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ECONOMIC AND SOCIAL IMPACT OF OCCUPATIONAL NOISE EXPOSURE REGULATIONS

SEPTEMBER 1976

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16. ABSTRACT

This report elaborates on the costs and benefits associated with alternative occupational noise exposure regulations. The limitations of cost/benefit analysis for social decision-making are enunciated. The impact of various regulatory alternatives for 85 dBA and 90 dBA criteria are analyzed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
occupational noise, occupational health and safety, regulatory alternatives, health effects of noise, cost/benefit analysis of occupational noise regulations		

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ECONOMIC/SOCIAL IMPACT OF OCCUPATIONAL NOISE EXPOSURE REGULATIONS

Testimony Presented at the OSHA Hearings on
the Economic Impact of
Occupational Noise Exposure
Washington, D.C.

SEPTEMBER 1976

PREFACE

The information and analysis contained in this report were presented by Dr. Nicholas A. Ashford at public hearings conducted by the Department of Labor's Occupational Safety and Health Administration in October 1976, regarding the proposed Occupational Noise Exposure Regulation. He was accompanied by Dr. Dale Hattis and Mr. Eric Zolt. Dr. Ashford is a senior staff member of the Center for Policy Alternatives at the Massachusetts Institute of Technology, and has had graduate training in science, law and economics. Dr. Hattis is an environmental scientist and Mr. Zolt is a certified public accountant and has graduate training in both law and business economics.

This report builds on research performed earlier by the Center for Policy Alternatives which was the subject of a report entitled "Some Considerations in Choosing an Occupational Noise Exposure Regulation", dated February 1976.

The testimony derived from this report was not intended to recommend a safe noise exposure level. Rather, it presents a methodology for analyzing the true costs and benefits of alternative regulatory requirements.

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ECONOMIC/SOCIAL IMPACT OF
OCCUPATIONAL NOISE EXPOSURE REGULATIONS*

I. INTRODUCTION

My name is Nicholas A. Ashford and I am a senior staff member of the Center for Policy Alternatives at the Massachusetts Institute of Technology. I have had formal graduate training in science, law and economics and am accompanied today by two of my colleagues at the Center, Dr. Dale Hattis, an environmental scientist, and Mr. Eric Zolt, a regulatory policy analyst with a master's degree in business administration and training in law.

While we do not claim to be experts in noise regulation, we are considerably involved with the problems of technology and society, with particular emphasis on the areas of occupational health and safety, environmental regulation, and the effects of government intervention on the innovation process.

We have recently published research relevant to these hearings entitled Some Considerations in Choosing an Occupational Noise Exposure Regulation.[1] This research was also reported in the OSHA hearings last July.** In the interests of brevity we will make reference to our earlier work wherever possible.

On the basis of the experience outlined briefly above, we hope to be of assistance in the selection of an appropriate workplace noise exposure standard by further elucidating both the nature of the social and economic costs and benefits and alternative bases for decision-making in this troubled area. We are presently undertaking research on these very subjects for EPA. However, we are testifying today on our own behalf and not as advocates for a particular agency's point of view.

*Testimony presented at the DOL-OSHA hearings on the Economic Impact of Occupational Noise Exposure, September 30, 1976, Washington, D.C.
**Testimony Presented at the DOL-OSHA hearings on the Proposed OSHA Noise Standard, July 23, 1975, Washington, D.C.

[1] Some Considerations in Choosing an Occupational Noise Exposure Regulation, D. Hattis, et. al., EPA 550/9-76-007 (Februrary 1976), hereafter cited as EPA 550/9-76-007.

2. THE USEFULNESS OF COST-BENEFIT AND ECONOMIC IMPACT ANALYSES

In difficult economic times, it is expected that a society re-examine the question of whether the longer-range benefits that are likely to accrue from environmental/safety regulation are justified by potentially high shorter-range costs. This is the simplest way to state the problem; it can also be the most deceptive. There are really three important considerations relevant to the Occupational Safety and Health Administration's (OSHA) standard-setting function:

- The important distinctions in the justification of government intervention in occupational or environmental health matters as compared to economic regulation such as that found in antitrust or utility regulation.
- The limitations of traditional cost-benefit techniques for making social decisions.
- The mandate of the OSHAct.

These issues will be examined in order to view in the proper context the use of cost-benefit and economic impact analysis for setting our occupational noise exposure regulation.

The Justification for Government Intervention in Occupational or Environmental Health Matters

The rationale for government intervention in the marketplace through regulation is usually expressed in terms of one of two purposes: either

- To improve the working of the market for goods and services by encouraging competition, economic efficiency, and the diversity of available goods and services, or
- To ameliorate the adverse consequences of market activities and technology in general by reducing the attendant social costs.

The underlying reason for pursuing these goals is not to improve the efficiency of the market for its own sake, but to optimize social welfare. Economic regulation generally addresses itself to the first purpose by attempting to ensure that the price mechanism operates efficiently to properly allocate goods and services between economic sectors and between producers and consumers, but also to properly allocate resources between generations. Economic regulation, properly carried out, thereby is generally expected to reduce the price of the goods and services it seeks to regulate, unless the goods and services were underpriced to begin with. Examples of economic regulations include antitrust regulation, energy consumption pricing, etc.

Occupational or environmental health regulation, on the other hand, attempts to internalize the social costs attending market activities - especially those associated with technology - and it does this by making sure that the prices of goods and services reflect the true costs to the consumer. Thus, it might be expected that prices would increase in some cases to reflect true costs. Including the costs of minimizing adverse health consequences from technology in the price of goods and services represents a shift in the way the costs are accounted for and not necessarily a true increase in the cost to society.

Inflationary impact statements, now required by Presidential directive for major government undertakings, are of course simply economic impact statements and ought to be renamed such. Otherwise, any attempt to internalize social costs carries with it the onus of being "inflationary." There are costs and price rises associated with regulation, but they are not necessarily inflationary.[1]

[1]" - the public interest and the general efficiency of the economic system would be [better] served to the extent that product prices are a true reflection of both the private costs (those borne by the manufacturer and the workers) and social costs (those borne by any "third" parties) of production. Consumption of certain products produced under unhealthy conditions should not be encouraged by deceptively low prices which ignore the "human" costs of production, which are just as real as the actual material production costs although less tangible and harder to quantify. If the welfare of the public is to be maximized, the appropriate noise control standard should impose added costs on industry (and indirectly, society) that are equal to the value society places (and is willing to pay for) on the need to prevent the deterioration in worker health and well-being that would otherwise result". Statement of Allan F. Ferguson, President, Public Interest Economic Center before the OSHA Public Hearings on Proposed Noise Standards, July 1975, p.3.

Thus, it can be seen that the two kinds of regulation - economic and occupational or environmental health - are expected to operate somewhat differently, because they address different aspects of market activity. There is, however, one further critical distinction: occupational or environmental health regulation also has a fundamental purpose, the protection of certain groups of people - for example, children, workers in an asbestos plant, or the less educated. This is justified under the principle of equity or fairness, whereby some economic efficiency is said to be sacrificed for the health or safety of those special groups.

The fact that economic efficiency is sometimes traded for equity considerations should not be disturbing unless it is either unnecessary for the result or one forgets that economic efficiency is a measure of *maximizing* rather than *optimizing* social welfare. In fact, it should be remembered that small business is paid special attention in formulating economic regulatory strategies - and there is a conscious tradeoff between economic efficiency and equity considerations in maintaining the viability of the small firm. Regulatory policies aimed at fairness to the worker are no less justified.

