census of Population: 1970, Occupation by Industry, Final Report, p. c(2)-7c.

†The range of growth rates was -6% (SIC 33) to 22% (SIC 34).

Another way to estimate the number of operators is to use the number of presses in each press category (as presented in our response to Filter a) and to estimate the number of presses that each operator tends. From this information, we can develop the number of operators. The following table presents our estimates for the number of operators for each press category in metalworking industries.

Press Category	Estimated Number of Presses per Operator[1]	Total Number of Presses	Estimated Total Number of Operators	Number of Presses Capable of Causing OSHA Noise Problems[2]	Estimated Number of Operators Overexposed
Semiautomatic	2.5	138,396	55,358	106,288	42,515
Small hand-fed	1	69,198	69,198	17,300	17,300
Large hand-fed	0.7	23,066	32,951	11,533	8,073
Total		230,661	157,507	135,121	67,888

[1]BBN estimate.

[2]From Filter a.

A substantial number of operators are affected by press noise. The number of peripheral workers impacted by press noise is even more difficult to assess because the census does not publish data broken out by worker categories affected by press noise, and because time and motion data on the peripheral workers' involvement with the presses have not been reported to date.

On the basis of our analysis of worker categories that might be involved, however, we conclude that the number of peripheral workers is likely to be large, substantially more than 50,000.

FILTER g. Not addressed.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE No user can buy a press of under 300 tons capacity with built-in noise controls that can replace an existing unit and provide compliance with the OSHA noise regulation. Some manufacturers sell free-standing enclosures as an optional attachment, but these are no different than enclosures marketed by noise control product suppliers. Therefore, they suffer from the same constraints of enclosures discussed in Filter b. Many manufacturers integrate features into their products that provide small amounts of quieting, as a by-product of their use (such as using cast rather than assembled frame components) or as a direct consequence of their use (such as exhaust mufflers), but because of the dominance of die-involved noise, none of these features approaches solving the overall noise problem.

Users can, according to a few equipment suppliers, buy quieted large presses. As discussed earlier, these large (600 tons or greater) presses do not normally cause OSHA noise violations, and they represent only a small fraction (under 10%) of the total mechanical stamping press population. The noise controls featured in these large presses are usually versions of die-bed enclosures.

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE Noise control technology that can be supplied to stamping presses and provide significant noise reduction is currently available for the majority of new presses. However, no press manufacturers sell equipment incorporating this technology. Noise control product vendors do offer machine-applied controls though, as retrofit kits for presses. These kits are die-bed enclosure systems, which are essentially acoustical versions of commonly used safety shields.

Many other kinds of technology could eventually be used to quiet presses, but they have the following constraints.

- Die-bed cushions and shock-absorbers are still in the research and development stage, although their potential has been demonstrated experimentally.
- The application of damping materials to press parts and mufflers to air exhausts for clutch and brake press components can reduce the noise

from those parts, but not the overall noise of the press action (at least not until the die noise is reduced).

- Die modifications have not been developed, and they are not the responsibility of the press maker.
- Structural modifications to reduce the radiation efficiency of the press frame are still purely conceptual for presses, even though the technology for designing such parts is demonstrable.

We conclude that the only effective treatments available at this time are die-bed enclosure systems.

There are several reasons why press manufacturers do not incorporate the available noise abatement technology into their presses. Press manufacturers do not think they can quiet the press. Even though this sounds incongruous, during the past 15 years of working in mechanical stamping operations, we have discussed the concept of press noise control with numerous manufacturers, and they have consistently responded that the noise problem is associated with the operation of the die and the parts ejection mechanisms, and therefore, the die maker or parts-ejection system designer (often the user) has the opportunity to quiet the machine. Their conclusion is erroneous for two reasons. First, of all those involved in making a press operational, the manufacturer is the only one who could make it possible to readily adapt machine-applied noise control features; and second, the manufacturer is the only one who could modify structural/ mechanical elements to make those parts quiet.

Another reason the technology is not applied is that the press manufacturers do not have much incentive to do so. There is ample demand for the existing press models — customers now have to wait about 18 months for delivery of a new press. Furthermore, manufacturers do not appear to believe they can sell a quiet press. Indeed, the customers who buy new presses usually plan to locate them in areas that have many old presses, and hence, they feel that a quiet press would not improve matters in that area. In addition, customers are unwilling to pay a premium for a quiet design. Customers are also reluctant to be the first plant to try a new press unless it improves production. Customers tend to buy new or replacement presses that are compatible with existing models, parts, maintenance schedules, and operator skills. Users of presses do not appear to see OSHA penalties as significant enough motivation to demand quieter presses.

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APPENDIX C.3

ANALYSIS OF PEDESTAL GRINDERS

A review of our experience with pedestal grinders suggests that these machines do not cause chronic violation of the OSHA noise regulation. Most pedestal grinders are used only for brief periods during the day. Thus, even though they are often noisy when used [causing more than 90 dB(A) at the operator positions], noise exposures caused by their operations are well within compliance levels.

Some pedestal grinders are used as production machines. These are principally in the foundry industry, where they are used to finish castings. Typical noise exposures for such operations are about 100% of what OSHA allows, with a range of 50 to 200% [equivalent to average sound levels of 85 to 95 dB(A)]. These grinders cause exposures in excess of the allowed limits when they are not maintained properly, when large numbers of them are used in close proximity to one another, or when they are used to grind castings that ring.

We have not investigated this machine in greater detail, because the pedestal grinders that cause OSHA noise overexposures appear to be the exception and are found mainly in one industry, the majority of excessively noisy situations can be quieted via *in situ* controls,* and there are too few of these grinders to impact 10,000 workers.†

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*BBN opinion.

†The *American Machinist Inventory* classifies pedestal grinders as floor grinders and lumps them together with the more common bench and snag grinders. Thus, there are no available data on the number of pedestal grinders in use.

APPENDIX C.4

ANALYSIS OF TUMBLERS

Tumblers are essentially automated pieces of equipment. Manual operation is required only to load or unload the units. Thus, even though these machines are noisy [noise environments in their vicinity range from 92 to 115 dB(A) and average close to 95 dB(A)], most of them that require treatment can be quieted to meet the OSHA standard via *in situ* controls such as segregating the tumbling area, providing the operator with a noise refuge, or enclosing the individual units. There are also too few such units to have much impact. The *American Machinist Inventory* estimates that there are about 19,000 barrel finishing machines and about 12,000 vibratory finishing machines in metalworking industries. One man may operate as many as 10 or more of these machines. Thus, there are probably fewer than 2000 barrel finishing operators and fewer than 1500 vibratory finishing machine operators. Because of these factors, we have not investigated this machine in greater detail.

APPENDIX C.5

ANALYSIS OF FURNACES (FOUNDRIES)

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- The noise exposure of furnacemen (melters) is in chronic violation of OSHA standards.
- Sound levels in excess of 110 dB(A) are measured close to furnaces on occasion. The noise exposure of the operator depends on his location relative to the furnace, but a mean daily noise dose of an OSHA equivalent sound level of 92 dB(A) has been reported (7*).
- There are many different types of furnaces used in the foundry industry, and each has its own characteristics of noise generation. The following list of furnace types gives the principal source of noise generation (3, 6, 9).

  Cupola (material loading, blower)

  Gas-fired crucible (combustion process, blower)

  Electric induction (electromagnetic vibration of coils, material loading)

  Electric arc (electric arc, material loading, ventilation equipment).
- The noise levels generated often depend on the quality and maintenance of the machinery.

*Numbers in parentheses refer to Annotated Bibliography for Pneumatic Tools and Foundry Machinery, Appendix C.9.

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- None of the 282 foundries visited by BBN had solved the noise problem associated with their furnaces (1).
- A search of OSHA contested cases revealed no instances of furnace noise.
- Mufflers can be added to blowers; combustors can be changed; covers and hoods can be added to control noise (BBN opinion).
- The foundry industry is conservative and the owners are more often concerned with productivity than with complying with the strict letter of the OSHA regulations. There is some disagreement over the emphasis on engineering controls rather than with the use of personal hearing protection. The American Foundrymen's Society represents the owners and has conducted studies and provides information, but a great deal of it is negative regarding the potential for extensive foundry noise control (6).
- User industries do not have the technically aware engineering staff to undertake the major problems of noise control on furnaces necessary to reduce the

exposure of the operators to less than the limits of the OSHA noise regulations (BBN opinion). The foundry industry contains many small units. Over 50% of the foundries employ fewer than 50 workers (1).

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE

- The furnace usually stands alone, with additional equipment restricted to material supply services, melted metal removal, and heat and ventilation control systems. Some automatic furnace and pouring systems are integrated into a complete foundry system.
- With the exception of the electric induction furnace, most of the furnaces can be treated with *in situ* controls.
- User industries experience difficulty in reducing the noise of furnaces, but chiefly through lack of available information (BBN opinion).
- Mufflers can be fitted to fans on cupolas and gas-fired crucible furnaces (manufacturer's catalogs).
- Quieter combustors are available for some gas-fired crucible furnaces (manufacturer's catalog).

- Noise barriers can be combined with ventilation to reduce the noise radiated (BBN files and manufacturer's catalogs, 6).
- Existing electric induction furnaces cannot readily be treated. Reducing the vibration of coils and other electrical components requires basic changes in the construction (BBN opinion).

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries or production processes.

RESPONSE

- Foundry furnaces are unique to the foundry and metal casting industry.

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed by the OSHA formula.

RESPONSE

- The furnace will usually dominate the noise exposure of the operators in the immediate vicinity of the machine (BBN files, 7). If the furnace were quieted, the exposure of many, but not all, of the furnacemen could be brought into compliance. The furnace may or may not be an important contributor to the noise exposure of other workers. Pourers, who have to approach the furnace to obtain molten metal, may be exposed to the noise of shakeouts and molding machines, depending on foundry layout. In that case, their noise exposure may be largely a consequence of these noisier machines. The noise influence of the furnace on these workers may only be secondary. Material handlers may be exposed to the noise of furnaces, depending on the arrangement that is used to supply raw materials to the furnace.

FILTER f. On a national basis, a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE

- More than 10,000 furnace operators are overexposed.
- Of the total of approximately 450,000 employees in the foundry industry, it is estimated that about 7% of them could be classified as melters (furnacemen) and that 53% of these workers will be overexposed to noise in excess of the limits of the current OSHA regulations (7). The total overexposed is thus approximately 16,000 workers.
- The industry is changing. Smaller foundries which use crucible furnaces and cupolas are being replaced by larger and more automated foundries. Some of the newer furnaces, such as electric arc, are noisier, while others, such as electric induction, are quieter. The number of furnacemen is probably decreasing (BBN opinion).

FILTER g. Not considered.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight hour, 90 dBA noise level reuqirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE

- Quieter versions of many furnaces are available, and most new furnaces are likely to incorporate features that reduce noise, even though the main purpose of these features is to reduce energy consumption.
- Whether a furnace will meet an 8-hr, 90 dB(A) noise exposure limit for the operators will depend on the installation and operating procedures of the furnace system. As now produced, it is probable that very few systems do meet the current limits of the OSHA noise regulations.

FILTER j. There is available appropraite noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE

- The work that has been done to produce noise-reduced versions of furnaces could be extended to produce even quieter systems.
- At the present time, the current political and philosophical climate of the foundry and metal casting industry provides no incentive to the manufacturers of furnaces to produce quieter furnaces. The competitive advantage of low noise will be more than offset by the additional cost of such units.

APPENDIX C.6

ANALYSIS OF MOLDING MACHINES

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- The noise exposure of molding machine operators is in chronic violation of OSHA standards.
- Sound levels in excess of 110 dB(A) are measured on occasions close to molding machines, and a mean daily noise dose of an OSHA equivalent sound level of 95 dB(A) has been reported (7*).
- The high noise exposure of molding machine operators has continued for many years (3, 6, 9). The sources of noise have been identified as the action of the machine and the associated support systems. The machine noise includes the impact sources of the metal flasks on the machine bed during the sand jolting sequence, the radiated sound of the vibrating surfaces excited to ensure a clean separation of the sand from the pattern, and the air release flows of the pneumatic pistons used to provide pressure during the squeeze sequence. System noise includes the sand supply system with the conveyors and hopper vibrators, the pneumatic supply system, the air-jets of the parting fluid sprays and blow-off sand cleaning guns, the hydraulic motors and pumps of the hydraulic systems, and the material and flask conveyor systems.

*Numbers in parentheses refer to Annotated Bibliography for Pneumatic Tools and Foundry Machinery, Appendix C.9.

- There are many different types of molding machines, but often it is the medium-sized machines such as the rollover semi-automatic systems that produce the highest noise exposures (7).
- Automatic molding machines can produce high noise exposure (greater than allowed by OSHA) for the operator who is constantly required to maintain the function of the working parts of the machine with lubricant, parting sprays, and blow-off guns.

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- User industries experience difficulty in reducing worker noise exposures caused by molding machines.
- Available noise controls for manual molding machines are restricted to pneumatic system mufflers, quiet sand hopper vibrations, and local acoustic barriers. These treatments are not likely to reduce the noise exposure of the operators, except marginally. Only the replacement of existing machines by newer, quieter, or alternative automatic systems will provide significant noise reductions (BBN opinion).

- For the automatic molding machines, the noise exposure of the operators can be reduced somewhat by application of mufflers, bumpers, reduced air pressures, revised layout of accessories, operator refuges, and local acoustic enclosures or barriers (BBN opinion, 5).
- Industry is reluctant to use enclosures and acoustic refuges, as operators like to be able to view operations and have access to the machinery to prevent jams (BBN opinion).
- The foundry industry is conservative and the owners are more often concerned with productivity than with complying with the strict letter of the OSHA regulations. There is some disagreement over the emphasis on engineering controls rather than with the use of personal hearing protection. The American Foundrymens Society, which represents the owners, has conducted studies and provides information, but a great deal of it is negative regarding the potential for extensive foundry noise control (6).
- User industries do not have the technical skill to tackle the major problems of noise control on molding machines. Such skill is necessary to reduce the exposure of the operators to less than the limits of the OSHA noise regulations (BBN opinion). The foundry industry contains many small units. Over 50% of the foundries employ fewer than 50 workers (1).

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE

- The noise of the molding machine and its associated systems is generally responsible for the complete noise exposure of the operator. Reduction of the noise of the molding machine would result in most molders being exposed to noise less than the allowable limits of the OSHA noise regulations.
- Controls to reduce the noise of manual molding machines are generally not available (6).
- Controls to reduce the noise of automatic molding machines are available, not in retrofit kit form, but suitable for installation under the direction of a good acoustic engineer well versed in the mechanical requirements of the machines (BBN opinion).

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries of production processes.

RESPONSE

- Molding machines are unique to the foundry industry.

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed by the OSHA formula.

RESPONSE

- The noise exposure of the operators is controlled by the sounds of the molding machine and its associated sand, pneumatic, and hydraulic systems (BBN files, 7). If the noise of the molding machine were reduced, the noise exposure of most operators would be less than the limits of the OSHA noise regulations. It may be necessary also to apply noise control to the associated systems. However, this problem is not as technically difficult as quieting molding machines (BBN opinion).
- The molding machine can be an important contributor to the noise dose received by nearby workers, depending upon the foundry layout and whether their operations are particularly noisy (BBN files).

FILTER f. On a national basis a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE

- More than 10,000 operators would benefit from noise reduction of molding machines.

- Of the total of approximately 450,000 employees in the foundry industry, it is estimated that about 20% could be classified as molders and that 57% of these employees will be exposed to noise in excess of the limits of the current OSHA regulations (7). The total overexposed is thus approximately 50,000 workers.
- The industry is changing. Smaller foundries with labor-intensive manual and semimanual molding machines are being replaced by larger, more fully automated foundries. The number of molders is thus probably declining and the noise exposure of these workers could be decreasing also (BBN opinion).

FILTER g. Not considered.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE

- For some of the smaller machines, such as the manual jolt-squeeze machine, the manufacturers now offer a quieter version which, with proper installation, could result in an operator exposure less than the limit of the OSHA noise regulations. In this machine, the jolt phase of the sequence is typically reduced in magnitude, and the squeeze sequence is increased to become a more significant part of the process (manufacturers' catalog). The market for new jolt-squeeze machines is limited. The smaller foundries that use these machines are closing with the trend to larger, automated foundries. In addition, these machines do cost more, and they are not suitable for use with all sands and in maintaining quality of molds produced for precision moldings (discussions with manufacturers and catalogs). Careful installation and selection of associated systems is necessary for the operators' noise exposure to be less than the 8-hr 90 dB(A) limit of the OSHA regulations.

- Quiet versions of automatic molding machines are not available.

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selecting machine.

RESPONSE

- Automatic molding machines could be designed by the original equipment manufacturers to operate so that the exposure of the operators is less than the limits of the OSHA noise regulations. (Note: proper attention will also be needed to those parts of the system not provided by the molding machine manufacturer.)
- Manufacturers of automatic molding machines do not include extensive noise control features in their

current designs, other than the use of simple techniques such as blow-off mufflers. The competition in automatic machines is based on productivity, reliability, quality of product, and cost. Noise is not a significant factor, and therefore it is not addressed by the manufacturers to any extent (BBN opinion).

APPENDIX C.7

ANALYSIS OF PNEUMATIC HAND TOOLS

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- Pneumatic hand-held tools, which are used in many industries, include: belt sanders, chipping hammers, drills, horizontal grinders, impact wrenches, needle scalers, nut runners, piston scalers, reciprocating saw/files, rivet busters, rivet hammers, sand rammers, screw drivers, vertical grinders, and weldflux hammers. The pneumatic tools analyzed here are chipping hammers, horizontal grinders and vertical grinders, which are often used by the same group of employees in the metal working and metal casting industries. Operators of this equipment hold the tools in their hands and lean against the workpiece, using the action of the tool to remove surplus material.
- In the metal casting industry, the noise of cleaning and casting and the resulting consequences to the employees have been recognized for many years. (For example, see 3*, "Noise Problems in Foundries," published in 1956.) Metalworking generally has been noted as a noisy occupation, and deafness was accepted as one part of its occupational hazards until quite recently. Among the many noisemakers in the industry, the noise contribution of portable hand tools has not been documented generally.

*Numbers in parentheses refer to Annotated Bibliography for Pneymatic Tools and Foundry Machinery, Appendix C.9.

- In recent years, the problem of chipping and grinding noise has been studied by government (4, 9, 22), toolmakers, users, and subcontracted research groups. (2, 6, 8, 13, 14, 19).

- OSHA noise standard violation rates in the metalworking industry are high. Typical reported values are:

  Fabricated metals — 25%
  Primary metals — 41%.

  In this discussion of pneumatic tools, we have selected two user industries, foundries and steel plate fabrication, as representative of industries affected by excessive noise exposure.

  It is not clear how much of the OSHA noise violations reported are due to the use of pneumatic tools. However, for the foundry industry, BBN found that for the sample of 282 foundries visited under the OSHA consultation program, approximately 70% of all of the workers assigned to the job classification of cleaners were exposed to noise in excess of the OSHA standards. (1.) In the cleaning operations, it could be expected that at least half the workers would be using pneumatic hand tools to chip and grind the castings.

- In the BBN study for the Steel Plate Fabricators Industry (2), 202 employees out of 4,123 surveyed were classified as hand grinders, and their average daily noise exposure was 6.33 times the allowable OSHA dose. In a noise control priority index, this job operation was then graded as second only to air arc gouging.