Having reviewed some of the distinctive justifications for occupational or environmental health regulation, the question arises as to the appropriateness of traditional cost-benefit techniques for making social decisions in this area of regulation.

The Appropriateness of Cost-Benefit Analysis for Making Social Decisions

Economic analysis not only helps to describe many issues in occupational or environmental health regulation, it also provides tools such as cost-benefit analysis for helping evaluate the consequences of decisions.

Some of the major problems in using cost-benefit analysis arise because health and safety benefits are not easily compared to dollar costs. The market value of human life is not adequately represented in the traditional measures of lost wages, awards for pain and suffering, or willingness to trade off risk of harm for lower prices in the marketplace. It is extremely difficult for one to relate to long-range, low-probability risks of harm or, to put it another way, it is difficult to value benefits likely to accrue in the future, if at all. Further, since the costs and benefits of regulation occur in different time frames, one is faced with the inevitable difficulty of applying an appropriate discount rate to items difficult, if not impossible, to quantify monetarily in the first place. The situation is further complicated because often too little is known about adverse health effects of occupational and environmental hazards; yet decisions, and valuation of these effects must nonetheless be made.

Often, decision-making has economic efficiency as its only objective. However, the question of who pays the cost and who reaps the benefit is also important. Minimizing nonrandom victimization through a concern for individual justice is a legitimate social goal which may at times conflict with attainment of economic efficiency. Society may prefer to move away from an economically efficient point to have a fairer distribution of costs and benefits. Of course, different people view what is fair differently - but this fact makes the consideration of equity no less important. Whatever the alternative value judgments are as to what is fair, the costs should be known for those alternatives being considered.

In short, cost-benefit analysis takes no special notice of the fact that the cost and benefit streams accrue to different elements of society. To what extent then is cost-benefit useful as a rational basis for action?

Expert consultants, economists or otherwise, have little more to contribute than other citizens to the evaluation of equity effects of occupational health decisions. Such an evaluation should be made collectively by an informed public and should be a reflection of the societal values. The value put on equity consideration in occupational health matters has been expressed in the OSHAct and is, in practice, further refined and interpreted by the administrative law and judicial systems.

What economists can do is specify the equity effects, as well as allocative effects, of regulatory decisions. Despite its limitations and the methodological problems associated with its use, one might think that cost-benefit analysis is at least employed in good faith, solely as a technical aid by decision-makers. In practice, unfortunately, this description is often not the case. Cost-benefit analysis is often used in an attempt to convince other parties that a course of action (predetermined on other grounds) is justified. Value judgments are often hidden in the assumptions on which the calculation is based, and balancing costs and benefits without consideration of equity is value-laden itself - it is a decision to ignore equity.

The guidelines for balancing costs and benefits in a particular social contest are often established by legislation. Economic impact analyses then becomes useful primarily in the design of cost-effective means of fulfilling the mandate of that legislation. We next examine the OSHAct specifically.

The Mandate of the OSHAct

Because lives and dollars are incommensurables, there is no theoretically correct way to balance costs and benefits. The decision is a political decision and Congress has given guidance on what the proper OSHA posture should be in section 6(b)(5) of the OSHAct.

> The Secretary, in promulgating standards dealing with *toxic materials or harmful physical agents* under this subsection, shall set the standard which most adequately assures, *to the extent feasible*, on the basis of the *best available evidence*, that *no* employee will suffer *material impairment* of health or functional capacity even if such employee has regular exposure to the hazard dealth with by such standard *for the period of his working life*.

Whether or not OSHA complies with its mandate depends on the interpretation of what "to the extent feasible" implies in terms of economic and technological burdens and how many workers are left unprotected. The term material impairment can be defined to give a larger or smaller number of these unprotected. Finally, the minimum quality of the evidence that OSHA uses to make its decisions will also determine the kind of standard it will establish. "To the extent feasible" by ordinary construction would appear to mean that the workplace is to be made safe as long as the industry is not incapable of complying. A balancing of costs and benefits is to be done heavily in favor of worker health, not necessarily with the result that workplace disease is at an economically efficient level.

Whatever conflicing definitions of hearing impairment have been offered, there still remains a substantial proportion of workers harmed by either an 85 or a 90 dBA standard, and there are approximately twice as many workers at risk at 90 dBA than as at 85 dBA. The basic issues are: (1) whether OSHA should, under its mandate, impose additional costs on industry and society, (2) the time frames for compliance, (3) the mix of engineering, personal hearing protectors, and administrative controls, and (4) the desirability of industry-specific standards. It should be emphasized that in its proposed standard, OSHA has decided not to use as part of material impairment the existing evidence of nonauditory harm - expecially possible implications of noise for coronary heart disease.

In the setting of other health standards, OSHA has been considerably more protective of the workers in adopting relatively more stringent standards. Further, the courts have upheld the OSHA protective posture as legislatively determined. In a D.C. Circuit case challenging the asbestos standard[1], Judge McGowan stated, in commending on the standard of review:

> there are areas where explicit factual findings are not possible, and the act of decision is essentially a prediction based upon pure legislative judgment, as when a Congressman decides to vote for or against a particular bill. Furthermore, policy choices of this sort are not susceptible to the same type of verification or refutation by reference to the record as are some factual questions. Consequently, the court's approach must necessarily be different no matter how the standards of review are labelled.

[1] Industrial Union Department, AFL-CIO v. Hodgson, 499 F. 2d. 467 (D.C. Cir. 1974).

In a Second Circuit case challenging the vinyl chloride standard[1], former Supreme Court Justice Clark stated, in commenting on the asbestos case approach, "The problems involved in according judicial review in such circumstances have been wisely discussed by Judge McGowan." In commenting on plaintiff's contention that the available scientific evidence does not support the 1-ppm standard, Justice Clark stated:

> We find, however, that the evidence is quite sufficient to warrant the Secretary's choice. First, it must be remembered that we are dealing here with human lives... Moreover the animal exposure study ... identified fatal liver angiosarcoma and other kidney and liver diseases at the 50 ppm level.
>
> As in the IUD [asbestos] case, the ultimate facts here in dispute are on the frontiers of scientific knowledge, and though the factual finger points, it does not conclude. Under the command of OSHA, it remains the duty of the Secretary to act to protect the working man, and to act even in circumstances where existing methodology or research is deficient. The Secretary, in extrapolating the MCA [Manufacturing Chemists' Association] study's findings from mouse to man, has chosen to reduce the permissible level to the lower detectable one. We find no error in this respect.

OSHA may wish to distinguish the noise standard from the standards for asbestos or vinyl chloride, because in the latter cases, life and death issues are involved. However, (1) the OSHAct does not speak in terms of life and death issues and (2) if OSHA gives any acknowledgment of noise as a general stressor and a cocausitive factor in coronary heart disease and other diseases, life and death issues are involved.

The OSHA Inflationary Impact Statement

The BBN report forms the basis of OSHA's economic impact assessment. Having set out the inherent limitations in assessments of this kind, we next procede to evaluate the cost and benefit basis for establishment of an occupational noise exposure regulation. If a cost-benefit approach is to be used, it at least ought to be used with parallel treatment of benefits and costs.

[1] The Society of the Plastics Industry, Inc. v. OSHA, 509 F. 2d 1301 (2nd Cir. 1975).

3. SUMMARY OF FINDINGS

3.1 Usefulness of Cost-Benefit and Economic Impact Analysis

- Cost/benefit analysis, as usually performed, has important limitations for use in clarifying environmental/health policy choices:
  - -- Costs and benefits are generally in different units (dollars, lives, person-years of hearing impairment), occur in different time frames, and accrue to different groups of people. Comparisons of cost and benefit which ignore these aspects of incommensurability between costs and benefits can conceal important value choices which are properly the province of social policy decisions, not objective analysis.
  - -- Both cost and benefit estimates generally have considerable uncertainty which may not be fully conveyed in executive summary statements of results.

- Given the mandate of the OSHAct, that the Secretary must set the standard "which, to the extent feasible...ensures that no worker will suffer material impairment...." and the fact that an 85 dBA standard will protect significantly more workers than a 90 dBA standard, the choice of standard level must be determined by the issue of feasibility. Different time-phasing for compliance may be used in different industries, however, in recognition of the different capabilities of specific industries to comply quickly and to prevent inordinately high costs for the benefits received.

- If cost/benefit analysis is to be performed for the latter purpose (time-phasing), it must be performed using parallel treatment of costs and benefits, with a minimum of other methodological flaws. The purpose of our written testimony is to illustrate proper analytical techniques with exemplary calculations, and explore the policy implications of the results of those calculations.

3.2 Costs

Methodological Conclusions

- Although there are uncertainties in the underlying data and there are major methodological flaws in the BBN cost analysis, we believe that we have demonstrated that a proper methodological treatment yields (after-tax effects) costs of the same magnitude. Furthermore, we believe that the BBN estimates do provide a rational basis for the adoption of an occupational noise exposure regulation.

- For compliance periods of more than one year, the cost of noise reduction must be discounted to its present value.

- The annual maintenance charge of 5% of capital cost must be included in the calculation of total compliance costs.

- The after-tax cost of compliance should be considered in determining the effective cost of noise reduction equipment to industry.

- An analysis of the compliance costs on an industry-by-industry basis tends to suggest a potential wide variation among industries in the economic burden to comply with a 90 dBA or an 85 dBA standard. This variation could form part of the basis for meaningful distinctions among industries in selecting different compliance scenarios. However, in order to provide a rational basis for setting an industry-by-industry standard (should that be desired) the BBN cost estimates need to be confirmed and adjusted, where necessary.

Results

- The magnitude of the effect that discounting has on compliance costs and the practical considerations making immediate compliance not feasible, suggest the consideration of alternative compliance scenarios with different time-phasing for compliance.

- The effect of including the costs of noise monitoring, audiometric testing, and hearing protectors is to increase the cost of complying with a 90 dBA standard relative to an 85 dBA standard.

- The effect of extending the compliance period by 5 years, 10 years, and 15 years will be to reduce the effective cost of noise control equipment by about 25%, 40%, and 60%, respectively.

- The effect of the inclusion of the maintenance cost in the cost calculation is to increase the BBN compliance cost estimates by over 50%.

- It is likely that about half of the net costs of the regulation on industry will be borne indirectly by governments in the form of tax reductions.

- There exists a potentially wide variation among industries in the economic burden to comply with a 90 dBA and an 85 dBA standard.

3.3 Benefits

Methodological Conclusions

- Because noise-induced hearing loss is a change from one continuous population distribution of hearing levels to another, it is not possible to gain a valid appreciation of hearing conservation benefits by simply calculating the numbers of people crossing a given "fence" of hearing levels. It is essential to use a series of fences and determine the numbers of individuals falling between the fences for specific periods of time under different regulatory options. For our computations, we determine benefits for three hearing level ranges: 20-25 dB, 25-50 dB, and over 50 dB (hearing levels averaged at .5, 1, and 2 KHz).

- Because each individual's hearing loss reflects noise exposure experienced over his/her entire previous work history, the ultimate equilibrium level of hearing conservation benefits will not be experienced until more than forty years after compliance with any noise control regulation, when complete replacement of the work-force will have taken place. It is therefore essential to express hearing conservation both in terms of the ultimate equilibrium flow of benefits (reduction in number of workers in different hearing level ranges at any one time) and in terms of the stock of benefits realized prior to equilibrium (reduction in the person-years of impairment in different hearing level ranges from the time of compliance to forty years thereafter).

- The BBN estimate of noise exposure in individual industries must be regarded as highly preliminary and subject to error. Properly interpreted, however, they can: (1) form the basis for assessments of the overall hearing conservation benefits likely to be produced by compliance with different noise regulations under different assumptions, and (2) give some indication of how much the hearing conservation benefits of noise control may vary among industries. The data for specific industries need to be critically assessed, however.

Results

- Ultimate Equilibrium Flow of Benefits

  If present exposures remain unchanged, approximately 1.9 million workers will experience hearing levels above 25 dB due to industrial noise at any one time (after subtraction of the workers who will be over 25 dB due to presbycusis alone). The implementation of a 90 dBA standard will reduce the number over 25 dB by about 770,000 and the implementation of an 85 dBA standard will reduce the number over 25 dB by about 1,350,000.

  Of this hearing impairment over 25 dB which is prevented, approximately 15% represents hearing impairment in the "severe" over 50 dB category. In addition, the number of people prevented from experiencing 20-25 dB hearing levels is approximately one-third as large as the number of people prevented from experiencing hearing levels over 25 dB.

- Pre-Equilibrium Benefits of Different Compliance Scenarios

  Compliance with a 90 dBA standard within five years will prevent about 18 million person-years of impairment over 25 dB prior to equilibrium (at year 45). Compliance with an 85 dBA standard within five years will prevent about 30 million person-years of impairment over 25 dB in the same time period. A two-step compliance scenario with compliance to 90 dBA within five years and compliance to 85 dBA within ten years will prevent about 28 million person-years of impairment over 25 dB prior to equilibrium.

- Worker Mobility

  Worker mobility is a crucial determinant of the size of the hearing conservation benefits anticipated to result from regulation of noise levels. Higher levels of mobility substantially increase the impairment produced in the population by any given job, and the benefits of noise control. Different mobility assumptions can lead to benefit estimates differing by several fold.

- Worker's Compensation

  The total potential savings in worker's compensation benefits that will accrue from either a 90 or 85 dBA standard are small ($.28 billion and $.53 billion, respectively) when compared to the capital and maintenance costs of compliance. It is clear that the savings from the worker's compensation payments alone cannot serve as an adequate economic incentive for industries to voluntarily reduce the level of noise exposure in the workplace.

- Absenteeism

  The benefits of prevented absenteeism are substantial. For the 90 dBA standard with a five-year delay, the expected benefits are $3.9 billion and for 85 dBA, $6.3 billion.

- Other Benefits (reduction in cardiovascular disease processes, and in annoyance) are plausible and, though of uncertain magnitude, must be included in any complete assessment of benefits.

3.4 Cost/Benefit

- Cost/benefit comparisons excluding all benefits except pre-equilibrium hearing conservation indicate that:
  -- Cost/effectiveness for hearing conservation of the noise control expenditures to reach 85 dBA in five years is similar to the cost/effectiveness of the noise control expenditures needed to

reach 90 dBA in five years. For the 85 dBA regulation, $840 present value would be spent to prevent each person-year of impairment over 25 dB, and for the 90 dBA regulation $790 would be spent for each person-year over 25 dB prevented.