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour (8) 90-dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- User industries have encountered difficulty in quieting pneumatic tools.
- Although quieting methods exist, such as enclosures to isolate operators of chipping and grinding tools, sound-deadening treatments for workbench tops to reduce casting "ringing," and pneumatic exhausts for tools (5, part 2), how effective these treatments are is not clear.
- In foundries, for example, a BBN study shows that where the treatments listed were used in response to OSHA citations, a sound reduction equivalent to 5 dB was achieved, although the chief benefit was often noise reduction for nearby workers. However, some members of the foundry industry do not find these noise-control methods effective (6), and one U.S. government study (4) finds a lower rate of noise reduction than the 5 dB determined by BBN.
- In the steel plate fabricating industry, such treatments as use of damping panels applied to the workpiece and sand-bed supports for structural steel when grinding and chipping tools are used have achieved

some noise reduction. (BBN files.) These approaches, however, are not generally practical, because they create other health problems (such as sand dust and silica exposure) and because configurations for application of damping panels are not readily obtained.

- In sum, the additional problems caused by using the available noise control treatments for pneumatic tools and the uncertainty about the effectiveness of these treatments have made user industries reluctant to use presently available methods to try and achieve compliance with the OSHA standard.

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE • In the operation of pneumatic tools, noise levels in excess of the OSHA standard are produced from three sources, (1) the exhaust noise and casing vibration of the tool itself, (2) noise from the vibration of the grinding wheel or the cutting bit, and (3) induced vibration of the workpiece. Typical sound levels from these sources range from 90 to 105 dB(A) at the operator's ear for grinding operations and 95 to 120 dB(A) for chipping operations. (BBN files, 4.)

- To bring this type of machine into compliance with the OSHA standard, *in situ* noise control methods must address each of the three sources listed, for which the following problems exist:

  1. Tool noise — Add-ons (quieting devices that can be attached to existing tools) to reduce exhaust noise are available for some tools, but they are not widely used because they can adversely affect performance.

  2. Cutting bit vibration — Internally damped chisels are now being developed to reduce the noise from chipping hammer operations (8), but they are not yet ready for general use.

  3. Reducing the noise of the workpiece by using bench clamps and other techniques is possible in some situations, but treatments are not universally applicable, and they are often too technically complex for most small metal-working companies. (BBN opinion.)

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries or production processes.

RESPONSE Pneumatic tools are used in all the metal working industries (SICs 33-39), the manufacturing industries that have maintenance and repair shops (SICs 10-32), the transportation, communication, electrical, gas, and sanitary service industries that have maintenance and repair shops (SICs 40-49), and in the service industries for automotive repair and metal repair and refinishing. (SICs 753, 7692, and 7699.)

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed by the OSHA formula.

RESPONSE
- For operators, the noise of pneumatic tools is normally the controlling factor in determining their noise exposure.
- For peripheral operators, the noise of pneumatic tools can be a major cause of noise exposure.
- Therefore, reduction of the noise level of pneumatic tools would be the critical factor in bringing the noise exposure into compliance for operators, and a significant factor for peripheral workers.

FILTER f. On a national basis a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE
- More than 10,000 operators are impacted.

In foundries, we estimate that nearly 50% of the 126,732 cleaners exposed to daily noise dose in excess of the equivalent of eight hour 90 dB(A) could be exposed directly as the result of pneumatic hand tools alone (7).

In the steel plate fabricating industry, the estimate is that hand grinders are used typically by 50% of the employees in the total industry, who are all exposed to noise in excess of the OSHA allowable noise dose (2).

FILTER g. Not addressed.

FILTER h. See Industrial Machine Trends, Appendix D.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE • To determine the availability of quieted versions of pneumatic hand tools, BBN staff interviewed eleven major manufacturers of such tools. Table 1 is a list of the manufacturers contacted and a summary of their responses.

- Discussions indicate that the majority of these manufacturers offer either quieted versions of their tools or devices (such as mufflers) referred to as "add-ons," which can be fitted to existing tools to reduce noise. Of the 11 manufacturers listed, 7 say that their tools have been quieted. Two of these give dB(A) readings for the quieted tools, and one manufacturer says the tools met OSHA requirements. Other manufacturers, however, refuse to discuss the question of tool noise. Therefore, BBN was unable to obtain information about the availability of quieted versions of tools from these manufacturers.

- The figures quoted by the manufacturers are measured according to the standard developed by the Compressed Air and Gas Institute (CAGI) in the U.S. and the European Committee of Manufacturers of Compressed Air Equipment (PNEUROP) for the measurement of air tool noise – later American National Standard (S5.1 – 1971). Although this test method gives a measure of the sound produced by the tool, it does not give an accurate picture of worker noise exposure, because the tools are not run as they are actually used, in contact with the workpiece.

  Further, the measurement is made at a distance of 1 m, whereas the typical working distance might be one third of this value.

- We conclude that while there are quieted versions of pneumatic tools available, they are not such that the exposure of the operator is going to be in accordance with the eight hour 90 dBA limit of the OSHA standards.

TABLE 1. MANUFACTURERS OF PNEUMATIC HAND TOOLS (CONTACTED BY BBN).

Atlas Copco 70 Demarest Drive Wayne, NJ 07470	Fitted with muffler
Chicago Pneumatic Tool Company Utica, NY 13503	"Acoustically engineered exhausts" — catalog
Cleco Air Tools Dresser Industries, Inc. 300 N. Wolf Franklin Park, IL 60131	Retrofit kit for noise — muffler
Dotco Pneumatic Tools P.O. Box 182 Hicksville, Ohio 43526	Retrofit muffler for some models. Gives sound level measurements (ANSI S5.1, 1971)
Ingersol-Rand Company Tool and Hoist Division 28 Kennedy Boulevard East Brunswick, NJ 08816	Piped away exhaust kit. Working on quiet bits for chippers.
Rotor Tool Cooper Industries 26302 Lakeland Blvd. Euclid, Ohio	
Sioux Tools, Inc. 2802 Floyd Blvd. Sioux City, Iowa	
Stanley Air Tools 700 Beta Drive Cleveland, OH	Quiet version
Superior Pneumatic and Manufacturing Inc. P.O. Box 9667 Cleveland, OH 44140	Quotes dBA readings for tools. (Says OSHA OK.) Uses mufflers.
The Ridge Tool Company 400 Clark Street Elyria, OH 44035	Electric only?
Thor Power Tool Co. Stewart Warner Corp. 175 N. State Street Aurora, IL	

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE

- Exhaust noise and casing vibration can be controlled using available technology. (8, 23.)
- Research is in progress to develop controls for reducing wheel vibration and bit noise, which may become applicable to tool design shortly. (8.)
- One potential area for reduction of noise exposure of pneumatic tool operators is to reduce the ringing noise of the workpiece which can be done with available technology. However, the tool manufacturers have indicated that they have no immediate interest in this program and that technology for noise control of the workpiece should be developed by users who encounter the problem. The original equipment manufacturer is not likely to pursue this area of noise control until the user industry is willing to pay a premium for the control.

APPENDIX C.8

ANALYSIS OF FOUNDRY SHAKEOUTS

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- Shakeouts cause a pervasive, long-standing OSHA compliance problem.
- Sound levels in excess of 110 dB(A) are routinely measured close to shakeouts (3*, 6, 9).
- All shakeouts make noise by the impact of the flasks and castings on the grate, the rattle of sprues and risers trapped on the grate, and the vibration of the drive machinery.
- Manual shakeouts, where the operator physically loads the full flasks (by hand or crane) and removes the flasks and castings, will expose the operator to high-level noise. Automatic shakeouts will expose people nearby, and if an operator is used to monitor the machine and unclog it as necessary, he will also be exposed to excessive noise.

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a

*Numbers in parentheses refer to Annotated Bibliography for Pneumatic Tools and Foundry Machinery, Appendix C.9.

request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- The industry experiences great difficulty in quieting manually operated shakeouts. This problem is difficult because of the nature of the operation of the machine (the impacts are necessary to remove the sand and castings) and the manual requirements that the operator must place items on the grate and remove them from it (forbidding the use of simple barriers and enclosures) (6). None of the foundries visited by BBN had solved the manual shakeout noise problem (1).
- Replacement of manual shakeouts by enclosed automatic systems is not always possible, primarily because of the cost. In addition, the foundry system may not be compatible with an automatic system – it could use individual flasks, for example (BBN opinion).
- Automatic shakeouts can be enclosed to control noise and are therefore much easier to quiet, so that it is possible to reduce the exposure of the operators to less than the 8-hr, 90dB(A) limits of the OSHA regulations (13,33).

- The foundry industry is conservative, and the owners are most often concerned with productivity rather than with complying with the strict letter of the OSHA regulations. There is some disagreement over the emphasis of engineering controls rather than the use of personal hearing protection. American Foundrymens Society, which represents the owners, has conducted studies and provides information, but a great deal of it is negative regarding the potential for extensive foundry noise control (6).

- User industries do not have the technical skill to undertake the major problems of noise control on shakeouts. Such skill is necessary to reduce the exposure of the operators to less than the limits of the OSHA noise regulations (BBN opinion). The foundry industry contains many small units. Over 50% of the foundries employ fewer than 50 workers (1).

FILTER c. The degree to which the noise level of a given work environment exceeds and eight hour, 90-dBA standard, prinicpally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

- Automatic shakeouts can be readily enclosed with appropriate inlet and outlet acoustic tunnels and conveyors (33.34). Therefore, these machines do not pass this filter.

- User industries experience great difficulty in reducing the noise of manual shakeouts.
- Manual shakeouts control the noise level exposure in excess of the 8-hr, 90dB(A) limit of the OSHA regulations for the operators. Noise exposures caused by these machines can only be reduced by the construction of facilities that allow opening the side and possibly the top for loading. The units could then be switched off, the enclosures opened, and the shakeouts loaded or unloaded as appropriate. Such a system would necessarily add to the time and cost of operations and would significantly lower the production (BBN opinion). No record, either published or in BBN files, is available to indicate that such an approach has been taken. An alternative approach of replacing the manual shakeout with an automatic one results in costs that are extraordinarily expensive.

FILTER d. The commonality of a major noise-producing piece of equipment to multiple industries or production processes.

RESPONSE • Shakeouts are unique to the foundry industry.

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight-hour environmental noise level equal to or less than 90 dBA* as computed by the OSHA formula.

RESPONSE

- The noise exposure of the operators in the immediate area of the machine is completely controlled by the shakeout (BBN files, 7). If the noise of the shakeout were reduced, the operator's exposure would be within the limits of the OSHA noise regulations. The noise dose received by nearby workers can be influenced by the shakeout, depending on the foundry layout and the noisiness of operations of those workers (BBN files). If the noise of the shakeout were reduced, the noise exposure of the peripheral workers would be substantially reduced

FILTER f. On a national basis, a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE

- BBN estimates that there are fewer than 10,000 operators of shakeouts and fewer than 50,000 peripheral workers affected by shakeout noise.
- There are about 4000 foundries in the U.S. On average, each might have one shakeout (BBN files). The total number of operators would be about 8000 (BBN opinion). The total number of affected nearby workers could be 30,000 (BBN opinion).
- The industry is changing. Smaller foundries where the manual shakeout may be used intermittently are being replaced by larger, more fully automated foundries. The noise exposure of the operators is increasing because of the newer, bigger machines that run longer, but the total number of shakeout cperators is dropping (BBN opinion).

FILTER g. Not considered.

FILTER h. See Appendix D, Industrial Machine Trends

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight-hour, 90-dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE

- No manufacturer offers a quieted version of a shake-out (6, BBN files) or has tried to build quiet machines (BBN opinion).

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE

- Noise technology for manual shakeouts is not readily available. The only potential techniques would result in loss of production (BBN opinion).
- Although technology is available, the manufacturers of automatic shakeouts do not offer acoustic controls in the form of appropriate enclosures and/or remote controls. There is no competitive advantage to offering quieted shakeouts, and the cost of a quiet unit would be significantly greater than the cost of unquieted units (BBN opinion).

APPENDIX C.9

ANNOTATED BIBLIOGRAPHY FOR PNEUMATIC HAND TOOLS AND FOUNDRY MACHINERY

(SHAKEOUTS, MOLDING MACHINES, AND FURNACES)

1. Potter, R.C., Pei, H-S., Pilgrim, H.G., and Bruce, R.D., "Consultation Service in Industrial Hygiene and Safety to the Foundry Industry," BBN Report No. 3744, March 1978.

Describes Bolt Beranek and Newman Inc. program to provide service to foundries. Notes that noise was the most pervasive OSHA health regulation violated, with 46 percent of employees exposed to sound in excess of the daily limits of the OSHA regulations.

2. Wilby, J.F., Kugler, B.A., and Wilby, E.B., "Occupational Noise and Noise Control in the Steel Plate Fabricators Industry," BBN Report No. 3700, May 1978.

Describes a study of noise generation and control in the steel plate fabrication industry. It is determined that chipping and grinding on welded structures normally exposes the operators to noise doses in excess of the daily limits of the OSHA regulations. The principal cause of noise is noted as the vibration of the structures induced by the action of the tools. Further, it is noted that only very limited success, in the case of a number of specialized items, had been achieved in efforts to damp this vibration.

3. "The Noise Problem in Foundries," *Modern Castings*, 29:37-52, 1956.

Describes the problems of high noise levels caused by foundry operations.

4. NIOSH, "An Evaluation of Occupational Health Hazard Control Technology for the Foundry Industry," DHEW (NIOSH) Publication No. 79-114, October 1978.

This review of practices in a number of foundries notes the problem of noise exposure and reports limited success in quieting tumblers. Indicates that most success is achieved by substituting quiet machinery for noisy items. The conclusions indicate that little immediate noise reduction can be expected and suggest the need for further work.

5. Heine, H.J., "Noise Control Review and Outlook," *Foundry M & T:* Part I, October 1978; Part II, November 1978; Addendum, December 1978.

These articles describe the mechanisms of noise generation and control specifically for foundry machinery. The tone is very optimistic, and several successful programs are described to reduce the noise of machinery by application of vibration control, acoustic wrapping of hydraulic systems, vibration isolation, balancing, eliminating impact, reducing air pressures and velocities, replacement of machines by quieter versions, and using damping to control casting vibration.

6. American Foundrymens Society, "State-of-the-Art Noise Control for Chipping and Grinding, Combustion, Electric Arc Furnaces, Shakeout, Molding Operations," Current Information Report, 1978.

This pamphlet describes the mechanisms of noise generation by foundry machinery. It presents a dismal view of the potential for reducing the noise of cleaning operations, where the workpiece noise is identified as the principal noise source; the shakeout, where the action of the vibrating grate on the flasks and castings is identified as the principal noise source; and the arc furnace, where the electric arc is identified as the principal noise source.

7. Potter, R.C., Potter, J.F., and Jokel, C.R., "The Extent, Causes and Control of Noise Exposure in the Foundry and Metal Casting Industry." Paper to be presented. (Based on papers given to Noise Expo 1979 and 6th National Conference on Energy and the Environment, Pittsburgh, May 1979.)

This paper presents a statistical breakdown of the noise exposure of foundry workers by job classification. Cleaners in particular are noted as being exposed to high levels of sound. It is noted that workers in larger facilities tend to be exposed to more noise than are workers in smaller facilities. This exposure is believed to be the result of the greater mechanization of larger facilities, which also tend to be newer, more modern, and more productive.

8. Auerbach, E.I., "Percussive Tool Noise and Vibration Control." Paper given at the Symposium on Occupational Health Hazard Control Technology in the Foundry and Secondary Non-Ferrous Smelting Industrial, sponsored by U.S. Dept. of Health, Education and Welfare, Chicago, IL, December 1979.

This oral presentation described the Ingersol-Rand program to reduce the noise generated by the tools and the cutting bits. Exhaust mufflers and lead-filled chipping tools are used to reduce the noise of the tool itself.

9. "Noise in Foundries," Joint Standing Committee of Health Safety and Welfare in Foundries, HMSO, London, 1978.

Reviews exposure and methods of noise control in foundries. Notes that control of noise in existing plants is difficult. Suggests control of noise by design is the most promising approach.

10. Willoughby, R.A., "Noise Measurement Techniques for Power Tools," ASME Paper 73-DE-11, 1973.

Reviews ANSI S5.1-1971 method of rating noise of air tools; indicates on-the-job evaluation needed.

11. "Industry's Quiet Rush to Silence," *Iron Age,* December 16, 1971, 73-78.

Indicates that OSHA requirements are causing industry to examine and apply noise control. However, BBN now considers that this article reflects only the immediate response to the first OSHA regulations that had then just been issued.

12. Auerbach, E.I., "Evaluation of Noise from Portable Air Tools," *Sound and Vibration,* May 1979.

Reviews ANSI S5.1-1971 method of rating noise of air tools.

13. "Controlling Noise in Foundries," OSHA, University of Wisconsin-Extension, September 1975.

Reviews available controls, such as mufflers and damped tables for pneumatic hand tools, enclosures for exhaust mufflers for molding machines, care in loading furnaces, and other controls.

14. Cudworth, A.L. *et al.*, "Pneumatic Muffled Noise," INTER-NOISE 78, May 1978.

Reviews reduction in noise and test methods for pneumatic mufflers.

15. Craig, H.D., "Noise from Compressors and Pneumatic Tools," INTERNOISE 78, May 1978.

Reviews noise control of road breaker — tool ringing noise, and suggests solution is to use damping.

16. Cudworth, A.L. and Hansen, W.J., "Noise Generation in Pneumatic Blow-Off Guns," NOISE-CON 75, 1975.

Review of available nozzles to reduce noise and their performance.

17. Elvhammar, H. and Moss, H., "Silenced Compressed Air Blowing," INTERNOISE 78, May 1978.

Design and choice of blow-off air nozzles for reduced noise is discussed.

18. Lopatowa, H., "Examination of Acoustic Field Generated by the Use of Vibotamper for Moulding Sands," INTERNOISE 79, September 1979.

Describes patented exhaust muffler.

19. Diehl, G.M., "Sound Power Levels of Small Hand-Held Tools," *Compressed Air Magazine*, October 1977.

Discusses noise of tools including pneumatic items.

20. Potter, R.C., "OSHA and the Noise of Pneumatic Systems," ASME 77-DE-49, 1977.

Reviews mechanisms of noise generation by pneumatic systems.

21. Redwood, R.A. *et al.*, "Measurement of Hand-Arm Vibration Levels Caused by Chipping Hammers of Two Designs," *Ann. Occup. Hyg.*, Vol. 20, pp. 369-373, 1977.

Quotes noise results, notes that "most of the noise was radiated by the workpiece rather than the hammer."

22. Chester, J.W., "Noise from Pneumatic Rock Drills," U.S. Department of the Interior, Bureau of Mines Reports 6345 and 6450, 1964.

Reviews effects of muffler and gives noise measurements.

23. "Design Cuts Chipping Hammer Vibration," *Foundry M & T*, April 1977, pp. 154-159.

Describes a redesigned impact piston and the tool sleeve to isolate the impact mechanism from the tool casing. This reduces the vibration felt by the operator and also reduces the casing-radiated noise as a side effect.

24. Pombo, J.L. *et al.*, "Inexpensive and Efficient Elastic Mount for a Bench Grinder," 9th International Congress on Acoustics, 1977.

Uses vibration isolation to reduce induced vibration, principally to reduce grinding wheel wear.

25. Martin, A.W. *et al.*, "Recurrent Impact Noise from Pneumatic Hammers," *Ann. Occup. Hyg.*, Vol. 13, 1970, pp. 59-67.

Reviews difficulties of assessing high sounds of pneumatic hammers for hearing loss criteria.

26. Willoughby, R.A. and Parker, E., "Reducing Pneumatic Tool Noise," *Plant Engineering,* Sept. 6, 1973, pp. 109-111.

Reviews exhaust muffler, adding damping and absorption retrofit kits to reduce tool noise – notes problem of workpiece noise.

27. Jensen, J.W. and Vishapun, A., "Pneumatic Rock Drill Noise Can be Reduced," *Noise Control Engineering,* March/April 1975, pp. 54-63.

Describes modifications, including special drill covering case with mufflers and bit dampers to reduce operator noise exposure.