-- The "two-step" scenario (compliance with 90 dBA in five years, compliance with 85 dBA within ten years) has a slightly better cost/benefit ratio ($760/person-year over 25 dB prevented) than the other scenarios.

-- The data tend to suggest wide variation in the cost/benefit ratios for the different compliance scenarios in different industries.

- Inclusion of absenteeism benefits, tax benefits, worker's compensation and other non-auditory benefits, all move the cost/benefit ratio in the direction of providing more benefits to workers at lower costs to firms.

3.5 The Choice of Compliance Scenarios

The form of the standard must reflect not only the best available technological and scientific information, but must also consider the administrative burdens of setting the standard and enforcing the law. In Section 7 we raised important issues likely to surface in legal challenges to whatever standard is promulgated and enforced. The challenges may differ as to technological versus economic feasibility, who proves something as opposed to what needs to be proved; and whether the challenge is to a broad-based standard, an industry-specific standard, or to the particular burden placed on an individual firm.

The facts would appear to mandate an ultimate compliance with an 85 dBA standard in all industries.

Considerations of both costs and realiability support the preference of engineering controls as the primary compliance strategy, supplemented by personal hearing protectors and some administrative controls (such as the running of night or weekend shifts) in the interim phase of compliance. Some industries may be harder hit. Government policies favoring further cost-sharing by society through tax changes and government participation in research and development should be considered if engineering controls impose a particularly severe burden on a substantial number of industries.

A slight delay in compliance time (less than five years) is probably inevitable. If a longer delay is deemed desirable, the standard ought to require compliance with an 85 dBA standard in no longer than 10 years, with an interim compliance with 90 dBA at no later than five years.

There are differences between industries in the economic burden likely to be imposed. The factors which can be used to differentiate industries in order to promulgate industry-specific standards, which differ in compliance times, in certain cases are:

- cost/benefit ratio
- cost per measure of industry profitability
- the likelihood of a technological breakthrough
- the existence of government assistance
- the likely effectiveness of proposed machinery regulations
- OSHA enforcement priorities vis-a-vis industries, and
- OSHA abatement and variance posture.

In sum, we believe that there is sufficient evidence in the record to justify setting an occupational noise exposure regulation. It would not be beneficial to wait until more evidence is required. The form of the standard must be such that the regulation is enforceable and likely to elicit an effective response by those regulated. The regulation must be of the form that can be effectively administered. The damage resulting from further delay in the setting of a standard is substantial and warrants prompt and deliberate action.

4. COSTS

This section will evaluate the capital and maintenance cost of compliance of the proposed noise control regulations. A discussion of the effects of a decrease in the noise level on absenteeism is included in section 5.2.1 of the Benefits section. However, it is important to realize that the savings from lower absenteeism could also be properly treated as a reduction in the gross capital and maintenance costs of noise control equipment. Finally, the reader is cautioned to note the final section on the assumptions and limitations of the calculation and data presented below.

4.1 Evaluation of the Cost Estimates in the Aggregate

While the Inflationary Impact Statement is the most complete analysis of the noise level exposure and the costs of reducing the noise in the workplace to date, several factors must be considered in order to determine the usefulness and accuracy of the cost estimates. We conclude that although many criticisms of the treatment of the aggregate data are justified and certainly merit further discussion, the result of the proper treatment of the initial cost data yields approximately the same after-tax cost estimates.

Listed below in summary fashion are the methodological flaws present in the cost estimates included in the Inflationary Impact Statement.

Failure to Discount Capital and Maintenance Expenditures Over Proposed Compliance Periods.

Because capital expenditures usually involve major outlays over long periods of time, proper decision-making requires the consideration of the time-value of money. Discounting is the process of converting future payments of money into the present value of those payments. Figure 4-1 is a graphic view of the relationship between present value interest factors, interest rates and time.

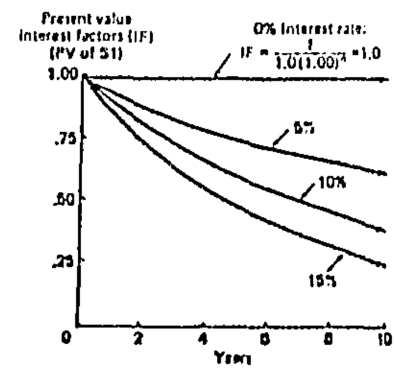


FIGURE 4.1
Relationship between present value interest factors, interest rates, and time

The Inflationary Impact Statement treated the compliance costs as if all expenditures are made in the same time period as the standard is promulgated. The only allowance for cost reduction over time is the 3% per year estimated by considering both the firm's opportunity to replace noisy equipment through normal capital replacement and the cost decreases from technological change in the production and installation of noise control equipment.

If the policy maker is considering compliance periods of more than one year, then the costs of noise reduction must be discounted to its present value. The magnitude of the effect of discounting is demonstrated by the fact that a dollar spent on noise control equipment fifteen years from now is equivalent to 36¢ spent on noise control equipment today (for discount rate at 7%).

Table 4.1 is a summary of the discounted present value of BBN compliance cost estimates for different compliance alternatives. Although the table will be discussed in further detail later, it is useful to look at the discounted capital cost column in the first 20 year time frame. Note that the immediate compliance costs of an 85 dBA and 90 dBA regulation are the BBN

TABLE 4.1

DISCOUNTED PRESENT VALUE OF BDN COMPLIANCE COSTS ESTIMATES* (BEFORE TAX EFFECTS)

DOLLARS IN MILLIONS

Compliance Alternative	1st 20-Year Time Frame: Discounted Capital Cost	1st 20-Year Time Frame: Discounted Maintenance Cost[2]	1st 20-Year Time Frame: Total 1st 20 Years	2nd 25-Year Time Frame: Discounted Capital Cost[3]	2nd 25-Year Time Frame: Discounted Maintenance Cost[4]	2nd 25-Year Time Frame: Total 2nd 25 Years	Total 45 Years
A. Immediate Compliance 85 dBA--85 (0 yr.)	18,540	9821	28,361	1913	1106	3019	31,380
B. Immediate Compliance 90 dBA--90 (0 yr.)	10,545	5586	16,131	1088	629	1717	17,848
C. 5 yr. Compliance 85 dBA--85 (5 yr.)	14,268	7775	22,043	1913	1106	3019	25,062
D. 5 yr. Compliance 90 dBA--90 (5 yr.)	8,115	4408	12,524	1088	629	1717	14,241
E. 10 yr. Compliance 85 dBA--85 (10 yr.)	10,576	5724	16,300	1913	1106	3019	19,319
F. 5 yr. Compliance 90 dBA; within 10 yr. Compliance 85 dBA--90 (5 yr.);85 (10 yr.)[1]	11,789	6366	18,154	1913	1106	3019	21,173
G. 5 yr. Compliance 90 dBA; within 15 yr. Compliance 85 dBA--90 (5 yr.);85 (15 yr.)[1]	10,704	5757	16,541	1913	1106	3019	19,560
H. 15 yr. Compliance 85 dBA--85 (15 yr.)	7,754	4105	11,859	1913	1106	3019	14,878

*Assuming:

- 3% per year cost reduction for noise control equipment
- discounted at rate of 7%
- inclusion of maintenance charges of noise control treatments
- 45 year time frame analysis

[1]Assuming cost to go from 90 dBA to 85 dBA levels is equal to the incremental compliance costs ($7995) provided by BDN.