28. Soderholm, L., "Metal-Filled Epoxy Collar Cuts Noise?"

Describes deflector for drill to direct exhaust air into muffler.

29. Berg, P.A. and Lagerberg, G., "Are Pneumatic Tool Noise Data Useful for Predicting Working Noise in Shell Structures?" INTERNOISE 79, September 1979.

Discusses use of standard workpieces to obtain more relevant noise exposure of pneumatic tool operators.

30. Clarke, J.B. *et al.*, "Noise and Vibration in an Electric Arc Melting Shop," 8th International Congress on Acoustics, London, 1974.

Indicates high noise levels near arc furnaces.

31. Cudworth, A.L. *et al.*, "Noise Generation in Pneumatic Blow-Off Guns," *Am. Ind. Hyg. Assoc. J.*, Vol. 38, December 1977, pp. 670-688.

Describes system to rate and select air blow-off guns for noise and efficiency.

32. Cudworth, A.L. *et al.*, "Pneumatic Muffler Noise," *Am. Ind. Hyg. Assoc. J.*, Vol. 39, November 1978, pp. 904-913.

Reviews noise reduction produced by 65 commercially available mufflers.

33. Volante, J., "Noisy Foundry Operations Quieted by Careful Engineering," *Pollution Engineering*, Vol. 9, No. 4, April 1977, pp. 36-37.

Describes booths for grinding and enclosures for automatic shakeouts.

34. Knight, J., "Reducing Shakeout Noise at Midwest Foundry," *Modern Casting*, February 1973, p. 43.

Describes enclosure to reduce shakeout noise from peak 112 dBA to 87 dBA.

35. "Volvo Installs Cleaning Room Work Stations," *Foundry M & T*, November 1977, pp. 50-52.

Describes completely self-contained booths for casting finishing to control dust and noise.

36. Proux, L.J., Jr., "Pneumatic Hammer on Plate with Resilient Support," *Ind. Hyg. J.*, October 1958, pp. 415-416.

Describes how a sponge rubber sandwich is used beneath the mold plate to reduce noise when cylinders are inserted to make mattress molds by using pneumatic hammer.

37. Pressman, W., "An Approach to the Noise Problem in a Large Machine Shop," *Ind. Hyg. Quart.*, March 1956, pp. 37-40.

Describes problems of chipping hammers and failure of using damping blankets to reduce workpiece noise radiation.

38. Dindinger, P., "Evaluation of Some Foundry Noise Control Techniques." Paper to Symposium on Occupational Health Hazard Control Technology in the Foundry and Secondary Non-Ferrous Smelting Industries, Sponsored by U.S. Dept. of Health, Education and Welfare, Chicago, IL, December 1979.

This oral presentation described the use of tight-fitting enclosures to control the noise of tumblers, blow-off gun nozzles that generated less noise, and modifications to a squeeze-jolt molder to reduce the noise exposure by 8 dB. The molding machine modifications included lining the sand hopper, placing elastomeric pads (which did not last), under the jolt mechanism, adding rotary vibrators instead of piston-type, and placing mufflers on the pneumatic exhausts.

APPENDIX C.10

ANALYSIS OF DRAW FRAMES

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- Draw frame operators are exposed to high sound levels in excess of 90 dB(A) (6*, 14, BBN files).
- A search of a limited number of OSHA-contested cases does not reveal any specific cases referring to draw frames. However, one of BBN's clients has been cited for draw frame noise and has come to agreement with OSHA to have the citations vacated on the basis of promised engineering work (BBN files).
- While OSHA recognizes the high noise levels produced by drawing machines, they appear reluctant to cite, because of the lack of generally available controls. Rather, OSHA has emphasized the personal protection program to ensure that employees are protected (BBN opinion). The violation rate for the textile industry is 25%, making it one of the leading industries for chronic violation of the noise standards (Appendix B).

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request

*Numbers in parentheses refer to the Annotated Bibliography for Spinning Frames, Twisters, and Draw Frames, Appendix C.13.

for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE • User companies do not generally have an engineering staff that is capable of tackling draw frame noise problems (BBN opinion).

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour dBA standard principally because of the operation of a single type of class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE

- Draw frames generate noise principally from the drawing mechanism, where the linkages and drive pulleys cause impact noise and induced mechanical vibration of the machine structure. Drive mechanisms can also be significant noise generators.
- The noise levels generated often depend on the condition and maintenance of the machine (6).
- The draw frame can be a major contributer to the noise exposure of the operator. However, often the duties of the operator will require him to go to other noisier areas, such as the carding room. (BBN files).
- *In situ* retrofit noise control is generally not available. However, some manufacturers are now

offering retrofit covers for some of their older machines based on the designs of their newer machines. However, the user industry is generally not aware of these items (perhaps because the sales representatives are more concerned with selling newer machines), and the user industries prefer to purchase new, more productive machines rather than costly items added to older, less productive machines) (BBN opinion).

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries or production processes.

RESPONSE Draw frames are particular to the textile industry – although the applications are widespread.

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to less than 90 dBA* as computed by the OSHA formula.

RESPONSE

- The draw frame is a single independent machine (although complicated and containing many moving parts). The machine is generally responsible for the noise exposure of an operator in the vicinity of the machine.
- Draw frames are now being incorporated into complete carding systems (20). In such systems, the draw frame is only one component of a continuous arrangement of machines. The operators will be subjected to the noise of all the components.

- Reduction in draw frame noise alone will not ensure a noise exposure equal to or less than the limits of the current OSHA regulations.

FILTER f. On a national basis a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE • Approximately 10,000 machine operators are currently impacted by draw frames, on the basis of 20,000 machines in place in June 1978 (U.S. Dept. of Commerce, Bureau of the Census, 1977 Census of Manufacturers, Textile Machinery in Place, MC77-SR-3 (P) and BBN observations of the number of machines per operator).*

FILTER g. Not considered.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

*(20,000 machines $\times \frac{1 \text{ operator}}{4 \text{ machines}} \times$ 4 shifts × .50 utilization)

RESPONSE • Machines now available from the manufacturers incorporate some noise control, but generally they are not sufficiently quieted to ensure that the noise exposure of the operators will meet OSHA requirements when several machines are set together (BBN files, discussions with manufacturers).

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE • Machines offered today incorporate some noise control.

• Technology is available for the original equipment manufacturers to develop draw frames that will not cause operator noise exposures in excess of that allowed under OSHA. This product development will require sufficient funds and a time period long enough for design and testing to assure that production and performance requirements are met (BBN opinion).

APPENDIX C.11

ANALYSIS OF SPINNING FRAMES

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- Spinning frame operators are noted as suffering from noise-induced deafness, second only to weavers in the textile trade. (2*, 19.)
- Spinning frame operators are exposed to high sound levels in excess of 90 dB(A) and reaching 105 dB(A) on occasion. (5, 6, 13, 14.)
- A search of a limited number of OSHA-contested cases reveals only a single case relating to spinning frames, and in that case, the citation was concerned with an inadequate hearing protection program rather than lack of application of engineering controls.
- While OSHA recognizes the high noise levels produced by spinning frames, they appear reluctant to cite, because controls are not available. Rather, OSHA has emphasized the personal protection program to to ensure that employees are protected. (BBN opinion.) The violation rate for the textile industry is 25%, making it one of the leading industries for employee exposure. (Appendix B.)

*Numbers in parentheses refer to the Annotated Bibliography for Spinning Frames, Twisters, and Draw Frames, Appendix C.13.

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- In several textile mills that BBN has visited and consulted with, programs to reduce spinning frame noise have been undertaken. These have mostly concentrated on muffling the vacuum system and using administrative controls to limit employee exposure. Only limited work to reduce spindle noise has been observed on the mill floors. (BBN files.)
- A search of OSHA-contested cases revealed no instances where application of noise control was recommended for spinning frames. Rather, the cases were concerned with the adequacy of heating protection programs.
- User companies do not generally have an engineering staff that is capable of solving spinning frame noise problems. (BBN opinion.)

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE

- Spinning frames generate noise principally from the high-speed rotating spindles, the ring-travellers, the vacuum system, and by the drive mechanisms (tapes, pulleys, etc.). The bearings cause vibration of the frame, and the eccentricity of rotating parts causes aerodynamic noise. (3, 10, 12, 13, 24.)
- The noise levels generated often depend on the condition and maintenance of the machine. (6, 7.)
- The spinning frame controls the noise exposure of the operator.
- Retrofit controls are not generally available from the manufacturer to control the noise of the spindle. The manufacturer of the vacuum system has experimented with acoustic controls (27), and it may be possible to retrofit selected models of machines for limited noise reduction.
- Controls developed by researchers and universities could be applied. (10, 13, 21, 26, 27, 28.) However, they will require extensive development work, which will be expensive and also probably beyond the capabilities of the user industries. (BBN opinion.)
- The textile industry has reported that efforts by textile equipment manufacturers to reduce noise, while considerable, have been "almost entirely fruitless." (17.)
- In conclusion, *in situ* controls are too expensive to apply to spinning frames.

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries or production processes.

RESPONSE

- Spinning frames are unique to the textile industry - although the applications are widespread, including cloth, carpets, ropes, and tires.

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed by the OSHA formula.

RESPONSE

- The spinning frame is a single independent machine (although complicated and containing many moving parts). The spinning frame is usually set in a room containing several banks of machines. Thus, it is generally responsible for the total noise exposure of the operators. The only other source of noise could be the air-conditioning equipment, which maintains the necessary atmospheric conditions. (6, 12, 13, 14, BBN files.)

FILTER f. On a national basis a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type of class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE

- More than 10,000 machine operators are impacted by spinning frames.
- First estimate is made on the basis of a reported 17,400,000 spindles in place in June 1978 [U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufacturers, Textile Machinery in Place, MC77-SR-3(P)] and BBN observations of the number of spindles per operator.*
- In 1977, it is stated that there are 75,000 employees involved in spinning and 19 million spindles. (26.)
- In 1979, it is stated that 50,000 workers in the U.S. are exposed to spinning frame noise of 90 to 100 dB(A). (28.)

FILTER g. Not considered.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

$$* \left(\frac{17{,}400{,}000 \text{ spindles}}{200 \text{ spindles/machine}} \times \frac{1 \text{ operator}}{4 \text{ machines}} \times 4 \text{ sh. fts} \times .50 \text{ utilization} \right)$$

RESPONSE

- Quieted versions are now available by the application of noise control by the equipment manufacturer, but noise is generally not sufficiently reduced to ensure that noise exposure of operators will meet OSHA requirements. (BBN files, discussions with the manufacturers.)
- U.S. manufacturers report work on quieted machines but suggest that the expense means that they will not be competitive. Also, strict maintenance is necessary to keep the machinery quiet. This will increase user industry operating expenses, and it is likely that maintenance for noise control will be neglected in the efforts to maintain productivity. (Discussions with manufacturers.)
- BBN has heard that one foreign manufacturer produces a machine that meets OSHA regulations when new, but this has not been substantiated, and neither published data nor measurements of the noise have been obtained. (BBN files.)

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE

- The OEMs say noise control is not generally available and disparages all work completed prior to 1973. (17.)

Recently researching researchers have reported results and given opinions that quieter spinning frames could be constructed using polyurethane and rubber bushes (10), intake mufflers on vacuum system (21, 27), elastomeric ring holders (27, 28), spindle mount isolation (27), tighter fitting bobbins (27,28), and tighter machine covers (28).

Exposure can be further reduced by use of room absorption (6, 7).

There are differences in the estimated costs for providing noise control. In Ref. 26, Emerson estimates that noise control to comply with the OSHA regulations can be provided for $6.55 per spindle. BBN used a figure of $31.00 per spindle in its economic impact analysis of the regulation. The textile industry implied that the BBN figure was too low, if indeed the noise control could be achieved at all (25).

Sufficient noise control technology is available to enable the development of quieter spinning frames that would result in OSHA compliance. However, the product development will require considerable effort and time. (BBN opinion.)

APPENDIX C.12

ANALYSIS OF TWISTERS (TWISTING MACHINES)

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- Twisting machine operators are exposed to high sound levels in excess of 90 dB(A) (6,* 10, 11, 14, 15, BBN files) and in general are overexposed to noise according to the current OSHA standard.
- A search of a limited number of OSHA-contested cases does not reveal any particular cases relating directly to twisters. However, several of BBN clients have been cited for twister noise and have come to agreement with OSHA to have the citations vacated either on the basis of promised engineering work or OSHA acceptance of the claim that controls were not available. (BBN files.)
- While OSHA recognizes the high noise levels produced by twisting machines, they appear reluctant to cite, because of the lack of generally available controls. Rather, OSHA has emphasized the personal protection program to ensure that employees are protected. (BBN opinion.) The violation rate for the textile industry is 25%, making it one of the leading industries in violation rate (Appendix B).

*Numbers in parentheses refer to the Annotated Bibliography for Spinning Frames, Twisters, and Draw Frames, Appendix C.13.

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- In only one textile mill visited by BBN in the last five years has the company modified the machinery or the facility to reduce the noise, other than by adding available better quality spindle bearings (BBN files).
- A search of OSHA-contested cases revealed no instances where application of noise control was recommended for twisters; rather, the cases were concerned with the adequacy of hearing protection programs.

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE

- The twister controls the noise exposure of the operator.

- Twisters generate noise principally from the high-speed rotating spindles and bobbins, and by the drive mechanisms (tapes, pulleys, etc.). The bearings cause vibration of the frame, and the eccentricity of rotating parts causes aerodynamic noise. (3, 6, 18.)
- The noise levels generated often depend on the condition and maintenance of the machine. (6, 7, 11, 18.)
- Maintenance to reduce spindle vibration is expensive and can put a user company in an uncompetitive position. Maintenance is performed only to keep machines operational. (BBN opinion.)
- User companies do not generally have the technologically aware engineering staff to tackle twister noise problems. (BBN opinion.)
- Retrofit controls are not generally available from the manufacturer to control the most serious noise source – the spindle. The use of narrower drive belts, changes in idler pulley configuration, and better maintenance are offered as one solution for reducing the noise. (Discussions with manufacturers.)
- No modifications are generally available for the newer, larger, faster, and foreign manufactured machines. (BBN opinion.)
- The textile industry association has reported that efforts by textile equipment manufacturers to reduce noise, while considerable, have been "almost entirely fruitless." (17.)

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries or production processes.

RESPONSE

- Twisters are unique to the textile industry – although its applications are widespread, including cloth, carpets, ropes, and tires.

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed by the OSHA formula.

RESPONSE

- The twister is a single independent machine (although complicated and containing many moving parts). The twister is usually set in a room containing several banks of machines. Thus, it is generally responsible for the total exposure of the operators. The only other source of noise could be the air-conditioning equipment, which maintains the necessary atmospheric conditions. (6, 11, 13, 14, BBN files.)

FILTER f. On a national basis a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE

- More than 10,000 machine operators are impacted. This estimate is made on the basis of a reported 3,500,000 twisting spindles in place in June 1978 [U.S. Department of Commerce, Bureau of the Census, 1977 Census of Manufacturers, Textile Machinery in Place, MC77-SR-3(P)] and BBN observations of the number of spindles per operator.*

FILTER g. Not considered.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE

- Quieter versions are now available by the application of noise control by the equipment manufacturer, but noise is generally not sufficiently reduced to ensure that the noise exposure of operators will meet OSHA requirements. (BBN files, discussions

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* $(3{,}500{,}000 \text{ spindles} \times \frac{1 \text{ machine}}{150 \text{ spindles}} \times \frac{1 \text{ operator}}{4 \text{ machines}} \times 4 \text{ shifts} \times 0.70 \text{ utilization})$

with manufacturers.) Noise produced is increased somewhat by the increase in size and speed of the current machines.

- U.S. manufacturers report working on quieted machines but suggest that the expense means they will not be competitive. Also, strict maintenance is necessary to keep the machinery quiet. This will increase user industry operations expenses, and it is likely that careful maintenance will be neglected in the efforts to maintain productivity. (Discussions with manufacturers.)
- One quiet twister was reported, offered in 1971, but it appears to have disappeared since that date. No reported noise results for this machine are available (9).

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE

- The industry says that noise control is not generally available and disparages all work completed prior to 1973 (17).
- Recently engineering researchers have reported results and given opinions that quieter twisters could be constructed using polyurethane and rubber bushes (10),

spindle isolation (1, 18), plastic pulleys (11), added weights for balancing (13), and quality bearings (18).

- Exposure can be further reduced by use of room absorption (6, 7).
- The technology is available to design, test, and produce production twisters that are quiet enough to meet the current OSHA regulations. Such an effort will require substantial funds and considerable time. Noise control is not generally applied because of cost. (BBN opinion, discussions with manufacturers, 25). Manufacturers say it would be uncompetitive. Providing capital for new designs could cause financial difficulties for U.S. manufacturers (BBN opinion).

APPENDIX C.13

ANNOTATED BIBLIOGRAPHY FOR SPINNING FRAMES, TWISTERS, AND DRAW FRAMES

1. Higgs, E.R., "Vibration Behavior of the Textile Spindle," ASME Paper 63-TEX-1, 1963 — ST*.

Review of spindle eccentric rotation that is caused by unbalanced masses. Includes a discussion of spindle isolation. Work is relevant to later noise studies.

2. Burns, W. *et al.*, "An Exploratory Study of Hearing and Noise Exposure in Textile Workers," *Ann. Occup. Hyg.* 7, 1964, pp. 323-333 — S.

Notes the high noise levels in weaving and spinning operations and the corresponding loss of hearing. Finds that workers at spinning machines averaged hearing losses of about half that of weavers. At 4000 Hz, the mean hearing impairment of spinners is 24.7 dB, while it is 46.7 dB for weavers. Finds a further decrease of the group over a three-year period of 2.1 dB for spinners and 6.1 dB for weavers.

3. Crawford, R., "Noise of Rotating Spindles and Bobbins in a Textile Machine," *J. Sound Vib.* 5(2), 1967, pp. 317-329 — ST.

Describes the noise produced by a rotating spindle and identifies the eccentricity of the bobbin itself and the bearing as the principal noise sources.

4. Crawford, R., "IV Noise Control of Factory Plant — Noise Control on Textile Machinery," *Phil. Trans. Roy. Soc.* 263A, 1968, pp. 347-367 — S.

Describes noise generation mechanism of textile spindles — discrete tones result from eccentricity of bobbins displacing air, and broadband noise is associated with surface roughness and bearings. Shows needle bearings quieter. Belt noise,

*Letters refer to particular application, viz., S = Spinning Frames; T = Twisters; D = Draw Frames.

which is caused by vibration of guide and tensioning pulleys, is also significant. (The study was principally aimed at draw twist machines used in the synthetic fiber industry.) Notes also the importance of drive mechanisms in spinning machines.

5. Walker, R.P. *et al.*, "Preliminary Report on Noise in the Textile Industry," Institute of Textile Technology Report, Project 82, 1968 – S.

   Notes that sound levels as high as 105 dB(A) were recorded in spinning rooms. The range of sound overlapped the low end of the results for weave rooms.

6. Hoover, R.J. and Bruce, R.D., "Noise Problems in the Textile Industry," paper to the 1969 Textile Engineering Conference, May 1969, Raleigh, NC – TSD.

   Shows noise levels for twisting, spinning, and drawing in the 90 to 100 dB(A) range. Describes the reduction that might be achieved by use of room absorption – up to 3 dB when away from the machines – and notes that greater reductions can be achieved by work on the machines.

7. *Textile World*, "How to Get Started on Noise Control," June 1970 – SD.

   Describes programs to measure exposure and requirements to reduce machinery noise. Indicates acoustic absorption in room may lower sound levels by only 2 dB. Suggestions for machinery noise reduction include replacing worn parts on spinning machines and acoustic absorption in drawing area.

8. Stout, H.P., "Noise Reduction in the Textile Industry," *Textile Institute and Industry*, May 1971, pp. 129-130 – S.

   Indicates that noise in spinning frame areas is 85 to 100 dB(A).

9. *Modern Textiles*, "6th International Exhibition of Textile Machinery Opens in Paris Next Month," May 1971, pp. 20-26, 50 – T.

   Says U.S. Textile Machine will exhibit a ring twister with soundproofing kit. No details given.

10. "Textile Machinery Noise Control," *Textile Industries*, September 1971, pp. 167-170 – ST.

Describes work completed to identify sources of noise in spinning frames and twisters, and rates speed as the "biggest enemy" because faster machines produce more noise. Describes the reported use of polyurethane and rubber bushings to reduce the induced vibration, and notes spindle isolation is not new. Particularly references a paper by John D. Page of Saco Lowell Maremont to IEEE in 1971 (we have not obtained or traced a copy).

11. Farmer, B.R., "Ring Twister Noise Level Control," *Textile Industries*, October 1972, pp. 117-119 – T.

Says noise in ring twister rooms is from 90 to 95 dB(A) and noise is the result of rotation and vibration of moving parts. Suggests use of plastic pulleys, baffles, and curtains to reduce noise. Also recommends balanced shafts and pulleys and choice of bobbins.

12. Cudworth, A.L. and Stahl, J.E., "Noise Control in the Textile Industry," *Inter-Noise 72 Proceedings*, October 1972, pp. 177-181 – S.

Notes that noise is associated with the machinery and not the thread. Refers to previously reported studies identifying spindles, drives, and belts as sources. Gives typical levels for spinning at 90 dB(A) plus.

13. Emerson, P.D. and Overmann, H.S. III., "Reduction of Noise from Rotating Textile Spindles," *Amer. Ind. Hyg. Assoc. J.*, April 1972, pp. 252-257 – ST.

Notes that sound levels in spinning and twisting rooms can reach 105 dB(A) and spindles are responsible for 80% of the total noise. Describes program to reduce the vibration of spindles by use of added weights, but no corresponding reduction in noise is observed. Concludes that noise originating from spindle vibration can only be reduced by better isolation from a frame that radiates noise, and that noise caused by eccentric rotation can only be reduced by better quality of components.

14. Emerson, P.D., "Some Aspects of Noise Control in the Textile Industry," paper to AATCC Symposium on "The Textile Industry and the Environment – 1973," – STD.

Describes the way to set up and conduct a noise control program. Says spinning, twisting, and drawing areas are typically 90 to 95 dB(A). Says source control is best but gives no examples.

15. Royster, L.H. *et al.*, "Characteristics of North Carolina Industrial Noise Environments," North Carolina State University, April 1973.

Notes that sound levels in most textile industry facilities are in excess of CHABA 85-dB(A) criterion.

16. Evans, J.D. *et al.*, "An Investigation of Noise Radiated by an Eccentrically Rotating Bobbin," *Proc. Noise-Con 73*, 1973, pp. 423-427 – ST.

Describes a theoretical model of the noise produced by a rotating bobbin in terms of an acoustic dipole source, and compares the result to measurements. This refers to the aerodynamic noise of the rotating element. Recommends the use of a stabilizer inside the bobbin to provide a snug fit on the spindle.

17. Prince, P., "Statement of ATMI to Members of the Advisory Committee on Noise," August 9, 1973, Colby College, Waterville, Maine.

Reviews problems and requirements of reducing textile machinery noise. Says most of the effort by textile equipment manufacturers and acoustical engineers, while considerable, has "been almost entirely fruitless."

18. Timbie, R.W. and Howe, F.J., "Drawtwister Spindle Noise Reduction," ASME Paper 73-Tex-8, 1973 – T.

Notes that on drawtwisters the spindle is the dominant source of noise and that vibration is important. Noise reductions of 11 dB are achieved on experimental machines using quality bearings and soft mounts. Reports experiments using electric drive to individual spindles were underway.

19. Bailey, J.R. and Brown, C.M., "Guidelines for Textile Industry Noise Control," *J. Engineering for Industry*, February 1974, pp. 241-246.

Notes that spinners and weavers have significantly greater hearing loss than other workers not noise exposed. Describes progress in textile machinery noise control as limited, and suggests this may be due to fragmentation of industry. Describes mechanisms of noise generation and difficulties of enclosing sources.

20. ATMI Tax Committee, "Technological Obsolescence in the Textile Industry," August 1975.

Reviews the costs of industry to meet government regulation.

Notes that there have been rapid changes in drawing machines since 1966.

Notes that since 1966, a new generation of spinning frame has been marketed and costs on the order of $90 per spindle. Four and one half million new spindles have been sold in recent years and 315,000,000 have been fitted with automatic doffer which increases production expenses at a cost of $25 per spindle. Estimates replacement rate at 560,000 annually.

Notes newer twisters are being produced at costs of $350 per spindle and are coming onto the market slowly.

21. "Case Histories of Noise Control in the Textile Industry," presented at North Carolina State University, September 19, 1974 – S.

Fred C. Craft, Jr. of Cheraw Yarn Mills Inc. describes the use of foam to cut the intake noise of the Pneumafil motor collection end on a Roberts spinning frame. One-inch-thick acoustic foam is used to achieve a reduction of 2.5 dB. The foam needs periodic cleaning.

Up to 5 dB reduction of noise to the side of a H and B spinning frame is reported by use of ball bearing spindles rather than oil base spindles.

A test on a Roberts spinning frame involving an insulated Pneumafil box and shroud failed because of reduced suction initially, but modifications to allow airflow produced up to 6 dB reduction eventually.

Regreasing spindle bearings on a Saco-Lowell Spinomatic spinning frame produces a noise reduction of 12 dB.

22. Hudson, R.S., "Noise Reduction in the Pin Drafting Area of a Spinning Mill," *Proc. Noise Expo 1975*, pp. 54-57 – D.

The use of room absorption produces noise reductions of up to 3 dB in the area of pin and servo drafting machines.

A hinged cover over the faller bar area of a Warner and Swasey pin drafter with damped enclosure panels at the side of the machine produces a drop in sound level near the machine of 6 dB. In an area of such machines, the sound level would be 92 dBA, if all machines so treated.

23. Stewart, N.D. *et al.*, "Spinning Frame Noise Sources," ASME Paper 75-Tex-7, 1975 – S.

The major noise sources of spinning frames are identified as the ring traveler and the spindle-bobbin system. Other sources are the drive cylinder, drive tapes, idler pulleys, vacuum system, and gears. Several suggestions to reduce the noise are offered as part of an ongoing program.

24. Stewart, N.D. *et al.*, "Identification of Textile Spinning Noise Sources," *Proc. Inter-Noise 75*, 1975, pp. 71-73 – S.

Identifies ring traveler system, spindle-bobbin combination, spindle drive system, and vacuum system as noise sources in spinning machines.

25. Kemp, F.B., "Statement Before Public Hearing Concerning the Change in OSHA Noise Standard (CFR 1910.95 – Occupational Noise Exposure Regulations and Procedures) 1976.

Says that even if BBN figures are right, industry cannot afford what could be a 70% increase in debt.

26. Emerson, P.D. *et al.*, "Economic Impact of a 90 dBA Noise Standard on Textile Spinning Operations," ASME Paper 77-RC-15, 1977.

Says spinning frame machine noise can be reduced below 90 dB(A), 8-hr equivalent exposure level. There are 75,000 employees involved in spinning and 19 million spindles. Says cost of replacement of machines is $80 per spindle, and that noise control can be provided for $6.55 per spindle as opposed to the BBN figure of $31 per spindle used in the Economic Impact Analysis. (Note: this is opposite to textile industry, which says BBN estimates are low.)

27. Emerson, P.D. *et al.*, "Manual of Textile Industry Noise Control," North Carolina State University, 1978 – DS.

References the hearing loss of workers in the textile industry.

Includes references to most reported work to control textile noise.

The case histories cited include a study on a Whitin Model M7B5 short staple draw frame where the principal noise sources were identified as the first and second bottom draft rolls, the sliver coiler, and the head gear drive. (The processing elements – the drafting system itself – were not studied under this first phase program.) A redesigned unit (except for the drafting system) was designated Model DW 2000 and included a top cover, head end, and pin enclosure treated with acoustical foam. A reduction in noise of up to 5 dB was achieved.

Another case history involved modifications to a Roberts spinning frame to include Platt Saco-Lowell elastomeric ring holders, tighter fitting bobbins, and reduction in spindle rail panel areas. The noise was reduced by 4 dB with this treatment.

With a Whitin Model F2 spinning frame, it is reported that installation of Platt Saco-Lowell elastomeric ring holders, Lord Kinematics spindle mounts, and modifications to the idler pulleys reduced the predicted room noise level by 4 dB.

Finally the Pneumafil Corporation reported as another case history the development of retrofit kits for their vacuum systems used on spinning frames, whereby the noise of this particular unit was reduced by up to 17 dB.

28. Stewart, N.D. and Bailey, J.R., "Noise Reduction on Textile Ring-Spinning Frames," ASME Paper 79-DET-33, 1979 – S.

Indicates that 50,000 workers in the U.S. are exposed to spinning frame noise of 90 to 100 dB(A). Notes that the noise sources on spinning frames are the spindle-bobbin system, the ring traveler system, the vacuum end-collection system, and the overhead traveling vacuum cleaners. Also notes that idler pulleys, gearboxes, drive cylinders, motor, and drive tapes can be important noise sources.

Experiments on four spinning machines to include the use of elastomeric holders for the spindle mounts, narrower drive tapes, nylon gears, bearings, and ring holders set on elastomeric mounts, quieted vacuum fan exhausts, idler pulley dust ring removal, better and tighter fitting bobbins, and tighter machine covers produced up to 7 dB of sound reduction to give predicted aisle levels for many machines of near 90 dB(A).

APPENDIX C.14

ANALYSIS OF LOOMS

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- Weavers' deafness has been identified since before 1900 (9*, 13, 18, 20, 30).
- Deafness in weavers was responsible for many basic standards of industry-induced noise, in U.S.A. (10, 18) and abroad (8, 9, 13, 15, 16).
- OSHA has had little success in controlling exposures to loom noise. In the one case that went through the OSHA process, the Review Commission effectively ignored the expert opinion that looms could be quieted and accepted the user industry statements that loom noise could not be controlled through engineering techniques (1).
- Industry has generally resisted the application of noise control to looms (12, 17).
- As a result, OSHA enforcement has been limited in the weaving operations of the textile industry (BBN Opinion).

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

*References in Bibliography.

RESPONSE

- Weaving operations, like many other aspects of the textile mills, are in a period of major change (12). Older fly-shuttle looms are being replaced by newer shuttleless looms. These newer looms replace the parts of the mechanism that are generally agreed to be the major noise sources of the fly-shuttle loom – the picking stick and shuttle catcher and launcher mechanisms.
- Industry programs (in the U.S.A.) to provide retrofit kits for looms have ceased for economic and political reasons (BBN Opinion).
- Manufacturers (24, 30, 36) and University personnel (2, 6) have achieved 5 dB reduction in noise for shuttle looms.
- Because shuttleless looms are relatively new, no noise reduction has been seriously attempted on them. Instead, effort has been concentrated on making these machines work better. Water jet and air jet looms are limited by the width of cloth they can produce, but advances in design continue to occur. Foreign manufacturers offer serious competition to domestic loom manufacturers.
- Users have tried to quiet fly-shuttle looms, but with no success (28). Shuttleless looms are so new and so technologically advanced that users have not attempted to reduce the noise of these looms (BBN Opinion).
- Users do not usually have the technical capacity to solve loom noise problems (BBN Opinion).

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE

- Modifications such as retrofit kits for source control on fly-shuttle looms have been discontinued, probably because of industry indifference and because the cost of noise control could be high compared to that for a fully depreciated fly-shuttle loom (1).
- No modifications are available for newer shuttleless looms (BBN Opinion).
- Many of the items in response to Filter b apply here (BBN Opinion).

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries of production processes.

RESPONSE

- Looms are unique to the weaving operations of the textile industry.

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed by the OSHA formula.

RESPONSE

- The loom is a simple independent machine, usually set in a room containing only looms and atmospheric condition control equipment; it is responsible for the total noise exposure of the operator (2, 18, 20).

FILTER f. On a national basis a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE

- The numbers of exposed workers are affected by the changing nature of the machine and the industry. The less efficient fly-shuttle machines are being replaced by the shuttleless looms where mechanically possible. In such situations, productivity is resulting in a smaller work force (BBN Opinion).
- In 1973, there were 313,111 fly-shuttle looms and 18,818 shuttleless looms in operation in the U.S. (4). Assuming one worker for 30 looms (BBN Opinion and BBN Files) and four shifts, the approximate number

of loom operators is 44,000 for 1973. By 1978, there were 263,256 fly-shuttle looms in operation (4), a 16% reduction in fly-shuttle looms and a 77% increase in shuttleless looms. On the basis of the previous assumptions, the number of loom operators is 39,500 for 1978. This is a 9% reduction in operators.

FILTER g. Not considered.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE

- Manufacturers appear to have stopped all efforts to reduce noise of fly-shuttle looms (BBN Opinion). Programs of references 24, 30, and 36 appear to have stopped (1).
- Shuttleless looms represent a new technology, and manufacturers are more concerned with making the machines work efficiently and handle wider cloth than with providing them with noise control (BBN Opinion).

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selecting machine.

RESPONSE

- Despite OSHRC rulings (1), opinion among noise consultants is that noise of fly-shuttle looms could be reduced (6, 2, 29, 24, and 30).
- Work will be needed to identify relevant sources of noise operations — air jets, water jets, pneumatic systems, and drivers for shuttleless looms, before programs can be begun to produce noise control for these machines, which are already quieter than fly-shuttle looms (BBN Opinion).

BIBLIOGRAPHY FOR LOOMS

1. 5 OSHR 1257, "West Point Pepperell, Inc." Review Commission Decision; OSAHRC Docket No. 8255, April 1977.

   X2 and X3, Draper Fly Shuttle Looms. Review Commission reversed judge and disallowed citation because there was no feasible method of quieting, despite expert opinion that a reduction could be achieved. Justice Cleary dissented noting that expert opinions were not countered and no alternative qualified expert was offered.

2. Bailey, J.R. and C.M. Brown, "Guidelines for Textile Industry Noise Control," *J. of Engineering for Industry*, Feb. 1974, pp. 241-246.

   Reports on problems of loom noise; reports on Draper Division of NA Rockwell Study using nylon parts and other treatments, which eventually were discarded because of wear problems.

3. Emerson, P.D. *et al.*, "Manual of Textile Industry Noise Control," North Carolina State University, 1978.

   References hearing loss in textile industry; includes references to most report work to control textile noise. No looms in case histories. Describes mechanisms of loom noise generation.

4. 1977 Census of Manufacturers, "Textile Machines in Place," U.S. Department of Commerce MC 77-SR-3(P), May 1977.

   On June 30, 1978: Broad Fabric Weaving Looms; Shuttle looms – 263,256. Shuttleless – 33,439. By Dec. 21, 1973: Broad Fabric Weaving Looms; Shuttle looms – 313,111. Shuttleless – 18,818. Change in 4-1/2 years, Shuttle -16%, Shuttleless +77%.

5. American Textile Machinery Association, "ATMA Noise Measurement Technique for Textile Machinery," July 1973.

   Measures of dB(A), octave-band sound pressure level, average noise level dB(A), impulsive noise (dB), at typical operator locations in typical mill setup.

6. Crawford, R., "IV. Noise Control of Factory Plant – Noise Control of Textile Machinery," Richard, E.J., ed., *Phil. Trans. R. Soc.* 263A, 1968, pp. 347-367.

Reviews noise in textile industry and discusses replacing metal parts of loom with nylon and synthetics to reduce noise somewhat.

7. "Modern Developments in Weaving Machinery," Duxbury, V. and G.R. Wray, eds., Columbine Press 1962, reprinted 1971.

Describes loom types and mechanisms.

8. Atherly, G.R.C., "Monday Morning Auditory Threshold in Weavers," *J. Brit. Industries Med.*, Vol. 21, 1964, pp. 150-153.

Recovery of weaving loom personnel not complete after weekend in comparison with 16-day break.

9. Taylor, W. *et al.*, "Study of Noise and Hearing in Jute Weaving," *J. Acoust. Soc. Amer.*, Vol. 38, 1965, pp. 113-120.

Hearing loss of weavers is documented.

10. Noweir, M.H. *et al.*, "Exposure to Noise in the Textile Industry of the UAR," *J. Am. Ind. Hyg. Assoc.*, Nov.-Dec. 1968, pp. 541-546.

Documents hearing loss of weavers and sound levels for looms, typically 98 dB.

11. Lyons, D.W., "How to Get Started on Noise Control," *Textile World*, June 1970, pp. 51-55.

Reviews noise problems and how to tackle them. Says difficult to reduce noise in looms; 2 dB reduction for room absorption.

12. ATMI Tax Committee, "Technological Obsolescence in the Textile Industry," August 1975.

Reviews costs of industry to meet government regulations.

Notes:	1960	65% cotton	29% manmade	6% wool
	1973	29% cotton	70% manmade	1% wool

Notes changes in technology of looms since mid-1950s and suggest noise control will follow in response to government regulations.

13. Atherley, G.R.C. and W.G. Noble, "A Review of Studies of Weaver's Deafness," *Applied Acoustics*, Vol. 1, 1968, pp. 3-14.

Reviews published studies of deafness in weavers and indicates extent of problems. Dates back to 1896, Maljutin (Russia). At least 10% reach threshold of disablement.

14. Bailey, J.R. and C.M. Brown, "Guidelines for Textile Industry Noise Control," ASME Paper 73-TEX-2, 1973.

Describes approach to solving noise control problems.

15. Burns, W. *et al.*, "An Exploratory Study of Hearing and Noise Exposure in Textile Workers," *Ann. Occup. Hyg.*, Vol. 7, 1964, pp. 323-333.

Study determined that the hearing of textile workers was worse than that of rural workers.

16. Taylor, W. *et al.*, "A Pilot Study of Hearing Loss and Social Handicap in Female Jute Weavers," *Proc. R. Soc. Med.*, Vol. 60, Nov. 1967, pp. 1117-1121.

Noise levels of 92 to 101 dB, reviews study to reduce noise of plastic parts by 2 dB; new looms increased levels. Hearing disabilities qualified in terms of threshold shift, conversation, and telephone usage.

17. Kemp, F.B., "Statement before Public Hearing Concerning the Change in OSHA Noise Standard," (CFR 1910.95 - Occupational Noise Exposure Regulations and Procedures), 1976.

Says even if BBN figure is right, industry can't afford what could be a 70% increase in debt.

18. Royster, L.H. *et al.*, "Characteristics of North Carolina Industrial Noise Environments," North Carolina State University, April 1973.

Most of textile industry is in excess of CHABA 85 dB(A) criterion.

19. Fitzgerald, L.K., Letter to R.D. Bruce, BBN, August 1976.

Lists numbers and manufacturers of looms.

327,018 shuttle looms
36,583 shuttleless looms

20. Walker, R.P., "Preliminary Report on Noise in the Textile Industry," Institute of Textile Technology, Charlottesville, Virginia, Project 82, Feb. 1968.

Reports on noise in weave rooms — typically 101-111 dB(A). Also gives contributions to loudness (sones) of components of a loom. The picking stick produced 67.9 sones of a total of 176.1. Shaft rotation was the second largest contributor to loudness.

21. Hoover, R.M. and R.D. Bruce, "Noise Problems in the Textile Industry," Paper to 1969 Textile Engineering Conference, Raleigh, North Carolina, May 1969.

Noise levels in weaving rooms, 100 dBA. Illustrates methods of noise control.