[2]Maintenance charges are equal to 5% of capital cost charges.

[3]

Capital Costs		Adjustment for Cost Reduction for Technological Change & Inclusion of Noise Control in Machine Design		PV @ 7% For 20 Years	
To Reach 85 dBA: 18,540	x	.40	x	.258	= $ 1,913
To Reach 90 dBA: 10,540	x	.40	x	.258	= $ 1,088

[4]Maintenance Costs:

5% of Capital Cost		PV of Annuity 25 Years @ 7%		PV @ 7% For 20 Years	
85 dBA--370.8	x	11.564	x	.258	= $ 1,106
90 dBA--210.8	x	11.564	x	.258	= $ 629

cost estimates of $18.5 billion and $10.5 billion, respectively. The effect of extending the compliance period by 5 years (compliance alternatives C, D), 10 years (compliance alternative E), and 15 years (compliance alternative H), will reduce the effective cost of noise control equipment by about 25%, 40% and 60% respectively.

Maintenance Costs

Although the Inflationary Impact Statement provided an estimate of maintenance costs as 5% of capital costs, the statement failed to impress upon the reader the magnitude of these annual charges. If the immediate compliance cost for an 85 dBA standard is $18.5 billion, then the maintenance charge is $927 million per year for the 20-year life of the equipment. Note: this annual stream of maintenance costs must also be discounted to its present value. (Discounted maintenance cost = $9.8 billion.)

Refering again to Table 4.1, the discounted maintenance cost column in the first 20-year time frame is the summary of the present value of an annual charge for 20 years computed for each compliance alternative (for discount rate at 7%). The effect of the inclusion of the maintenance cost in the cost calculation is to increase the BBN compliance cost estimates by over 50%. (See column titled "Total first 20 years".)

45-Year Time Frame Analysis

In order to construct a more appropriate frame of comparison of the cost of noise control with the benefit of reduced hearing impairment, we have extended the cost time frame analysis from 20 years to 45 years. This is the time period needed for the hearing impairment benefits to reach full equilibrium levels. (See section 5. on Benefits.)

The costs for the second 25-year time frame are our best guesses at what the capital and maintenance charges will be after the original noise reduction equipment has completely worn out. Calculation of the capital cost were made by first taking BBN estimate of capital cost requirement to reach the proposed standard, adjusting the capital cost for cost reductions stemming from technological change and inclusion of noise control in machine design, and discounting the costs to the present value.* The effect of expanding the time frame from 20 years to 45 years will result in an increase of about 10% over the total for the first 20 years. (Compare columns 6 and 3.) The relatively small size of this increase is due to the fact that (1) the cost will not be incurred for at least 20 years and (2) an increased tendency away from expensive retrofit technique of noise control.

The After Tax Cost of Compliance

We have not undertaken a detailed study of the tax implications of the increases in capital expenditures and increases in maintenance costs to be produced by the installation of noise reduction equipment. In general, however, we can say that it is likely that about half of the net costs of the regulation on industry will be borne indirectly by governments in the form of tax reductions.

Capital expenditures for noise control offer the opportunity for a depreciation deduction as property used in trade or business, §167 Internal Revenue Code. In addition, the almost certain continuation of the 10% investment tax credit will further reduce the after-tax cost of the noise regulation to the industry. With a current corporate federal tax rate of 48%, additional state corporate income tax in some states, and the several percent of additional benefit due to the tax credit, about half of the prevailing dollar capital cost will be recouped by the industry.

Expenditures for maintenance costs will be deducted as an operating expense in the calculation of the firm's net taxable income. The effective after-tax cost of maintenance changes will therefore be about one-half the before tax cost.

The above discussion assumes that the firm undertaking the capital and maintenance expenditures operates at a profit and does in fact pay taxes. To the extent that portions of an industry do not operate profitably and absent any tax-carryback or carry-forward opportunities, the possibility of "government participation" in the costs of noise control will be reduced.

*See Table 4.1., footnotes 3 and 4 for a presentation of the calculation of capital and maintenance cost for the second 25-year time frame analysis.

Uncertainties in the Underlying Data

The following criticisms of a former set of BBN cost estimates were presented at the public hearings on the proposed noise standard, July, 1975 and will certainly be raised again at these hearings:

- the sample plants analyzed by BBN are not representative of each industry.
- the resulting industry-wide extrapolation of compliance cost for the sample firm significantly overestimates/underestimates the "true" cost of compliance.
- BBN failed to consider alternatives to noise control other than retrofit. Since retrofit is a high cost noise control procedure, failure to consider least-cost methods biases the cost estimates upward.
- BBN estimate of 3% per year cost reduction for noise control equipment, resulting from the firm's opportunity to introduce quieter equipment through normal capital replacement and cost decreases from technological change in the production and installation of noise control equipment, is too conservative because it largely ignores economies of scale and recognized "learning curves".
- BBN failed to consider the costs of "down-time" during the installation and maintenance of noise control equipment and decreases in labor and capital productivity as a result of add-on noise control equipment.
- BBN failed to consider increases in productivity resulting from a quieter work environment and the catalyst effect of noise regulation on the introduction of new and more efficient machines.

While we find merit in the criticisms expressed above, we have chosen not to attempt to quantify the effects of those criticisms in this report.

It is crucial to remember that the purpose of the BBN report was to estimate the aggregate cost of compliance with the proposed regulation. The sample of 68 firms in 19 SIC codes was to be utilized as the basis for a ballpark figure of total costs -- not as an industry-by-industry estimate of compliance costs. Once this point is fully comprehended, most of the above criticism is not relevant to the ultimate decision -- whether the aggregate cost, when compared to the benefits, justified the promulgation of a lower standard.

The point estimate of the aggregate total would probably change significantly if all the criticized factors were properly analyzed and computed. However, if the upward and downward biases in the data tend to be offsetting, and the magnitude of the benefits justify even a "high" cost estimate, then the decision-maker need only make a rough cut analysis on the disputed factors as the penultimate calculation in the cost-benefit analysis.

Conclusion

In sum, although there are uncertainties in the underlying data and there are major methodological flaws in the BBN cost analysis, we believe that we have demonstrated that a proper methodological treatment yields (after tax effects) costs of the same magnitude. Furthermore, we believe that the BBN estimates do provide a rational basis for the adoption of an occupational noise exposure regulation.

4.2 Evaluation of Cost Estimates as Basis for Setting Industry-Specific Standards

As discussed earlier, the purpose of the BBN study was to estimate the aggregate cost of noise control and not to estimate compliance cost on an industry-specific basis. The authors of the study will readily admit that the cost estimates are not meaningful at a two-digit level. Discussed below are several factors which limit the usefulness of the cost estimates as an aid in setting industry-specific standards.

Sampling Techniques

Conversations with BBN personnel revealed that between 45-55 of the firms in the sample of 68 firms were included because BBN had been recently retained by those firms for noise control projects. While the inclusion of those firms enabled BBN to construct a larger sample than would otherwise be possible given the time and money constraints, the type of firm that would retain BBN is not necessarily representative of the industry. Logically, one could assume that the retaining firm would tend to be noisier (Why else would it expend resources on noise control?) and perhaps more profitable (BBN reputation as high quality-high cost noise consultants) than the typical firm in the industry.