22. Bolleter, V., "On the Sound Propagation in Large Flat Weaving Sheds," Inter-Noise 77, March 1977.

Describes how sound propagates and discusses influence of hard floor, ceiling treatment (no large reduction can be expected), scattering of machines (not important).

23. Ho, M.T., "Noise in Weaving Mills, Results of a Survey of Twenty Two Factories — Reduction Possibilities," 9th International Congress on Acoustics, Madrid, July 1977.

Recommends quieted looms, new treatment and spacing. Finds 6 to 7 dB difference for same loom in different plants.

24. Cudworth, A.L. and J.E. Stahl, "Noise Control in the Textile Industry," Inter-Noise 72, Oct. 1972.

Noise of looms presented. Relates sound to the discontinuous motion of looms. Recommends using resilient materials at impact points; 10 to 15 dB reduction possible. Also recommends partial enclosures.

25. Cudworth, A.L., "Cutting Out Noise from Whole Cloth, Noise Control in the Textile Industry," Vol. 1, Summer 1973, pp. 24-30.

Recommendations similar to those in Ref. 24, above.

26. Stout, H.P., "Noise Reduction in the Textile Industry," *Textile Institute and Industry*, May 1971, pp. 129-130.

Weaving rooms — 90 to 105 dBA. Notes that speed increases noise; new looms (shuttleless) are quieter than older types.

27. Prince, P., "Statement of ATMI to Members of the Advisory Committee on Noise," August 9, 1973, Colby College, Waterville, Maine.

Reviews problems and acoustic energy requirements for shuttle looms. Indicates degree of problem and scope of effort (in general terms) by industry.

28. "Plugging Away at Loom Noise Control," *Textile Industries*, Sept. 1975, pp. 34-37, 90.

Reports on survey of 36 mills. Some tried noise control but most had no knowledge of capabilities. Consensus that quieted looms are needed.

29. "How to Quiet the Noise Issue," *Textile World*, May 1972, pp. 37-44.

Describes shuttle loom enclosure for narrow fabric looms four door openings and two acoustical windows. Enclosure reduces noise significantly. Curtains for loom areas give up to 25 dB reduction.

30. Cudworth, A.L., "Textile Loom Noise Study," Draft Working Paper, February 1966.

Noise levels in weave rooms is high. Shuttle loom has four sources: shuttle deceleration, shuttle acceleration, temple roll slap, and drives.

Describes attempt to modify shuttle looms, enclose shuttle box, replace link parallel assembly, enclose l pa, replace steel pick ball with nylon pick ball.

Gets reduction of about a factor of four (6 dB). Also calls for changes in basic function. Recommends: partial enclosure, nylon pick ball, resilient stops, simple conversion, and box surface investigation.

31. Pierce, A.D. and G.E. Johnson, "Sound Radiated from Picking Sticks in Looms," Working Paper, 1976.

    Analysis suggests test vibrations of picking stick generates sound waves.

32. Johnson, G.E. and A.D. Pierce, "The Relationship Between Picking Noise and Component Vibrations in Automatic Textile Looms," ASME Paper 75-DET-45, Sept. 1975.

    Relates noise produced by shuttle looms to acceleration measurements on loom surfaces. Two picking sticks appear to be "overwhelmingly the greatest source of noise."

33. Eckert, W.L. *et al.*, "Fly Shuttle Loom Noise," *Mechanical Engineering*, April 1977, pp. 40-43.

    Identifies sources of noise in shuttle picking mechanisms lug strap and pick ball.

34. Hart, F.D. *et al.*, "Mechanical Separation Phenomena in Picking Mechanisms of Fly-Shuttle Looms," ASME Paper 75-Tex-6, Oct. 1975.

    Reviews separation between cam and pick ball, which gives rise to impact and vibration, source of noise.

35. Zacharia, D. and E. Holpart, "Noise Level Prediction in Weaving Mills," 1976 Noise Control Conference, Warsaw, Oct. 1975.

    Provides formula for estimating sound levels in weaving mills. Based on acoustical power output of machines and acoustic characteristics of room (no real contribution).

36. "Proceedings of the Symposium on Noise in Weaving Machinery," Institute of Mechanical Engineers (UK), March 1963.

Papers on production and potential methods of control, including enclosures and the effects on humans of noise from looms. Also includes reduction methods. Representatives of industry, government, and research indicate in the future there should be a lower noise environment for mills. For example, Sulzer Bros., Switzerland, said, "Exhaustive investigations on a test machine show that the noise can be reduced below this injurious level, so that it is now possible to eliminate the particular occupational disability of the weaver - loss of hearing in the highest frequency range."

For fly shuttle loom, treatment involved application of damping, mostly to reduce sound radiated from vibrating surfaces.

37. Pierce, A.D. and G.E. Johnson, "A Fundamental Approach to Textile Loom Noise Reduction."

Identifies the picking stick as the principal source of noise for a fly shuttle loom.

38. Mills, R.O., "Noise Reduction in a Textile Weaving Mill," *J. Amer. Ind. Hyg. Assoc.*, Jan.-Feb. 1969, pp. 71-76.

Recommends use of ceiling absorption, plastic picking balls, and plastic drive wheels to obtain 5 dB reduction.

39. Springston, J.A., Sr., "Designing Noise Out of Draper Fly Shuttle Looms," Appendix B (testimony at OSHA DOL hearing), presented Feb. 18, 1975.

Describes progress starting in 1966; plastic picking ball, cushion lug strap, damped picking stick, damped covers and surfaces reduced noise by 5 dB; drive mechanism dominant noise source. Says parts to be released.

40. Pierce, A.D., "Vibrations and Noise of Textile Loom Picking Sticks," Paper presented at 89th Meeting of the Acoustical Society of America.

Picking stick is principal radiator of sound.

41. duPre, W.C., "Noise Reduction of Weaving Looms," Inter-Noise 79, Warsaw, Sept. 1979.

Recommends replacing shuttle looms by other types because of cost. Picking stick damping did not work. Use of damping to slow a mechanism after the shuttle was accelerated gave 5 dB reduction; now working on arresting mechanisms.

42. "Textile Machinery Noise Control," *Textile Industries*, Sept. 1971.

Notes that range of 10 dB is sound level for similar machines. Standardized measurements for test machines. Describes possible noise reduction, mostly for draw twist and spinning.

APPENDIX C.15

ANALYSIS OF KNITTING MACHINES

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- Knitting machines produce sound levels ranging from 84 dB(A) to 96 dB(A) at the operator location (1,* 2, 3, BBN files).
- The higher figure 96 dB(A) was one single recorded result over 92 dB(A), and it referred to a limited process. It is probable that only a small percentage of the knitting machines currently in use exceed 90 dB(A) at the operator position.
- A search of a limited number of OSHA contested cases revealed no recorded cases concerning knitting machines.

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- Reported noise control for knitting machines has been by use of shields (3).

*Numbers in parentheses refer to the references for knitting machines.

- Discussions with user industries indicate that while there is an awareness of potential exposure in excess of the 8-hr, 90 dB(A) limit of the OSHA regulations, it is not considered a major problem in comparison with other textile industry noise problems.

NOTE:

Further analysis was not completed. The study of knitting machines was terminated because of limited available data, low noise, and little activity by manufacturers and users.

ANNOTATED BIBLIOGRAPHY FOR KNITTING MACHINES

1. Cudworth, A.L. and Stahl, J.E., "Noise Control in the Textile Industry," *Proc. Inter-Noise 72*, October 1972, pp. 177-181.

   Quotes sound levels for knitting workers as follows: tricot knitting, 96 dB(A); knitting, 85 dB(A); and knitting with waste vacuum operating, 91 dB(A).

2. Emerson, P.D. and Overman, H.S. III, "Reduction of Noise from Rotating Textile Spindles," *Amer. Ind. Hyg. Assoc. J.*, April 1972, pp. 252-257.

   Reports noise of knitting is 85 dB(A).

3. Coles, G.M., "The Reduction of Noise from Knitting Machines," *Abstracts of 9th Int. Congress on Acoustics*, Madrid, July 1977, p. 224.

   Noise of hose knitting machines is quoted as 92 dB(A) and is controlled by air jet noise. Shields are used to reduce exposure.

4. BBN files – Sock knitting machines have noise levels of to 84/85 dB(A) at operator position. Circular knitting machines, including Morat and Meyer machines, recorded 85 to 87 dB(A) at operator positions.

APPENDIX C.16

ANALYSIS OF WOOD CHIPPERS AND WOOD HOGS

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- Chippers are listed as machines needing noise control effort in wood, lumber, and paper industries, according to EPA's *Noise Technology Research Needs*. Hogs are not so listed.
- Chippers, which make sized pulpwood chips from wood slabs and edgings, are noisy, but noise emissions depend on the unit size and the material processed, and noise exposures depend on operations. The largest units may idle at more than 110 dB(A) and process at more than 120 dB(A) near the machine (1–7*). All emit more than 90 dB(A) during operation (BBN opinion). Details of noise emissions and noise exposures caused by the emissions for both machine types are not reported in the literature. BBN files indicate, however, that typical chipper operator noise exposures are in the 85 to 95 dB(A) range. These exposures are so low mainly because the machines normally run without much operator attention (8,9).
- BBN believes the greatest impact of chipper noise is on the general noise environment in the vicinity of the units, since the machines are generally located within the mill confines.

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*Numbers in parentheses refer to the bibliography for wood chippers and wood hogs.

- Hogs, which reduce bark and wood edgings to material suitable for fuel or mulch, are also noisy. BBN has found that hogs are usually tended machines, run indoors. Typical operator exposures are in the range of 85 to 93 dB(A).

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- User industries experience some difficulty in complying with the OSHA noise standard. Users are reluctant to install *in situ* noise controls because the treatments make the process more difficult to attend to if problems arise and because the treatment may necessitate production changes, such as relocating the operation or making it automated.
- The difficulties experienced are neither technically nor economically insurmountable (BBN opinion). The one contested case on chippers found in the OSHA contested citation review indicates that this opinion is correct (Case 10639, Louisiana Pacific).

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE

- There are no off-the-shelf noise controls for chipper or hog problems. That is, no user can purchase a quiet unit or a noise suppression system for any of the machines considered here.
- Standard noise controls (enclosures, acoustically treated infeed tunnels, double walls for casings, damping treatments, operator booths) can solve all the chipper/hog noise problems (BBN opinion). The major difficulty is in the cost for the treatments. Controls for the larger units may be in the $10,000 to $12,000 range, which is roughly 25% of the cost of the basic unit. The smaller units may be quieted for $5000 to $6000. Only minor productivity losses, if any, would result from the treatments.

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries or production processes.

RESPONSE

- Chippers and hogs are mostly used in SIC 2421 (saw-mills and planing mills). The *Woodworking and Furniture Digest* estimates that there are 7788 of these machines in use (no breakdown is given for chippers vs hogs), 5662 (or 72.7%) of which are in SIC 2421. The balance are in 13 other 4-digit SICs in the woodworking industry.

- Since the *Digest* is oriented toward secondary wood operations, the actual number of units in SIC 2421 is probably understated. Industry representatives estimate that there are 1.5 chipper/hogs per plant in SIC 2421, on average (6). Since there are an estimated 8071 plants in SIC 2421 (1972 DOC data), there should be at least 12,000 chippers/hogs in that industry. We will assume the number of chipper/hogs given by the *Digest* for SIC 2421 is not included in the plants the Department of Commerce (DOC) says are in SIC 2421 (see response to FILTER f).

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed for the OSHA formula.

RESPONSE

- Quieting of chippers and hogs will produce little improvement in the number of workers exposed to more noise than allowed by OSHA, since most of the workers who are impacted by these machines have their noise exposures controlled by noise emissions from other machines. The main benefit of quieting chippers and hogs would be in reduction of the sound level in the general environment (producing immediate small improvements in overall noise exposures and making it easier to reduce the residual noise exposures).

FILTER f. On a national basis a minimum of 10,000 operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE

- The Department of Commerce includes hog and chipper operators under the category of "machine operatives, miscellaneous specified," a category that includes 27,044 workers in the wood industry exclusive of furniture operations, and another 19,620 workers in furniture operations. Only a fraction of these are hog or chipper operators.
- Assuming one operator per machine, and using data from the response to FILTER d, above, there may be 7800 operators in secondary wood facilities and 12,000 in primary wood facilities who are either chipper or hog operators. When multiple workshifts are employed in the industry, these numbers underestimate the actual number of operators involved. When the machines are untended, however, these numbers overestimate the number of operators involved.
- Assuming five peripheral workers per machine, and again using data from the response to FILTER d, above, there may be 39,000 peripheral workers in secondary wood operations and 60,000 peripheral workers in

primary wood operations impacted by chipper/hog noise. When multiple workshifts are employed in the industry, these numbers underestimate the actual number of peripheral workers involved. When these machines are run outdoors, where fewer than five workers would be impacted, these numbers overestimate the actual number of peripheral workers involved.

FILTER g. Not considered.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight (8) hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE

- To our knowledge, no manufacturer sells quieted chippers or hogs. The manufacturers have found it possible to avoid any nonproduction-oriented machine changes that would make their products uncompetitive simply by referring users to outside firms who provide custom retrofit designs for quieting the machines.

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE

- Manufacturers could provide units that are somewhat quieter, as built (through better design of the equipment casings), and quiet enough to meet OSHA requirements when fitted with accessory components such as infeed tunnels, which can be made available as options according to individual customer need.
- Manufacturers do not now see a market for these features.

ANNOTATED BIBLIOGRAPHY FOR WOOD CHIPPERS AND WOOD HOGS

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   Gives typical chipper sound levels and mentions typical noise controls.

2. Hagglund, G., "Controlling Noise in Woodworking," pamphlet, University of Wisconsin Extension, School for Workers, Madison, Wisconsin.

   Gives typical noise controls for chippers.

3. Hoover, R. and Miller, L., "Noise and Noise Control in the Wood Processing Industry," speech presented at the Northern California Section of the Forest Products Research Society, Berkeley, California, May 1965.

   Provides spectra of an idling and processing wood chipper.

4. Schwartz, A., "Noise Survey and Control in a Plywood Factory," Noise Control Conference, Warsaw, Poland, October 1976.

   Describes sound level and treatment (enclosure) for a chipper.

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APPENDIX C.17

ANALYSIS OF WOOD PLANERS

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE Noise exposures of planer operators are in chronic violation of OSHA standards.

The standard straight-knife planer, as furnished by the original equipment manufacturer, operates with average sound levels of between 95 and 115 dB(A) at the operator position, depending on the size of the unit and the material processed. The emissions cause OSHA noise violations in virtually every instance of planer use.* This opinion is based on analysis of the available literature (see Bibliography for Planers) and on direct field experience, and is supported by statements made by both user and supplier industries at the DOL hearings and in private communications made during the performance of this contract.

Standard planers are sometimes treated to reduce their noise levels. Enclosures, for example, have been installed on planers since the 1950s. Enclosures remain the most common kind of noise control retrofitted to existing planers. As they are used, enclosures provide noise insulation for peripheral

*We estimate that typical planer operator noise exposure in planing mills caused by these emissions, and taking the time of exposure into account, range between 150 and 2300% of that allowed by OSHA. Such exposures average about 400%. These are equivalent to continuous exposure to between 93 and 113 dB(A), averaging 100 dB(A). Typical planer operator noise exposures in operations other than planing mills are normally lower than in planing mills, because the machine duty cycle is usually lower. However, daily variation in machine duty cycle can make these other planing operation noise exposures on occasion as high as in planing mills.

personnel working away from the machine, but – because of poor acoustical design – they provide little benefit for the planer operator. (BBN and equipment supplier opinion.)

Also, cutterheads and quiet platen designs are available for retrofit. These can provide enough noise reduction to produce compliance in many installations, but the number of users who have installed the treatment is small. (Equipment supplier information.)

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

Users have difficulty in quieting planers. As the response to FILTER c explains in detail, the major difficulties for the users in dealing with planer noise problems are (1) costs of the available controls, (2) integration of the available controls into normal operations, and (3) solution of the acoustical aspects of the problem. These difficulties are especially serious for the smaller user plants whose resources – financial, technical, and physical – are more limited. Consequently, the user industry as a whole has not solved the planer noise problem, even though some progress is being made.

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE

Planer operators are most exposed to noise only from their own machines. Thus, planers are generally fully responsible for causing planer operator noise violations. *In situ* noise controls, which include enclosures, specially designed cutterheads, and platens, are feasible solutions for at least 70% of the planer OSHA noise problems. Utilization of the available treatments is, and will probably continue to be, significantly compromised by several factors discussed below.

Enclosures

Enclosures are a recognized means of quieting the large planers used for rough-surfacing wood (1, 2).* Equipment manufacturers and trade associations estimate that 50 to 90% of these planers are, in fact, enclosed. Enclosures seldom provide compliance with OSHA for the operator, however, because of the way they are designed or used.

Companies have the following problems with use of enclosures:

- Cost of the enclosures
- Reluctance to provide the necessary acoustical treatment at the feed openings into the enclosure (because any

*Numbers in parentheses refer to the bibliography for planers.

treatment that complicates the simple wall opening causes operational problems when jams occur)

- Getting operators to keep enclosure access doors and panels shut
- Exposure to noise when the operator works inside the enclosure (to adjust the machine).

These difficulties are accepted by the user industry as legitimate reasons for the status quo. However, it is our opinion that these difficulties would be relatively quickly overcome if some new form of incentive to produce attitudinal changes on the part of workers, managers, and plant owners were introduced in the marketplace.

Quiet Cutterheads and Platens

Few enclosures are used on small finishing planers, mainly because enclosures interfere with the need for frequent set-up changes, and also because enclosures on these machines are less effective than on the larger ones, since the feed opening is closer to the source of noise (original equipment manufacturers and trade association communications).

Instead, users are retrofitting the small finishing planers with commercially available quiet cutterheads. These are reported to provide 15 to 25 dB noise reduction. Planer users also employ specially designed platens (table lips placed near the cutterhead) that are claimed to provide 10 to 25 dB noise reduction.*

*These performance claims by the suppliers may be exaggerated for the general case, but they have been shown to provide that benefit in at least some circumstances.

Users encounter the following problems with quiet cutterhead designs:

- Initial cost is high (about 2-1/2 to 4 times as expensive as standard cutterheads).
- The quiet cutterheads are more difficult to maintain (they are more complex than standard straight knives).
- Surface finish problems occur when cutterheads are used in processing unseasoned wood (or wood with a moisture content exceeding 20%).
- The unit does not provide much noise reduction when narrow (3-1/2-in.) boards are processed.
- Quiet cutterhead suppliers estimate that 15% of the machines fittable with the device cannot be made sufficiently quiet to meet the OSHA standard.
- Many of the machines are old, and users are reluctant to spend any money for replacement parts on old equipment.
- There are some machines for which no quiet cutterheads are available. These are mainly the smallest surfaces.

In summary, the unavailability of quiet cutterheads for certain machine designs, the surface finish difficulties in some cases, and the lack of benefit provided in certain operations are problems with which the user industry has difficulty. Research and development by the equipment manufacturer will be needed to solve these problems. Although we think the other user difficulties could be overcome if the proper incentives were provided, we recognize that these controls are often extraordinarily expensive and represent the major impediment to noise control.

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries or production processes.

RESPONSE

Planers are used in 12 different 3-digit industries in the woodworking industry. The distribution of planers within the woodworking industry is shown in Table 1. (*Woodworking and Furniture Digest*):

TABLE 1. DISTRIBUTION OF PLANERS IN WOODWORKING INDUSTRY.

Industry	Planers in Use (%)*
SIC 242	39.4
SIC 243	19.2
SIC 245	1.6
SIC 249	8.7
Total for SIC 24	69.8
SIC 251	14.7
SIC 252	0.5
SIC 253	1.5
SIC 254	3.3
SIC 259	0.4
Total for SIC 25	20.4
SIC 393	1.4
SIC 394	4.7
SIC 399	4.4
Total for SIC 39	10.5

*Out of a population of 24,076 knife planers.

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed for the OSHA formula.

RESPONSE

Reduction of planer noise could reduce the exposure of the planer operator to a level that complies with the OSHA standard.

In secondary operations, planers are usually operated in separate rooms from other machinery. In such cases, reduction of planer noise could achieve compliance with the noise standard. In primary operations, such as planing mills, other noise sources in the planing area include conveyors and cutoffs. The other sources might affect the operator's noise exposure even though planer noise was reduced. However, planer noise generally dominates the planer operator's exposure, so reduction of planer noise would probably produce an acceptable noise level even in planing mills.

FILTER f. On a national basis a minimum of 10,000 operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE

There are no data available on the exact number of workers who tend to work near planers. Therefore, the number of workers impacted by planer noise must be estimated. Our best estimate is that there are close to 20,000 workers directly impacted and close to 80,000 peripheral workers impacted by planer noise.

According to DOC, *Classified Index of Industries and Occupations*, planer operators are counted under "machine operatives, miscellaneous specified," a grouping with hundreds of other worker categories. The number of these operatives given in the *1972 Occupation by Industry* is shown in Table 2. Also presented are the number of workers assisting with planer operations, aggregated by "checkers, examiners, and inspectors" and "graders and sorters." These data suggest that fewer than 46,000 workers are planer operators and fewer than 14,000 workers help out with planer operations.

The following operating scenario can be used to generate a second estimate of the number of operators and peripheral workers exposed to planer noise.

- Assume that 50% of planers "in use" are tended on a given day.
- Assume that the 8,801 in SIC 242 operate with only one worker tending the machine.
- Assume that planers in the remaining secondary operations (24,076 - 8,801 = 15,275) operate with two workers tending the machine. Therefore,

0.50 × 8,801* × 1 = 4,401 workers tend planers in SIC 2421

0.50 × 15,275 × 2 = 15,275 workers tend planers in other SICs

19,676 workers are directly involved with planers.

*See FILTER d.

TABLE 2. MAXIMUM NUMBER OF WORKERS EXPOSED TO PLANER NOISE.

Industry	SIC Code	Number of Machine Operatives, Miscellaneous Specified	Number of Checkers, Examiners, and Inspectors	Number of Graders and Sorters
Lumber and Wood Products	SIC 2421 and 2431	19,895	1,632	1,061
Furniture	SIC 25	19,620	8,602	195
Miscellaneous	SIC 3931, 3944, 3949, and 3993	7,149	1,599	1,000
TOTALS		46,614	11,833	2,256

To the extent that plants operate more than one shift, the total understates the number of workers directly impacted by planer noise. To the extent that the redundancy of plant equipment is under- or overestimated, the number of workers directly impacted is incorrect. From this and other scenarios, we conclude that more than 10,000 operators are impacted.

As far as peripheral workers are concerned, the following assumptions apply:

- 10% of the 21,970 to 22,750 plants outside SIC 2421 using planers (estimates on the number of plants given by DOC and by the *Woodworking and Furniture Digest*, respectively) place their planers in the same area as other plant equipment.
- There are 21 workers per plant (BBN data).
- 95% of the 6,836 to 8,071 plants in SIC 2421 place their planers in the same area as other plant equipment, specifically stackers and cutoff saws.
- There are five workers per plant in SIC 2421 impacted by planer noise.

Using DOC Estimates	Using *Woodworking and Furniture Digest* Estimate
.10×21,970×21 = 46,137	.10×22,750×21 = 47,775
.95× 6,836× 5 = 32,471	.95× 8,071× 5 = 38,337
86,112	86,112

Thus, about 78,000 to 86,000 peripheral workers are potentially impacted by planer noise.

FILTER g. Not considered.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight (8) hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE

Two different kinds of products are sold that can quiet planers; the quiet cutterhead and the modified platen. The amount of quieting claimed by the suppliers is significant. This noise reduction would solve most of the planer noise problems, even if the claims are only partially true. These products are described below.

- Newman-Whitney sells a helical cutterhead that is supposed to quiet planers by 12 to 25 dB(A) and is sufficient, according to the supplier, to quiet about 85% of the planers for which the unit fits. They have sold 191 such heads for roughing planers and 176 for other planers in the past 5 to 6 years. Although no additional information is available, we anticipate that the quiet cutterhead is not sufficient to solve the noise problem for the noisier planers.
- Oliver sells a segmented cutterhead for which they claim 5 to 10 dB noise reductions on straight-bladed cutterheads, of which they say about 90% can be quieted. They only sell new planers fitted with the quiet cutterhead.

- Yates sells a modified platen for which they claim 10 to 20 dB noise reduction over standard units. They say larger companies always buy the option.

The equipment suppliers indicate to us that demand for these products is slowly increasing, as the products are gradually accepted by this conservative industry. It is our guess that the continued availability of noisier but initially cheaper standard components that have proven production capability and a long history of satisfactory usefulness, plus the absence of any incentives to try newer products, probably accounts for most of the reasons why more quiet machines are not being sold. In addition, users are reluctant to purchase the available noise controls because they have no reliable method of ensuring that the use of these available products will achieve compliance with OSHA standards.

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE

Other equipment manufacturers who do not manufacturer noise-reduced machines say their products are already in demand, so there is no need for them to research means for abating noise. Their customers are loyal, and the suppliers thus do not fear competition, for example, from foreign suppliers who are more aggressively pursuing quieting of wood planers. Because their customers do not pressure them to make a quieted product, they are not motivated to do so.

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2. Ibid., "Planing Mills Control High Noise Levels," April 1969.

   Describes enclosures in greater detail.

3. Brooks, T.F. and Bailey, J.R., "Mechanism of Aerodynamic Noise Generator in Idling Woodworking Machines," ASME 75 DET 47.

   Elaborates on next article.

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6. Dost, W.A., "Noise Levels in Software Lumber Mills," *Forest Products J.* 24:8, August 1974.

   Working vs idling noise for various equipment.

7. Edmondson, A.J. *et al.*, "Wood Planer Noise," ASME 75-WA/PID-6.

   Analyses parameters influencing planer noise. Experimental results show 10 to 15 dB noise reductions are possible with flexibly mounted knives or segmented cutterheads.

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Discusses enclosure, damping of boards, and cutterhead design.

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Commentary, using Christman data.

11. Lamb, F.M., "Industrial Noise Control Guideline," *Forest Products J.* 21:11, November 1971, pp. 12-15.

More commentary, converts Christman data to dBA, presents generalized approaches to noise control.

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Typical sound levels for machine categories and some control means.

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Describes relationships between noise emissions and various parameters influencing board noise radiation, sources of planer noise, control mechanisms.

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Assessment of noise suppression system that includes means to prevent workpiece vibration from propagating along entire length of stock.

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Idle and running sound levels for some equipment in five different woodworking plants.

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Spectrum for planers with and without enclosure.

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Foreign Research Projects Involving Planers

France. Noise from Planing Machines, INRS, 30, Rue Olivier Noyer, 75680 Paris Cedex 14 France. M.T. Ho *et al.*, 1977.

The noise emitted by an empty planing machine is essentially due to the rotation of the tool in the air and the passage of the knives in front of the working tables. When the machine is loaded, the noise of the machining of the wood is added to this aerodynamic noise.

Various systems have been proposed to reduce noise emission:

- use of perforated or toothed rim
- use of specially shaped air-guide
- use of spiral knives.

The last are difficult to manufacture and sharpen.

The study consists of verifying the acoustic efficiency and effectiveness of toothed rims and the air guides.

A theoretical study on the aerodynamic noise of the tool will be done to effect a better understanding of the emission mechanism and to optimize the usable reduction devices. No device will be recommended by the INRS if it is not certain that its use will involve no supplementary risk of accident or injury.

Sweden. "Sound Dampened Helical Cutter Head," AB Nora-Gomex, Kvarnvagen, S-713 00 NORA, Sweden. J. Danielsen, 1975-1977. Type: Development (Component).

Reduces noise in machines for planing and thicknessing. The products have been exhibited at the Ligna fair in May 1977 and tests in different applications and machines are carried out.

Sweden. "Reduction of Noise Generated in Sawmill Machinery," Swedish Forest Products, Research Laboratory, Box 5604 S-114, 86 Stockholm 5, Sweden. March 1973-February 1977.

The aim of this project is to ascertain how noise is generated and what machinery conditions can be influenced with a view to reducing the noise level.

West Germany. "Possibilities of Reducing Noise Emission by Lumber Processing Machinery," Inst. for the Physics & Behavioral Tech. of Wood, Fed. Research Inst. for Forestry and Lumber Economy, Hamburg 80, Leuschnerstr. 91C West Germany. Prof. Dr. Noack.

APPENDIX C.18

ANALYSIS OF WOOD AND METAL SAWS

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- Users and manufacturers acknowledge that saw noise is a significant, if not the predominant, noise problem in the woodworking industry (testimony at DOL noise hearings). Saw noise is also a problem in the metal industry, but it is restricted to more specific operations such as cutting aluminum extrusions, structural steel members, or cast metal parts.

  Saws are listed as the highest priority machine needing noise control effort in the metal industry and as an important machine needing effort in wood, lumber, and paper industries, according to EPA's Noise Technology Research Needs.

- Extensive industry and government-sponsored work has been initiated or completed on saw noise, including fundamental research projects, "design" guide documents, and demonstration programs.

- Over 70 articles on saw noise have appeared since the 1950s (see Saw Bibliography).

- Very few published data are available on noise exposures caused by saw operation, although there is a lot of scattered information on noise emissions of certain kinds of saws. The best available data on exposures are contained in two BBN projects – the Sawmill Noise Control Engineering Guide and the Noise Control Design Guide for Moulding and

Millwork Plants. These contain statistical assessments of noise exposure ranges for much of the equipment considered here. These data, supplemented with data from other studies in our files, indicate that noise exposures for the saw types considered can exceed OSHA limits. However, the data also show that there is a great deal of variability in noise exposures for any single kind of saw. Variability in noise exposure is attributable to how and where the saw is used and the kind of material processed.

- There are 13 major categories of saws considered in this analysis. Each saw is in essence a different machine. The groupings are:

  Headrigs, quadsaws, and resaws used in primary lumber industries
  Resaws used in secondary lumber industries
  Bandsaws
  Friction saws
  Variety saws
  Ripsaws
  Edgers
  Radial arm saws
  Chop saws
  Cutoff saws
  Trim saws
  Panel saws
  Abrasive wheel saws.

- Details about the noise exposure problem caused by the various kinds of saws considered in this analysis are provided in Filter f. A brief description of each of the saw categories is provided at the end of this analysis.

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- User industries experience significant difficulty in complying with the OSHA standard.
- The user industries have sought ways of reducing saw noise. They have sponsored research and applications-oriented studies on noise, and they continue to sponsor such studies. Because of this work, a "quiet" circular saw blade is manufactured that free-turns (idles) 8 to 10 dB more quietly than the typical standard blade. Many blade manufacturers now use these design techniques in their production. Design guides are also an outcome of this work. These are available to help users design practical noise controls.
- A workable noise emissions measurement standard for woodworking tools, including saws, has been developed by the Woodworking Machinery Manufacturers of America (WMMA).
- Notwithstanding these developments, throughout many of the user industries noise environments associated with saws remain substantially unchanged from what they were before OSHA (BBN and equipment manufacturer opinion).

- Users are reluctant to install *in situ* noise controls (see Filter c), preferring to purchase quiet equipment when and where possible. Following is a quotation from exhibit 150A of the DOL noise hearings:

  > The users of woodworking machinery look to the manufacturers to supply machinery that will not cause levels of noise exposure in excess of values prescribed in the Act (OSHA Act of 1970).

  According to at least one manufacturer, this is an outcome of the conservative nature of the industry; customers prefer to have new concepts proven to them before they will consider adopting the concept themselves. Since no one wants to take the first step, progress is slow.

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE

- There are no off-the-shelf noise controls for saw noise problems.* That is, no user can purchase a

*Except, perhaps, for the atypical problem, such as the resonating or "screaming" saw blade. Several techniques that might be considered off-the-shelf controls are discussed in the literature for this problem (various damping techniques, replacement of the blade, retensioning the blade, slitting the blade, etc.).

noise-suppression package for any of the saws considered here.

- "Standard" noise controls (enclosures, barriers, room treatments, etc.) can solve virtually all the saw noise problems. Affected industries can obtain information about the specific kinds of treatments they could use from the available literature. Users are faced, however, with the following problems in making use of the available information: (1) The available information is of varying quality, and the users may be easily confused, misled, or put off by some of it; (2) Successful case histories are lacking for most of the treatment concepts, so users can ascribe little confidence to the designs given; (3) Users are aware of the unsuccessful attempts at noise control. However, they may not fully understand or appreciate why these attempts failed, and thus they may draw improper conclusions about the noise control concept. This misunderstanding fosters a natural reluctance to pursue such work, even though it might be constructive.
- BBN's assessment of the likelihood of installation of the technically possible *in situ* controls is that very little will be done, mainly because of the costs involved. Table 1 summarizes the possible *in situ* controls and the reasons why installations of *in situ* controls are not likely to be accomplished. Note that use of quiet saw blades is not listed in the above analysis. This treatment is omitted because idling saw noise seldom dominates a noise exposure. Noise during cutting is most critical.

TABLE 1. POSSIBLE *IN SITU* TREATMENTS AND LIKELIHOOD OF IMPLEMENTATION.

Saw	Treatment	Potential Benefits	Likelihood of Being Implemented (1 = High, 2 = Moderate, 3 = Slim)
Headrig, quadsaw, resaw in primary lumber	Operator Booth	~5,100 overexposures eliminated	2 — moderate cost
	Wall Off Area	~61,000 peripheral workers would then be exposed only to noise of their own machines	2 — moderate cost
	Automate Equipment	~1,000 overexposures eliminated	3 — high cost
Resaws	Enclosure	~12,100 overexposures "eliminated"* ~16,100 peripheral workers' noise environments improved	2 — moderate cost
Bandsaws	Barrier	Small fraction of 27,500 overexposures "eliminated"*	2 — barrier makes it more difficult to operate
	Automate Equipment	27,500 overexposures "eliminated"*	3 — high cost
Friction Saw	Automate Equipment	Small fraction of 10,900 overexposures "eliminated"*	3 — high cost
Variety	Improved blade guarding, partial enclosure	~5,400 overexposures "eliminated"*	2 — guarding requires development, partial enclosure makes it more difficult to operate
	Barriers and room treatment	Necessary in high production areas to achieve above benefit	2 — spatial constraints
Ripsaws	Open top enclosure	~39,700 overexposures "eliminated"** ~119,100 peripheral workers would then be exposed only to noise of their own machines	3 — high cost
	Barrier and room treatment	~39,700 peripheral workers would then be exposed only to noise of their own machines	3 — because above is necessary first
Edger	Operator booth	Fraction of 13,200 overexposures "eliminated" (automated machines)	2 — moderate cost
	Enclosure	Fraction of 13,200 overexposures "eliminated"** ~41,800 peripheral workers would then be exposed only to noise of their own machines	3 — high cost
Radial Arm	Improved blade guarding	Majority of ~5,200 overexposures "eliminated"	2 — requires development
	Barriers and room treatment	Necessary in high production areas to achieve above benefit	2 — because above is necessary first, spatial constraints

TABLE 1. *(Cont.)*

Saw	Treatment	Potential Benefits	Likelihood of Being Implemented (1 = High, 2 = Moderate, 3 = Slim)
Cutoff in primary lumber and metals	Operator Booth	~23,200 overexposures "eliminated"**	2 – moderate cost
	Partial (blade) enclosure	Portion of 23,200 overexposures "eliminated"*, may be necessary as supplement to booth ~67,800 peripheral workers would receive some partial benefit	3 – high cost
Cutoff in Secondary lumber	Barrier and room treatment	~12,900 overexposures "eliminated"*	2 – spatial constraints
Trimmers in primary lumber	Operator Booth	~20,400 overexposures eliminated	2 – moderate cost
	Partial operator booth (for feeders)	~4,100 overexposures eliminated	2 – moderate cost
	Enclosure	~24,500 overexposures "eliminated"** ~61,100 peripheral workers would then be exposed to noise only from their machines	3 – high cost
Trimmers in secondary lumber	Enclosure	~7,400 overexposures "eliminated"**	2 – moderate cost
Abrasive wheel saws	Enclosure	~23,600 overexposures "eliminated"** ~70,800 peripheral workers would then be exposed to noise only from their own machines	2 and 3 – moderate cost, enclosure would hamper productivity on hand-operated saws used in trimming operations

*The workers who tend these machines are impacted by sounds from other equipment in the plant, and thus the overexposure is not truly eliminated. Also these same workers may tend other equipment on other days, which are also capable of causing a noise overexposure.

**The workers who tend these machines are impacted by sounds from other equipment in the plant, and thus the noise exposure is only reduced, not eliminated.

The quiet blades do not reduce cutting noise. Quieting blades alone would reduce many of the noise exposures by only a few dB at most. The treatments listed above include both idling and cutting noise.

- Our sampling of contested OSHA citation cases shows nine involving saws or sawmill equipment. Of these, only two discuss the feasibility of noise controls, and these seem to indicate that economics is of concern to the cited parties. The cases reviewed are given in Table 2.

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries or production processes.

RESPONSE

- According to DOC data, sawyers are found in every two-digit SIC industry. There are no details available about the kinds of saws these workers operate in the DOC publications. We assume that most of the sawyers outside SICs in the wood and metal industries tend carpentry saws, such as portable electric saws, small table saws, and radial arms saws, even though a small number of saws are also used for production in these other SICs (e.g., for cutting plastic sheeting). Because of the apparently small numbers of people involved and the difficulties in obtaining data for these other industries, our analysis is limited to saw equipment used only in the wood and metal industry.

TABLE 2. CONTESTED OSHA CITATION CASES INVOLVING SAWS OR SAWMILL EQUIPMENT.

Case Number	Cited Company	Cited Table Equipment	Comment
78-439	Masonite Corp.	Cutoff saw	Failure to comply determined to be beyond employers control, abatement period extension granted.
6435	Bonners Ferry Lunber	Sawmill	Legal technicality.
6832	Union Timber		Vacated because actual exposure was not assessed. Also employers could find no feasible control due to uniqueness of design and necessity to adapt machinery to meet competition.
1134	Idaho Travertine	Trimsaw	Violation for lack of use of hearing protection.
1231, 1758	Weyerhauser	Sawmill	Legal technicality.
2200	B.W. Harrison Lumber	Sawmill	Legal technicality.
3905	Union Camp	(Planer mill) and saws	Legal technicality.
4734	J.W. Black Lumber	Sawmill	Hearing conservation program issue.
6277	Louisiana Pacific	Sawmill	Controls not shown to be economically feasible, secretary did not prove levels would be substantially reduced, even though he did show controls are available.

- According to the editors of the *Woodworking and Furniture Digest*, their inventory of woodworking machines applies mainly to woodworking facilities outside of SIC 242 (sawmills and planning mills). Their data show that resaws, bandsaws, variety saws, ripsaws, radial arm saws, chop saws, cutoff saws, trim saws, and panel saws are found throughout the 22 four-digit woodworking industries in SICs 24, 25, and 39.
- According to the *American Machinist's Inventory*, bandsaws, friction saws, cutoff saws, and abrasive wheel saws are found throughout the various sub-groupings of metalworking industries in SICs 33 to 39.
- The remaining saws – headrigs, quadsaws, large resaws, edgers, large cutoffs, and large trimmers – are used principally in SIC 242.

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed by the OSHA formula.