Not surprisingly, other analysts have examined the sample firms chosen and concluded that they are not representative of the industry[1]. The legal requirement for setting different compliance periods for different industries is that meaningful distinctions must exist among industries. It is clear that additional information about firms in an industry should be examined to determine how representative of the industry the sample is.

Calculation of Total Cost of Noise Control as a Multiple of Material Cost

In calculating the cost of noise control for each sample plant, BBN first determined the total cost for acoustical material required to quiet the workplace, and then multiplied that total by six. This 6 multiplier represents an average across all types of noise control of the ratio of total cost to material cost. BBN has further indicated that the range of the multiplier of different types of noise reduction equipment is from 2 to 10.

[1]For criticisms of the sample used in the first BBN report see the statement of Ruth Ruttenberg, economist, on behalf of AFL-CIO before the OSHA Public Hearings on Proposed Noise Standards, July 1975, p. 4-5: Analysis of representativeness of sample firm in SIC 20, 28, 29, 30; and;

statement of Allan R. Ferguson, President of Public Interest Economic Center before the OSHA Public Hearings on Proposed Noise Standards, July 1975, p. 16-23: Analysis of representativeness of sample firms in SIC 20, 22, 24, 25, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 49.

Therefore, the cost estimates on a two-digit level could possibly be overestimated by a factor of 3 or underestimated by a factor of 1.7 due to this imperfection alone.

Extrapolation Technique

The Inflationary Impact Statement utilized capital cost per worker in the firm as the metric in estimating the total capital cost of compliance with the proposed noise standard. By focusing on the number of workers in the firm as a multiplier rather than physical equipment, the statement ignores differences in operating and production processes between firms within an industry.

This extrapolation technique would produce different costs for quieting the same machinery in cases where the size of the work crew or the number of operating shifts varies.[1] A better method of extrapolation would focus on the number and type of machinery. A recently completed report by BBN[2] catalogues by two-digit SIC codes the machinery and the noise control options available.

The suggestion of a machinery census approach is a reversion to the technique followed in an earlier BBN report[3]. It is important to note a major modification in the approach to cost calculation adopted by BBN since the issuance of that report. Proper noise control reduction requires quieting only those machines to which workers are exposed, and only to the extent necessary to limit the workers' exposures above a desired level. Therefore, a better estimate of the total capital compliance cost for a specific industry can be computed by estimating the cost of noise control options available and determining the number and type of machines to which workers are exposed.

---

[1] Arthur D. Little, Evaluation of the OSHA Noise Control Costs Developed by BBN and API, Cambridge, Massachusetts. (Working Paper).

[2] Report No. 3353, D. O. L. Draft Report, The Technical Feasibility of Noise Control in Industry.

[3] Bolt, Beranek, and Newman Report No. 2671, Impact of Noise Control at the Workplace, Cambridge, Massachusetts.

Conclusion

An analysis of the compliance costs on an industry by industry basis tends to suggest a potential wide variation among industries in the economic burden to comply with a 90 dBA and 85 dBA standard. This variation could form part of the basis for meaningful distinctions among industries in selecting different compliance scenarios. However, in order to provide a rational basis for setting an industry-by-industry standard (should that be desired) the BBN cost estimates need to be confirmed and adjusted, where necessary.

4.3 Costs of Alternative Compliance Scenarios

This section will discuss the effect of extending the compliance period on the cost of noise control to the firm. Reference will be made to Table 4.1 which presents compliance alternatives and the corresponding discounted costs.

Discussion of Compliance Alternatives

The magnitude of the effect that discounting has on compliance costs and the practical considerations making immediate compliance not feasible, requires the consideration of alternative compliance scenarios. Figures 4.2 A-H are a graphic presentation of the compliance scenarios included in Table 4.1.

Scenarios A and B represent immediate compliance with an 85 dBA and 90 dBA standard. The capital costs for the first 20-year time frame are the BBN estimates of $18.5 and $10.5 billion. To these figures were added the discounted maintenance costs and the 2nd 25-year time frame costs to arrive at the totals listed in Figures 4.2 A and B.

Scenarios C and D represent a 5 year compliance period for the 85 dBA and 90 dBA standard. The investment schedule is from the BBN estimates of the distribution of noise control capital costs over different compliance periods.[1] The effect of extending the compliance period by 5 years reduces

[1] BBN Report No. 3246, Economic Impact Analysis of Proposed Noise Control Regulation, Figure 3.1, p. 3-35.

the cost of the 85 dBA regulation by $6.3 billion and reduces the cost of the 90 dBA regulation by $3.6 billion. (Compare Figures 4.2 A and B with Figures 4.2 C and D.)

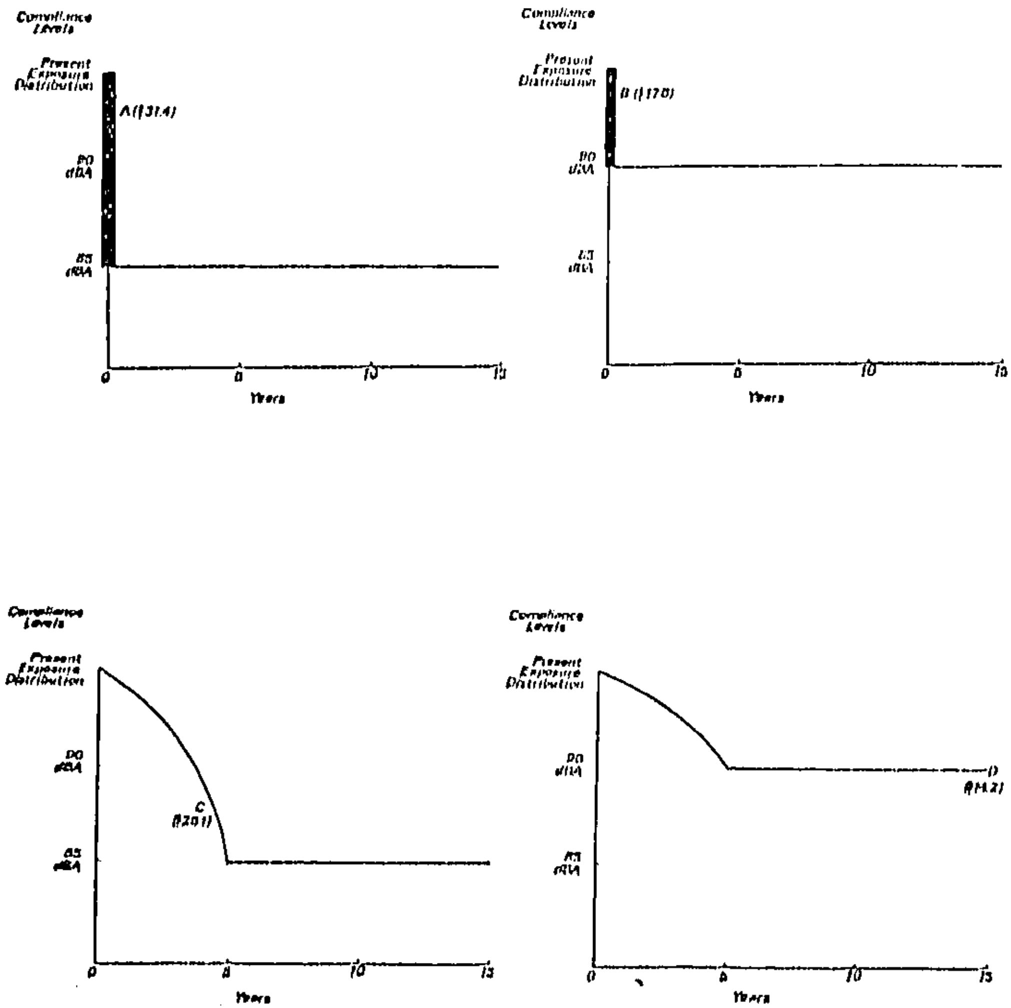
Scenario E represents a 10 year compliance period for the 85 dBA standard. The effect of extending the compliance period to 10 years reduces the cost of an 85 dBA standard from the immediate compliance cost of $31.8 billion to $19.3 billion.