RESPONSE

- The complexity of noise problems associated with saw equipment is described in more detail at the end of this analysis. From this material, it appears that some saws, principally the larger production units, are clearly the dominant noise source in the plants in which they are used. If these were quieted, some noise exposure reductions could be anticipated for peripheral workers as well as for the people associated with the big machines themselves. However, most of the peripheral workers overexposed to noise would probably remain overexposed, because their own machines are also noisy. If the noise of all saws was sufficiently reduced, the noise exposure of these operators would be in compliance with the OSHA standards.

FILTER f. On a national basis a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type or class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE

- More than 10,000 operators are impacted.
- According to DOC data, the number of sawyers in the manufacturing industries is as follows:

Industry	No. of Sawyers
SICs 24, 25, and part of 39	60,206
SICs 33-38, and part of 39	16,795
All other 2-digit SICs in manufacturing	5,531

Again, the sawyer category is not broken down by saw type in the DOC publication. These sawyers are people who are specifically assigned to operate particular machines. Many of the saws can, however, be operated by other classifications of workers besides sawyers, and thus the number of workers impacted is considerably larger than indicated by the above figures. In addition, many of the saws are sufficiently noisy to contribute to the general noise environment in the plants in which they are used. Our assessment of the number of workers impacted by each type of saw is given in Table 3. The assessment is primarily based on the BBN work described in FILTER a.

FILTER g. Not considered.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE

- Manufacturers currently do little to provide noise control for saws. Irvington-Moore and Stetson Ross sell trimmer saws that are acoustically treated (partially enclosed) and quieter than their unsilenced

TABLE 3. MAJOR CATEGORIES OF SAWS ANALYZED, NUMBER IN USE, AND NUMBER OF WORKERS IMPACTED.

Saw	Number in Use	Approximate Number of Operators Impacted [OSHA Noise Exposure dB(A)]	Approximate Number of Peripheral Workers Impacted [OSHA Noise Exposure, dB(A) Attributable Only To Machine in Question]
Headrigs, quadsaws, and resaws in primary lumber	10,235 (BBN files)	5,100 at 93-103[a] 1,000 at 99-112[b]	61,000 at 90-100[*,c]
Resaws in secondary lumber	8,059 (WFD)†	12,100 at 90-95[d]	16,100 at 85-90[*,e]
Band saws	60,277 in metals (AMI)‡ 31,316 in wood (WFD)	27,500 at 90-100[g,**]	
Friction saws	7,242 (AMI)§	10,900 at 90-100[h,**]	
Variety saws	17,834 (WFD)	5,400 at 90-95[i,**]	
Ripsaws	39,702 (WFD)	39,700 at 98-103 39,700 at 90-95	119,100 at 85-90[*,j]
Edgers	13,941 (BBN)	13,200 at 92-98[k]	41,800 at 89-95[*,l]
Radial arm saws	34,786 (WFD)	5,200 at 90-95[m,**]	
Chop saws	11,918 (WFD)	1,800 at 90-95[m,**]	
Cutoffs	25,723 in secondary wood (WFD)	12,900 at 90-92[n,**]	
	5,588 in primary wood (BBN)	5,600 at 98-100	16,800 at 92-94[*,o]
	16,944 in metals (AMI)	17,000 at 90-105	51,000 at 84-98[*,o]
Trimmers	20,382 in primary wood (BBN)	4,100 at 96-106[p] 20,400 at 94-104	61,100 at 88-98[*,o]
	7,422 in secondary wood (WFD)	7,400 at 90-95	
Panel saws	7,351 (WFD)	No data	
Abrasive wheel saws	23,607 (AMI)	23,600 at 90-105	70,800 at 84-99[*,o]
Totals	Wood saws — 226,906 saws, 183,004 operators Metal saws — 108,070, saws, 69,601 operators		

Notes to Table 3.

†*Woodworking and Furniture Digest.*

‡*American Machinists' Inventory.*

*Peripheral workers also incur noise exposure from their own machines.

**All workers who use the machine incur at least some partial noise exposure from its operation, since sound levels exceed 90 dB(A) at least part of the time. The quoted figure is the number of workers who would be noise overexposed just from operation of the saw being considered.

[a]Assumes half the operators of these machines are already in noise-insulated booths.

[b]Assumes 10% of the machines in use employ tail-off operators.

[c]Assumes 6 distant peripheral workers impacted per machine.

[d]Assumes average of 1.5 men per machine.

[e]Assumes 2 nearby peripheral workers impacted per machine.

[f]Assumes 10% of the operations expose workers to 90 to 100 dB(A) L_{OSHA} on a given day, and that an average of 3 workers per plant may use the saw on a given day.

[g]AMI includes friction saws in the category of "other" saws, and the quoted figure is a total for the "other saw" category. It is thus an upperbound estimate.

[h]Assumes 75% of the operations last a full day and that there are 2 people per plant specifically trained to operate the saw.

[i]Assumes 10% of the operations expose workers to 90 to 95 dB(A) L_{OSHA} on a given day and that an average of 3 workers per plant may use the saw on a given day.

[j]Assumes 3 nearby peripheral workers impacted per machine.

[k]Assumes 5% of the machines are equipped with noise insulated booths.

[l]Assumes 3 distant peripheral workers impacted per machine.

[m]Assumes 5% of the operations expose workers to 90 to 95 dB(A) L_{OSHA} on a given day and that an average of 3 workers per plant may use the saw on a given day.

[n]Assumes 50% of operations exceed 90 dB(A).

[o]Assumes 3 distant peripheral workers impacted per machine.

[p]Assumes 20% of operations have a feed operator.

models. These sell well in planing mills, where trimmer saws are located in areas that are not impacted by other equipment noise. They do not sell well in saw mills, because buyers are reluctant to purchase quiet equipment for use in areas that are noisy because of other operations. Oliver sells cutoff saws with acoustically treated guards that quiet idling blade noise.

- Manufacturers generally refer customers to contractors who could build enclosures. They admit, however, that none of their customers are actually planning to take such steps.
- Foreign manufacturers are actively pursuing means of quieting their products, and they sell more quieted machines than do American manufacturers. The foreign companies are generally bigger. They serve a worldwide clientele and have greater pressure on them to produce quieted equipment. They also have a more ready market for quiet products. According to some domestic manufacturers, foreign producers are also more eager for markets and so are more willing to do the necessary research and development to quiet their products.

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE

- Most American manufacturers of saw equipment are small firms; research and development for quiet models is difficult for them.
- Users put little pressure on the manufacturer to supply them with quieted equipment.
- Users are generally loyal to a particular equipment supplier; if only one offers a noise control (or other) innovation, the users will wait until their own supplier sells it.
- Even when foreign manufacturers provide quieter machinery, domestic manufacturers believe that the introduction of quieter products will not have much impact here, because of the loyalty of American customers to their traditional suppliers.
- The possibility for noise reduction through manufacturer-applied noise control is significant. More or less standard noise control principles can be applied to new designs to provide built-in quiet. The major problem is in integrating operational and acoustical requirements for the machine; some reluctance to make the design changes can be anticipated, because the manufacturers are used to traditional features (such as "openness"), and this reluctance would have to be overcome. Our assessment is that the designs can be made to work acoustically and functionally. The kinds of control that we believe could be developed include the following:

Enclosures for headrigs, quadsaws, resaws, ripsaws, edgers, trimmers, and abrasive wheel saws

Damped feed systems and blade tensioning devices, along with noise barriers for band and friction saws

Improved safety guarding systems and partial enclosures for variety saws

Improved guarding systems and damped stock hold-down systems for cutoff saws.

- In addition to standard noise control principles, there is significant promise for machine features that damp saw blade vibration during idling and cutting. Devices that could accomplish this damping have been designed and tested in prototype form here and abroad. These devices alone could significantly reduce overall noise emissions of saws for which stock vibration is of secondary consequence. Further research should be directed to this area.

TYPES OF SAWS ANALYZED

Headrigs, Quadsaws, and Resaws (primary lumber). These are large, basic sawmill processing machines used for raw timber breakdown (converting logs to lumber). They are semi-automated and operate continuously. The operator generally works from a console and is sometimes furnished with a noise-insulated cabin. However, the emissions from these machines impact the general noise environment in most mills, and in particular, they impact off-bearers who may assist in the material-handling at the machine. Typical unprotected operator noise exposures are in the 93 to 103 dB(A) L_{OSHA} range. Typical off-bearer noise exposures are in the 99 to 112 dB(A) L_{OSHA} range. Noise from both the cutting tools (usually bandsaws, but occasionally circular saws, and often chipping heads) and from wood being processed appear to be important.

Resaws (secondary lumber). These are essentially large bandsaws. Generally, a feeder and a sorter work the machine. Typically, the resaw is run continuously for several hours followed by a period of nonuse. The machine operation may impact nearby operations and may also be impacted by them. Typical noise exposures for both feed and sorter workers are in the 90 to 95 dB(A) range.

Band Saws. These are useful to both wood and metal processing industries because they are capable of machining irregular shapes and they have a narrow kerf (width of cut). They are seldom a continuous production machine, but they may run for many hours when processing quantities of special items. Idling noise is generally of secondary importance. Both blade and stock vibration contribute to cutting noise. Most cutting operations generate 90 to 95 dB(A) at the operator position, but work with some sheet metals can generate 95 to 105 dB(A) at the operator position. Noise exposures thus vary from well below 90 dB(A) L_{OSHA} to as much as 100 dB(A) L_{OSHA}. Usually, the bandsaw or bandsaw noise is of minor significance to the general noise environment.

Friction Saws. These are used only in the metal industries. Heat generated by the blade/work interaction causes the work to become locally plastic. The blade pulls the softened metal away, making a cut. Because of higher blade speed, idling noise is more significant, but here again, the machine is used only part-time. The sound level at the operator position is in the 98 to 103 dB(A) range during processing. Noise exposure depends on the duty cycle of the machine. Usually the friction saw is of minor significance to the general plant noise environment.

Variety Saws. This is essentially a table saw. Once again, operator noise exposures will depend on how the machine is used. Idling noise is typically 85 to 90 dB(A), cutting noise in the 95 to 105 dB(A) range. Idling time is often long in comparison to cutting time; hence, exposures are generally low. Usually table saws are minor contributors to the general noise environment.

Ripsaws. These are used specifically to cut lumber along the board length. Ripsaw machines may have an automatic feed or may be manually fed. Generally, there is a sorter who also works with the machine, at a greater distance from the machine than the operator. These are usually continuous production machines and are thus used full time and have assigned personnel. Noise emissions vary considerably, depending on the number of blades used, the type of wood processed, and the feed speeds. Generally, noise exposures for the operator are in the 98 to 103 dB(A) range, and the 90 to 95 dB(A) range for the sorter. The machine noise also impacts nearby personnel.

Edgers. These are essentially multibladed and may be semi-automated or manually fed. There is usually only one operator per machine. Occasionally operators are provided with noise-insulated booths. Typical operator noise exposures are in the 92 to 98 dB(A) range L_{OSHA}.

Chop Saws. These saws are used for quick production of lumber rough-cut to length. They work through plunging of the saw into the workpiece. Their operation is generally intermittent, and although many workers may use the saw, few are overexposed because of it.

Cutoffs. In the cutoff operation, a saw blade moves across the width of the material being processed, cutting it to length. There are many configurations; some are small, hand-tended, single-bladed units (used in metals and secondary wood operations); some are large, semi-automated, multibladed machines. Cutting noise predominates with these machines, the most significant cutting noise occurring for metal cutoffs, where the cut duration is longest. Idle noise may be high and of relatively long duration for these machines. Typical noise exposures are:

in secondary wood operations	88 to 92 dB(A) L_{OSHA}
in primary wood operations	98 to 100 dB(A) L_{OSHA}
in metal operations	90 to 105 dB(A) L_{OSHA}.

The latter two types may be significant contributors to the overall noise environment. The first two are generally noise-impacted by other equipment.

Trim Saws (trimmers). Trimmers are used to cut wood to length. They differ from cutoffs in that the wood moves into the blade rather than the blade traversing the wood. In primary wood processing, the trimmers are equipped with many blades and the blades are axially adjustable by the operator working from a console. A feeder may also be present. In secondary wood processing, trimmers generally have one or two blades, and the operator hand feeds the machine. Typical noise exposures are 90 to 95 dB(A) L_{OSHA} for the smaller units, and 94 to 104 dB(A) L_{OSHA} for operators of the larger ones [96 to 106 dB(A) L_{OSHA} for the feeder, if present].

Panel Saws. These are similar to the saws used in lumber yards to cut plywood sheets, but they are larger and work automatically once set up. We have no direct experience with panel saws.

Abrasive Wheel Saws. These saws are used in the metals industry; they are essentially grinders, which cut by wearing away metal. They function much like cutoff saws, and noise exposures caused by these machines are about the same as those caused by cutoffs used in the metal industry.

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APPENDIX C.19

ANALYSIS OF CRAWLER TRACTORS GREATER THAN 150 HORSEPOWER

FILTER a. The given industry(s) and/or particular production process(s) are in chronic violation of present OSHA standards.

RESPONSE

- Although the construction industry has a violation rate of only 3% (mining industry violation rate is unknown), there is evidence to suggest that operators of crawler tractors (bulldozers) greater than 150 horsepower are chronically exposed to noise levels in excess of the 8-hr, 90 dB(A) standard (1, 4)*.

FILTER b. The degree of difficulty user industries presently encounter in meeting an eight-hour 90 dBA environmental noise standard level and for which the most direct remedial action on their part would be a request for administrative controls, applications for variances, or other types of relief which would permit the continued production of their products without correction of the noise violation.

RESPONSE

- Users of these crawler tractors often do not have the technical skills to develop the required noise control treatments to reduce exposure of the worker to within the standard. Therefore, they have difficulty complying with OSHA and MSHA (Mine Safety and Health Administration) standards.

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*Numbers in parentheses refer to the references for crawler tractors.

FILTER c. The degree to which the noise level of a given work environment exceeds an eight (8) hour 90 dBA standard principally because of the operation of a single type or class of machine and for which *in situ* retrofit noise control is not possible or can only be achieved at extraordinary expense.

RESPONSE

- The noise exposure of the operator is controlled by the noise from his machine. The major sources of noise on the crawler tractor are the engine exhaust, engine casing, and fan. *In situ* noise control treatments include: muffler for the exhaust, windshield (if the machine does not have a cab), absorptive material on the FOPS (falling object protective structure), and sealing holes (floor, dash, battery cover, control levers, and seat) for a crawler tractor with a cab. The treatments reduce typical working noise levels for a machine without a cab from about 105 dB(A) to about 94 dB(A), under high idle conditions. For operators exposed to this level for more than about 4.5 hours, the exposures are still in excess of the OSHA/MSHA standards.
- For crawler tractors with cabs, typical reductions are from 100 dB(A) to 90 dB(A), with doors closed and under hign idle conditions. Depending on the type of activity, operation of the blade can increase the noise levels and the exposure of the operator. No quantified exposure data for typical operators are available.

FILTER d. The commonality of a major noise producing piece of equipment to multiple industries or production processes.

RESPONSE

- Crawler tractors are used in many industries, including agriculture, forestry, mining, construction (both durable and non-durable), and manufacturing.

FILTER e. The degree to which reduction of the noise level of the identified type or class of machine would result in an eight (8) hour environmental noise level equal to or less than 90 dBA* as computed by the OSHA formula.

RESPONSE

- The noise exposure of a crawler tractor operator is primarily controlled by the noise of his own machine. If the noise of the crawler tractor is reduced sufficiently, the operator's exposure can be brought into compliance with the OSHA regulation.

FILTER f. On a national basis a minimum of 10,000 machine operators and/or 50,000 peripheral workers are impacted by the noise emission of the selected machine type of class and thus would realize direct benefit from noise reduction actions on this specific device.

RESPONSE

- More than 10,000 operators are impacted by crawler tractor noise.
- In surface coal mines alone, more than 13,000 operators are exposed to noise in excess of the 90 dB(A) standard (1). If the noise of these machines were sufficiently reduced, the exposure of the operators would be in compliance with the OSHA regulations.
- Although there are no estimates of the number of operators who are overexposed in the other industries, it is not unreasonable to think that these crawler tractor operators are also overexposed when they work for more than four or five hours per day. Of the 57,385 crawler tractors used in construction (3), 8,125 are greater than 200 horsepower and are thus likely to cause overexposure of the operator. At 1 to 1.5 operators per machine (1), we estimate that 8,000 to 12,000 operators in construction work could be overexposed to noise, according to the OSHA standard.

FILTER g. Not considered.

FILTER h. See Appendix D, Industrial Machine Trends.

FILTER i. There are currently available quieted versions of the selected machine which are capable of meeting an eight hour, 90 dBA noise level requirement but for specific reasons (to be determined by contractor) do not make up a large percentage of machines currently in use or being sold.

RESPONSE

- Most manufacturers will supply a quieted version of the crawler tractor (>150 horsepower). In general, the manufacturers of these machines have elected to expand the ROPS/FOPS concept into a totally enclosed cab with sufficient noise control in the cab to meet the regulation. The primary reasons more of these units are not purchased are the additional cost of the cab (about 10% of purchase price), the reliability of the required air conditioning, and the reluctance to set a precedent of buying the first air-conditioned cab for their fleet.

FILTER j. There is available appropriate noise abatement technology which can be applied to the selected machine but for unknown reasons (to be determined in detail by the Contractor) has not been applied to the selected machine.

RESPONSE

- Noise abatement can be designed into all crawler tractors using available technology. In those instances where this has not been done, the primary reason is the lack of demand which is caused by increased cost and potential problems associated with air-conditioned cabs.

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APPENDIX D

INDUSTRIAL MACHINE TRENDS

Prepared by

Research Triangle Institute

RESEARCH TRIANGLE INSTITUTE

Contract No. 68-01-5036
RTI Project No. 41U-1726

February 25, 1980

Industrial Machine Trends

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Industrial Machine Trends

1. Introduction

This paper provides trend projections in several industrial machines including:

- metalworking machinery group
  - automatic screw machines
  - pedestal grinders
  - mechanical presses
  - mechanical shears
  - metal saws
  - tumblers
- textile machinery group
  - twisting frames
  - spinning frames
  - looms
  - knitting machines
  - draw frames
- woodworking machinery group
  - chippers and hogs
  - wood saws
  - planers
- foundry machinery group
  - moldmaking machines
  - shakeouts
  - furnaces
- miscellaneous machinery group
  - handtools
  - bulldozers

The four variables that are projected for each of the machines are: capital stock (the number of machines in place), domestic capital flow (the number of machines produced each year less exports), depreciation (the number of machines retired from service each year), and imports. The relevant projections are shown on the attached tables.

The methodology used to make the projections differs slightly for each of the industry groups due to differences in data availability. In general, the projected values are calculated by using an algorithim based on parametric values derived from historical datum. That is, historical relationships between the variables of interest and other economic variables are estimated. Then, given projections of the related economic variables, the historically generated parameters are used in the functional relations describing the determinants of the four basic variables to project their future values.

There are three variants of the methodology for providing the projections. One method is used for the metalworking machinery, a second different method is used for textile machinery and a third method is used for woodworking machinery. The foundry machinery group and the miscellaneous machinery group both use roughly the same method as is applied to woodworking. Each of these methods provides projections of the four variables of interest. The methods are discussed below for each of the industry groups. The final section provides a discussion of the limitations of the analysis.

2. Metalworking

The estimates of the four economic variables for the metalworking machinery industry includes the industry group for metal cutting machinery (SIC 3541, automatic screw machines, metal saws and pedestal grinders are the specific types of capital equipment), and the group metal forming machinery (SIC 3542, mechanical presses and mechanical shears are the specific capital equipment types). The projections for tumblers, which are included in metal cleaning and finishing equipment (SIC 3548), are calculated differently as is discussed below.