Scenarios F and G are hybrid compliance schedules. The first part of each scenario is compliance with the 90 dBA standard within 5 years. The second part is a subsequent reduction to the 85 dBA level in an additional 5 and 10 years. Note: the assumption that the cost to go from 90 dBA to 85 dBA levels is equal to the incremental compliance costs ($8.8 billion) provided by BBN. We considered the possibility that incremental cost may underestimate the costs of the second step. However, it is logical to assume that in those situations where it is cheaper to reduce the noise level to lower standard in one step, the rational industrialist will choose to comply with the 85 dBA standard, even though the standard may allow a two-step approach to the lower standard.

Finally, scenario H represents a 15 year compliance period for the 85 dBA standard. The effect of extending the compliance period to 15 years will further reduce the before-tax costs of an 85 dBA standard from the immediate compliance cost of $31.8 billion to $14.9 billion.

The final two graphs on Figure 4.3 represent all the compliance alternatives for which costs were computed. The graph on the left is significant because it highlights the 4 compliance scenarios for which detailed benefits calculations were made.

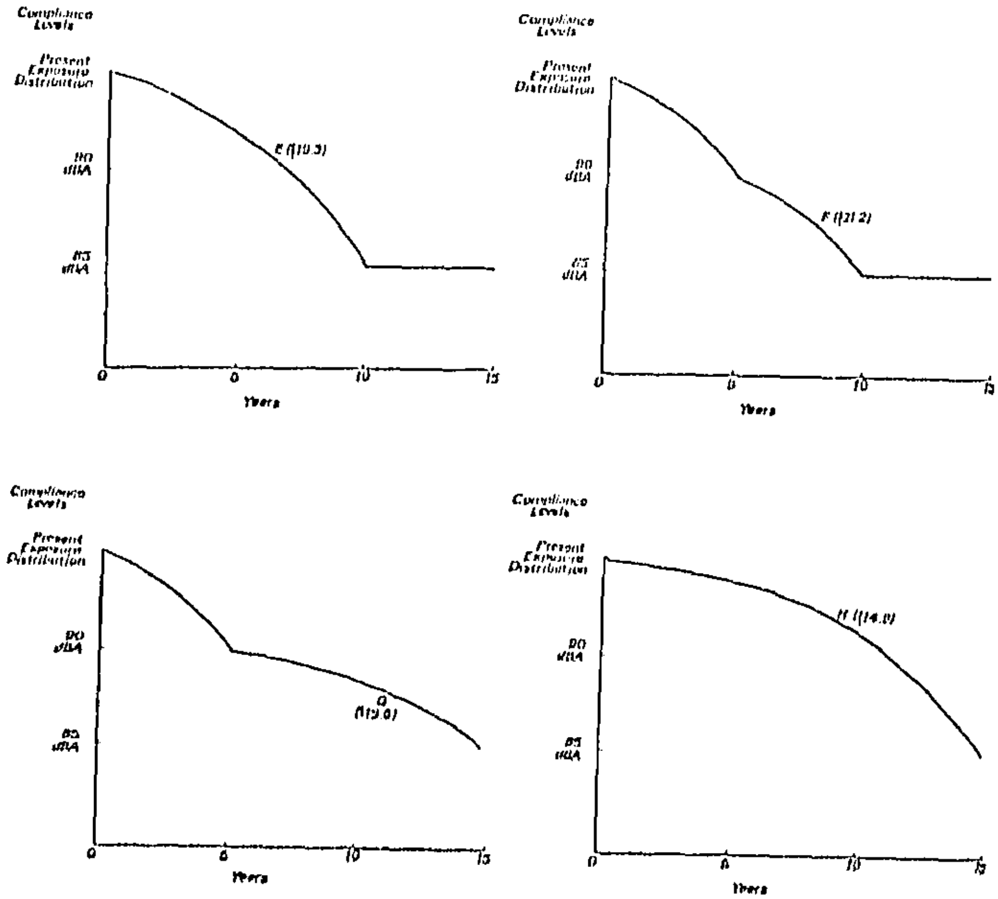
COMPLIANCE SCENARIOS



Discounted Present Value of BBN Compliance Cost Estimates (Capital and Maintenance Charges) <u>Before</u> Tax Effects (in billions of dollars)

FIGURES 4.2 A, B, C, AND D

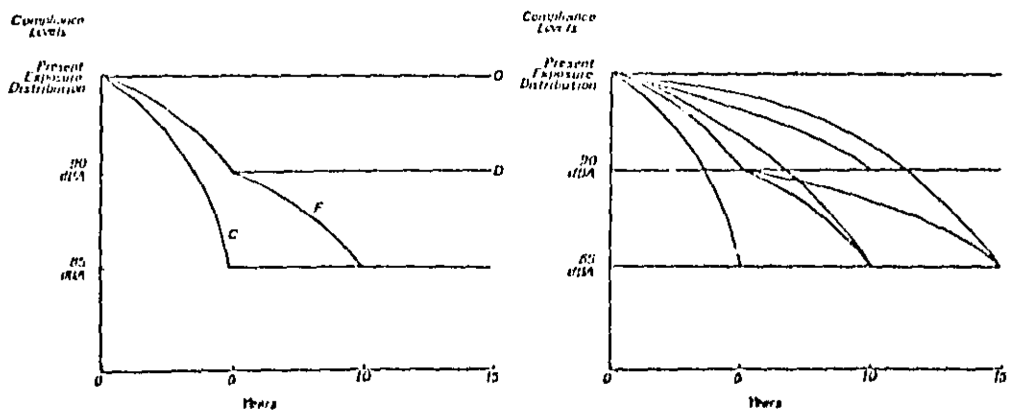
COMPLIANCE SCENARIOS



Discounted Present Value of BBN Compliance Cost Estimates (Capital and Maintenance Charges)
Before Tax Effects
(in billions of dollars)

FIGURES 4.2 E, F, G, AND H

COMPLIANCE SCENARIOS



Compliance Alternative	Cost
A. Immediate Compliance 85 dBA--85 (0 yr.)	$ 31.4
B. Immediate Compliance 90 dBA--90 (0 yr.)	$ 17.8
C. 5 yr. Compliance 85 dBA--85 (5 yr.)	$ 25.1
D. 5 yr. Compliance 90 dBA--90 (5 yr.)	$ 14.2
E. 10 yr. Compliance 85 dBA--85 (10 yr.)	$ 19.3
F. 5 yr. Compliance 90 dBA; within 10 yr. Compliance 85 dBA--90 (5 yr.);85 (10 yr.)[1]	$ 21.2
G. 5 yr. Compliance 90 dBA; within 15 yr. Compliance 85 dBA--90 (5 yr.);85 (15 yr.)[1]	$ 19.6
H. 15 yr. Compliance 85 dBA--85 (15 yr.)	$ 14.9

Discounted Present Value of BBN Compliance Cost Estimates (Capital and Maintenance Charges) Before Tax Effects (in billions of dollars)

FIGURE 4.3

Costs of Alternative Compliance Scenarios Industry-By-Industry Basis

The methodology for calculating the costs of alternative compliance scenarios for the aggregate compliance costs is similarly applicable for determining the costs of the scenarios on an industry-by-industry basis. Table 4.2 presents the costs of different compliance scenarios for each of the 19 SIC codes.