The estimates of the capital flows are the basis of the projections. A historical relationship is estimated between the production (capital flow) levels of the specific types of capital equipment and the constant dollar sales volumes of the major consuming industries.

$$^{t}K_{i} = f(^{t}Q_{ij}) \quad t = 1958, \ldots, 1976$$

where $^{t}K_{i}$ = output of capital equipment type (e.g., 1367 pedestal grinders produced in 1976)

$i = 1, \ldots, 4$

$^{t}Q_{ij}$ = dollar value of sales revenue for major industries consuming capital equipment type i (e.g. the $70M sales in 1976 of the motor vehicles industry which is the largest consumer of pedestal grinders)

$j = 1, \ldots, 5$

This relationship is estimated in an ordinary least squares econometric model. Then using projections of constant dollar sales (Q_{ij}) from the U.S. Bureau of Economic Analysis for the 1985-1990 period, capital flow ($\hat{K}$), is projected over the period.

The next step is to obtain the projections for the depreciation of the capital stock and the level of the stock. This is based on a conventional economic procedure where the survival probability of a machine of a given age or vintage is empirically determined based on historical data. This survival probability assumes the form of a logistic function and the specific probabilities for each vintage of machine are estimated using the probit econometric estimation technique.

The flow of machines, or the annual production, is then used in a simple multiplicative step to establish the expected number of surviving machines of a given vintage for the period 1985-1990. Thus, for one of these years the summation of the survival probability times annual production over all machine age vintages yields the surviving capital stock. Differences in this sum between years less the projected year's production (or capital flow) yields the depreciation over that projected year. This process is repeated for each year from 1985 to 1990 to obtain the capital stock and the level of depreciation over the period.

The level of imports and exports is calculated based on an observed trend in the relationship of imports and exports to total domestic usage of the capital equipment type. This relation is projected for the period 1985-1990 using a regression equation. Imports and exports are calculated as a function of the annual projected capital flows for the same period.

The estimation of the projections for tumblers departs from the methods used for other metalworking machinery. In fact, the third method, discussed below, is what is employed to project the four economic variables for tumblers. Briefly stated, an industry source provided an inventory of tumbler machines in place in a recent year. It is assumed that the stock of tumblers will grow at a constant rate over the period. The growth rate is that observed for all metal-working machinery in recent years according to Predicasts Basebook. The output and depreciation of tumblers is estimated as a constant proportion of the capital stock. The ratios used are those observed for other metalworking machines. The export and import data are also estimated as a constant ratio of exports and imports to output. The ratio used are those for all metalworking machinery.

3. Textile Machinery

The estimates of the four economic variables for textile machinery are discussed below. The textile machinery industry (SIC 3552) is included in the special industrial machinery group (SIC 355). The specific types of textile machines examined are looms, knitting machines, draw frames, spinning frames, and twisting frames.

The textile equipment projections are largely based on ad hoc procedures. The shortage of published statistics on this industry precludes a more refined analysis. There was only one complete annual time series available, for only one type of machinery. Thus, it was necessary to rely on data for the benchmark years of the Census of Manufactures for the other equipment types. In addition, the depreciation rate schedule was simply borrowed from the depreciation analysis used in the metal working machinery case. The methodology used for each type of industrial machinery will be reviewed in turn.

The time series was for the number of looms in place, and it was used to develop a regression equation which showed looms in place to be a function of the five largest consuming industries sales. Then, using data from the Bureau of Labor Statistics (BLS) on projected future sales in the consuming industries, it was possible to project the number of looms in place through 1990. The estimates of the capital stock for looms and the other textile equipment types used a relationship observed for knitting machines in 1972, i.e., that approximately eight percent of the stock of machines in place were provided by the annual production of this type of textile machinery. This same percentage was then applied to all textile equipment types.

The estimates of the foreign sector used the observed ratio of the value of all exports and all imports of textile machinery to the value of domestic textile machinery production over the last ten years. The average percentage of foreign to domestic commerce for all textile machinery was then applied to the domestic capital flow for each type of equipment. Therefore, the estimates of the foreign sector assumes that the ratio of foreign to domestic commerce is the same in the selected capital equipment types as is observed in the entire textile equipment industry.

The estimates of the number of knitting machines, draw frames, twisting frames, and spinning frames produced per year are derived from regressions of the annual production in bench mark years as a function of constant dollar sales in the two largest consuming industries. However, since only four observations were available from the benchmark years, the projections using this regression model are subject to sizable variance. Unite sales of textile machinery were projected based on the BLS data for the future value of constant dollar sales in the major consuming industries. The machinery sales projections were then used to estimate the capital stock assuming that a constant percentage of the stock is accounted for by the capital flow or the annual production. The same depreciation schedule was used for these types of textile machinery as was estimated for specific metal-working machinery. The foreign sector was projected assuming a constant percentage of exports and imports to total sales, as was observed in the entire textile equipment industry.

4. Woodworking Machinery

The estimates of the four economic variables for the woodworking machinery industry are discussed below. The woodworking industry (SIC 3553) is also classified within special industrial machinery (SIC 355). The specific types of woodworking machinery which are evaluated below are planers, chippers and hogs, and wood saws.

The estimates for the projected number of woodworking machines are subject to the largest error. The limited information available showed only the stock of each machine in place in 1978. This stock figure was projected through 1990 using the estimated annual rate of growth in the entire woodworking industry from Predicast, Inc. Thus, the stock of machines was projected assuming the growth rate of the entire industry was representative of the growth in the stock of each machine.

The flow of each type of woodworking machines or the annual production was assumed to be the same eight percent of the capital stock as was observed for the textile machinery group. The depreciation rate used for these machines was the same as that for metalworking. Finally, the foreign sector was estimated using an average ratio of the value of exports and imports to the value of domestic production for all woodworking machinery. The average ratio of foreign to domestic commerce was calculated using Predicast data for the three years from 1974 to 1976.

5. Foundry Equipment

The estimates of the four economic variables for foundry equipment are now discussed. The foundry equipment industry (SIC 3559) is another member of the special industrial machinery group (SIC 355). The specific types of capital equipment are molding machines, shakeouts, and furnaces. However, furnaces are actually classified in a separate industry industry (SIC 3567).

The estimates of the projected number of units of foundry equipment are provided using a method similar to that for woodworking. The conventional published data sources from the U.S. Commerce Department did not provide any indication of the number of units produced or in place for the foundry equipment industry. Since foundry equipment has a substantial variability in its technological specification, the compilation of data on the quantities of units is not available. That is, a molding machine is a label used to describe both a machine used to produce molds for, say, ashtrays, and it also describes a machine producing industrial molds which may weigh several tons used for heavy machinery production. Hence, comparing machines of these types in the same category of data is suspect, and thus published government documents deleted it. However, industry sources did provide some data.

The data sources used for the foundry machinery industry originate in a survey of foundry equipment conducted by the foundry equipment industry's trade publication. The survey provides some data on the standing stock of foundry equipment in current use. This data was then used to calculate the projections using some simplifying assumptions about the other variables.

The capital stock was projected using an assumption that the recent growth rate observed in the foundry equipment industry would continue through 1990. The growth rate was that provided by the U.S. Industrial Outlook. These projected values of the capital stock were then used to derive the remaining variables. The annual production of foundry equipment was assumed to be a constant percentage of the stock based on information from industry sources. Similarly, exports and imports were assumed to be a constant percentage of annual production. These percentages were based on recent observations of the value of exports and imports to the value of all shipments in the entire foundry equipment industry. Finally, depreciation was estimated by assuming that the useful life of a piece of equipment corresponded to it's life for tax purposes. That is, according to industry sources, an eleven year depreciation period may be used in determining federal corporate tax liabilities. Hence, it is assumed that approximately one ninth of the standing stock of machines are retired each year.

6. Miscellaneous Machinery Group

The purpose of this section is to discuss the projections of the remaining two types of industrial machinery of miscellaneous characteristics. These two machinery types are power driven handtools and mobile earthmoving equipment (bulldozers). The handtool group is classified in SIC 3546. The bulldozer group is in SIC 3530.

The methodology used to estimate the projections of the four economic variables for handtools is nearly the same as used in woodworking due to the limitations of data availability. The number of handtools produced was listed in the recent Census of Manufacturers. This figure was expanded to reflect an approximate measure of the quantity of units produced but not disclosed in the Census. This output figure was used to project the future output levels assuming the output of the handtools industry continues to grow at the rate observed in recent years, as listed in Predicasts Basebook. The capital stock and the retirement data were obtained by assuming the observed ratio of the value of exports and imports to the value of shipments over the recent period would reflect the relation of the domestic versus foreign market in the future. That is, exports and imports are assumed to be a constant proportion of output.

The data for bulldozers is estimated in roughly the same fashion. The available data indicates the current levels of output, stock in place, the proportion of output exported and imported, and the approximate length of useful life for a bulldozer. The growth rate in construction machinery observed over the recent years, according to Predicasts Basebook, was used to project the basic figures for the relevant period. That is, it is assumed that the production and stock of bulldozers will grow at the same constant rate as was observed for all construction machinery in recent years. The export and import figures were calculated using the observation of the ratio of output to exports and imports cited above. The depreciation figures were obtained from the data which indicated the useful life of a bulldozer is approximately ten years. Hence, about one tenth of the stock will be replaced each year.

7. Conclusions and Limitations of the Analysis

The purpose of this section is to reiterate the essentials of the methodology used to estimate the projections. Each of the three methods will be briefly reviewed. In addition, the limitations of the data and methods will be discussed.

The projected values of the four economic variables were estimated for five industry groups. The five industry groups are metalworking machinery, textile machinery, woodworking machinery, foundry equipment machinery, and miscellaneous machinery. Several specific types of industrial machinery were identified and examined separately within each group. Three basic methods were used to estimate the projections. The first method was used for metalworking machinery. This method included a multiple regression analysis of industrial machinery production and the sales of the consuming industries, as well as a regression model for the foreign sector. It also used a probit econometric model of depreciation. It required the most information, and probably is the most reliable.

The second method was used for textile machinery. It includes a regression model for the capital stock of one of the industrial machines and regression models for the output of the others. The data for the regression models was, unfortunately, largely inadequate. The projections for the remaining variables were made using assumptions about constant proportions of exports and imports relative to sales. The projections of depreciation and output similarly assume that these variables are a constant proportion of the stock.

The third method was used for woodworking, foundry equipment machinery, and miscellaneous machinery. This approach usually uses only information about the current standing stock of machines in place, due to the lack of other data. Using a constant growth rate these stock values are projected over the relevant period. The other economic variables were then estimated using the assumptions that the foreign section was a constant proportion of output, and the output and depreciation were constant proportions of the stock.

The above analysis has a substantial variance in the reliability of the results. The first method used the most information and hence reduces the degree of uncertainty. The second and third methods use progressively less information and increasingly rely on assumptions about the models used to project the variables and about the data itself. There are serious problems in the conceptual models which were implicitly employed in making these projections. Several of these limitations are particularly troublesome. First, many of the types of industrial equipment are too complex to be readily classified as a single machine type (e.g. molding machines). Second, the methods make an excessive number of simplifying assumptions about the contancy of observed relations between variables. Third, no provision is made to account for technological change. This is especially important because most of the newest types of machines are automated or computerized, meaning there is a trend toward fewer, more productive machines. As a result, the accuracy of these projections is open to question. In fact, it is our subjective conclusion that the standard deviation of some of these estimates are probably as large as the estimates themselves. Further study would be needed to improve the projections.

Revised Projections for Metalworking Machinery (Units)

Year	Metal Cutting			Metal Cleaning & Finishing	Metal Forming	
	Shears	Metal Saws	Mechanical Presses	Tumblers	Pedestal Grinders	Screw Machines
				Exports		
1985	196	2,904	24	1,346	385	121
1986	207	3,534	25	1,494	385	120
1987	219	4,299	25	1,658	385	119
1988	232	4,232	25	1,840	385	118
1989	246	6,366	26	2,043	385	116
1990	260	7,746	26	2,267	386	115
				Imports		
1985	616	2,320	539	718	133	326
1986	662	2,823	545	797	132	347
1987	711	3,435	551	884	131	369
1988	762	4,179	557	981	130	391
1989	816	5,085	563	1,089	129	415
1990	873	6,188	470	1,209	128	440
				U.S. Consumption		
1985	5,129	17,124	9,300	3,857	897	2,432
1986	5,386	20,837	9,866	4,281	861	2,546
1987	5,657	25,355	10,463	4,752	827	2,667
1988	5,979	30,850	11,096	5,275	795	2,795
1989	6,294	37,539	11,766	5,855	764	2,928
1990	6,626	45,665	12,474	6,499	736	3,069
				Stock of Machines in Place		
1985	46,219	124,942	117,425	64,079	27,001	32,842
1986	47,766	135,048	117,900	71,127	25,640	33,730
1987	49,448	148,330	118,819	78,951	24,378	34,701
1988	51,300	165,386	120,448	87,636	23,212	35,753
1989	53,130	187,072	123,157	97,276	22,189	37,040
1990	55,272	213,738	126,201	107,976	20,745	38,256
				Machines Retired		
1985	---	11,442	---	4,133	---	---
1986	3,839	12,937	9,391	4,588	2,222	1,658
1987	3,975	14,847	9,444	5,092	2,089	1,696
1988	4,127	17,134	9,567	5,626	1,961	1,743
1989	4,464	20,557	9,057	6,274	1,787	1,641
1990	4,484	24,112	9,430	6,965	2,180	1,853

Projections for Textile Machinery (Units)

Year	High Speed Knitters	Looms	Draw frames
		U.S. Production	
1985	1,096	12,915	2,809
1986	971	12,089	3,100
1987	860	11,316	3,421
1988	762	10,593	3,775
1989	675	9,916	4,166
1990	598	9,283	4,598
		Exports	
1985	299	3,526	767
1986	265	3,300	846
1987	235	3,089	934
1988	208	2,892	1,031
1989	184	2,707	1,138
1990	163	2,534	1,256
		Imports	
1985	397	4,675	1,017
1986	352	4,376	1,122
1987	312	4,096	1,239
1988	276	3,835	1,367
1989	244	3,590	1,509
1990	217	3,360	1,665
		U.S. Consumption	
1985	1,194	14,064	3,059
1986	1,058	13,165	3,376
1987	937	12,323	3,726
1988	830	11,536	4,111
1989	735	10,799	4,537
1990	652	10,109	5,007
		Stock of Machines in Place	
1985	14,197	167,282	36,386
1986	12,576	156,592	40,156
1987	11,140	146,586	44,316
1988	9,867	137,219	38,907
1989	8,741	128,451	53,974
1990	7,742	120,243	59,565
		Machines Retired	
1985	916	10,790	2,347
1986	811	10,100	2,590
1987	718	9,455	2,858
1988	636	8,851	3,154
1989	564	8,285	3,481
1990	479	7,756	3,842

Projections for Textiles Machinery (Units)

Year	Twisting Frames	Spinning Frames
	U.S. Production	
1985	3,077	4,674
1986	3,413	4,880
1987	3,786	5,094
1988	4,199	5,319
1989	4,657	5,553
1990	5,166	5,797
	Exports	
1985	840	1,276
1986	932	1,332
1987	1,033	1,391
1988	1,146	1,452
1989	1,272	1,516
1990	1,410	1,583
	Imports	
1985	1,114	1,692
1986	1,236	1,766
1987	1,371	1,844
1988	1,520	1,925
1989	1,686	2,010
1990	1,870	2,098
	U.S. Consumption	
1985	3,351	5,090
1986	3,717	5,314
1987	4,225	5,548
1988	4,573	5,792
1989	5,072	6,047
1990	5,626	6,313
	Stock of Machines in Place	
1985	39,858	60,544
1986	44,210	63,208
1987	49,038	65,989
1988	54,393	68,893
1989	60,333	71,924
1990	66,921	75,089
	Machines Retired	
1985	2,571	3,905
1986	2,852	4,077
1987	3,163	4,256
1988	3,509	4,444
1989	3,892	4,639
1990	4,317	4,843

Projections for Woodworking Machinery (Units)

Year	Planners	Woodsaws	Chippers and Hogs
		U.S. Production	
1985	5,225	31,699	1,204
1986	5,775	34,615	1,314
1987	6,347	37,800	1,435
1988	6,976	41,278	1,567
1989	7,666	45,075	1,712
1990	8,425	49,022	1,869
		Exports	
1985	367	5,706	217
1986	403	6,231	237
1987	443	6,804	258
1988	487	7,430	282
1989	535	8,114	308
1990	588	8,860	337
		Imports	
1985	946	2,219	84
1986	1,040	2,423	92
1987	1,142	2,646	101
1988	1,256	2,890	110
1989	1,380	3,155	120
1990	1,516	3,446	131
		U.S. Consumption	
1985	5,834	28,212	1,071
1986	6,412	30,808	1,169
1987	7,046	33,642	1,277
1988	7,745	36,737	1,395
1989	8,511	40,117	1,523
1990	9,353	43,807	1,663
		Stock of Machines in Place	
1985	30,868	432,839	17,196
1986	33,924	494,500	18,778
1987	37,282	539,994	20,506
1988	40,973	589,674	22,392
1989	45,030	634,924	24,452
1990	49,487	703,165	26,702
		Machines Retired	
1985	1,991	51,080	1,939
1986	2,188	55,779	2,118
1987	2,405	60,911	2,313
1988	2,643	66,515	2,526
1989	2,904	72,635	2,758
1990	3,192	79,317	3,012

Projections for Foundry Equipment (Units)

	Molding Machines	Shakeouts	Furnaces
		U.S. Production	
1985	5,808	1,215	4,727
1986	6,295	1,317	5,124
1987	6,824	1,428	5,555
1988	7,397	1,548	6,021
1989	8,019	1,678	6,527
1990	8,692	1,819	7,075
		Exports	
1985	1,859	389	1,513
1986	2,015	421	1,640
1987	2,184	457	1,777
1988	2,367	495	1,927
1989	2,566	537	2,089
1990	2,782	582	2,264
		Imports	
1985	482	101	392
1986	522	109	425
1987	566	119	461
1988	614	129	499
1989	666	139	541
1990	722	151	587
		U.S. Consumption	
1985	4,431	927	3,606
1986	4,803	1,005	3,909
1987	5,207	1,089	4,237
1988	5,644	1,181	4,593
1989	6,118	1,280	4,979
1990	6,632	1,387	5,397
		Stock of Machines in Place	
1985	38,717	8,101	31,515
1986	41,750	8,781	34,162
1987	45,257	9,519	37,032
1988	49,059	10,319	40,143
1989	53,180	11,186	43,515
1990	57,647	12,125	47,170
		Machines Retired	
1985	3,523	737	2,868
1986	3,819	799	3,109
1987	4,140	866	3,370
1988	4,488	939	3,653
1989	4,865	2,018	3,960
1990	5,273	1,103	4,292

Projections for Miscellaneous Machinery (Units)

Year	Hand Tools	Bulldozers
	U.S. Production	
1985	71,310	224,887
1986	77,371	249,625
1987	83,948	227,084
1988	91,084	307,563
1989	98,826	341,395
1990	107,226	378,948
	Exports	
1985	12,600	93,328
1986	13,671	103,594
1987	14,834	114,990
1988	16,095	127,639
1989	17,463	141,679
1990	18,947	157,264
	Imports	
1985	5,897	8,141
1986	6,399	9,036
1987	6,942	10,031
1988	7,533	11,134
1989	8,173	12,358
1990	8,868	13,718
	U.S. Consumption	
1985	64,607	139,700
1986	70,098	155,067
1987	76,056	172,124
1988	82,521	191,058
1989	89,535	212,074
1990	97,145	235,403
	Stock of Machines in Place	
1985	648,273	1,285,189
1986	703,373	1,426,560
1987	763,164	1,583,481
1988	828,036	1,757,664
1989	898,418	1,951,007
1990	974,782	2,165,618
	Machines Retired	
1985	4,992	128,519
1986	5,416	142,656
1987	5,876	158,349
1988	6,376	175,766
1989	6,918	195,101
1990	7,506	216,562