The reader is cautioned that Table 4.2 is included to show the potential wide variation among industries in the economic burden to comply with 90 dBA and 85 dBA standard. As discussed earlier, (see Section 4.2), there exists possible limitations in the usefulness of the BBN cost estimates as a base for setting industry-specific standards.

A comparison of the costs and benefits of alternative compliance scenarios on an industry-by-industry basis will be presented in a discussion of cost/benefit. (See Section 6).

TABLE 4.2

TOTAL DISCOUNTED COMPLIANCE COSTS* OVER 45 YEARS
(MILLIONS OF DOLLARS, PRESENT VALUE)

		Costs of Different Compliance Scenarios			
Compliance Scenario**		0	D	F	C
SIC	INDUSTRY	Present	90 (5yr)	90 (5yr) 85 (10yr)	85 (5yr)
20	Food and Kindred Products	0	777	1,730	2,264
21	Tobacco Manufacturers	0	61	113	142
22	Textile Mill Products	0	1,560	2,700	3,339
23	Apparel & Other Textile Products	0	0	13	20
24	Lumber and Wood Products	0	945	1,327	1,541
25	Furniture and Fixtures	0	480	560	602
26	Paper and Allied Products	0	270	365	419
27	Printing and Publishing	0	635	1,224	1,555
28	Chemicals and Allied Products	0	412	689	845
29	Petroleum and Coal Products	0	236	310	351
30	Rubber and Plastic Products	0	155	268	331
31	Leather and Leather Products	0	0	9	14
32	Stone, Clay & Glass Products	0	230	416	520
33	Primary Metal Industries	0	1,884	3,211	3,954
34	Fabricated Metal Products	0	1,762	1,983	2,109
35	Machinery, except Electrical	0	2,951	3,501	3,812
36	Electrical Equipment & Supplies	0	196	391	500
37	Transportation Equipment	0	905	1,234	1,419
49	Electric, Gas & Sanitary Services	0	777	1,128	1,325
	ALL INDUSTRY TOTAL	0	14,241	21,173	25,062

* Based on BBN Data

** See Figure 4.3 for a graphical representation of the lettered compliance scenarios

4.4 Costs of Noise Monitoring, Audiometric Testing, and Provision of Hearing Protectors

Heretofore the compliance cost calculation included only the capital and maintenance charges required to comply with the proposed regulation. This section will discuss the costs of other facets of regulation: cost of noise monitoring, cost of audiometric testing, and cost of provision of hearing protectors.

Table 4.3 shows the discounted present value cost of compliance with a regulation that requires noise monitoring and audiometric testing for those workers exposed to sound levels greater than 85 dBA. The cost was calculated by multiplying the BBN cost per worker estimate for noise monitoring ($12 per person)[1] and audiometric testing ($20 per person)[1] by the total number of production workers and the number of workers exposed to sound levels greater than 85 dBA, respectively. This figure, which represents the cost per year of compliance, was then discounted at a rate of 7% over 5, 10, 20, and 40 years.

The cost of providing hearing protectors was calculated by multiplying the BBN cost/per worker estimate ($10 per person)[2] by the number of production workers exposed to sound levels greater than 85 dBA. This total was then discounted in the same manner described above.

It is important to note the compliance costs of noise monitoring, audiometric testing, and hearing protectors vary with alternative compliance scenarios. A compliance scenario which requires engineering controls to 85 dBA would not require expenditures for audiometric testing and hearing protectors. A scenario with a 90 dBA compliance level, however, would require expenditures for audiometric testing and hearing protectors (if required by regulation) in addition to the capital and maintenance compliance charges. Thus, the effect of including the costs of noise monitoring, audiometric testing and hearing protectors is to increase the cost of complying with a 90 dBA standard relative to an 85 dBA standard. In other words,

[1] BBN Report No. 3246, Economic Impact Analysis of Proposed Noise Control Regulation, p.3-1.

[2] Ibid., p.3-33.

TABLE 4.3

DISCOUNTED PRESENT VALUE OF COSTS OF NOISE
MONITORING, AUDIOMETRIC TESTING AND HEARING PROTECTORS*

Dollars in Millions

Cost	1 year	5 years	10 years	20 years	40 years
Noise Monitoring (cost $12/worker x 14.5 million workers)	174	713.4	1222.2	1843.4	2318.9
Audiometric Testing (cost $20/worker x 5.1 million workers)	102	418.2	716.4	1080.6	1359.4
TOTAL Monitoring and Testing	276	1131.6	1938.6	2924	3678.3
Hearing Protectors (cost $10/worker x 5.1 million workers)	51	209.1	358.2	540.3	679.7
TOTAL Hearing Protectors, Monitoring and Testing	327	1340.7	2296.8	3464.3	4358

*Assuming:

- cost/worker for noise monitoring, audiometric testing and hearing protectors based of BBN estimates
- 14.5 million workers in workforce; 5.1 million workers exposed to sound levels greater than 85 dBA
- discount rate at 7%

the incremental dollar savings of a less stringent standard are reduced by the additional costs of audiometric testing and hearing protectors.*

4.5 Assumptions and Limitations

The following are the assumptions contained in our treatment of the costs of the proposed noise standards in the workplace. It is our intention to be as explicit as possible in stating our assumptions so that the reader may modify the analysis as additional information becomes available or other assumptions appear more appropriate. We assume:

- BBN capital cost estimates for compliance
- BBN maintenance cost estimates equal to 5% of capital costs
- no direct assessment of labor and capital productivity changes
- costs to go from 90 dBA to 85 dBA equal the incremental compliance costs ($7.9 billion)
- 3% per year reduction in capital cost estimated by considering:
  1) the firm's opportunity to introduce quieter equipment through normal capital replacement, and
  2) cost decreases from technological change in the production and installation of noise control equipment.

  Note: This tacitly assumes no technological breakthroughs in either the noise control field or those industries with severe noise problems.
- Capital costs for the 2nd 25 year time frame are equal to BBN estimate for current compliance adjusted by a .40 multiplier for cost reduction for technological change and inclusion of noise control in machine design.
- a discount rate of 7%
- qualitative treatment of tax implications

*The important issue of reliability of audiometric testing and hearing protectors is raised in Section 8.

- cost of noise monitoring and audiometric testing are not included in the compliance cost calculation
- cost estimates do not reflect the dollar savings that would be achieved through the use of administrative controls and possible use of hearing protectors in lieu of engineering controls.

This concludes our examination of the costs to industry from complying with the proposed noise standards. The next section will discuss the benefits that will accrue to the workers and to industry from the expenditure of the compliance costs.

5. BENEFITS

As in the case with the costs, many of the benefits of reducing workplace noise can only be estimated with considerable uncertainty. Nonetheless, if care is taken in the analysis it is possible to make benefit calculations which clarify the likely social efficacy of different noise standards and compliance scenarios. Further, it is possible to clarify how assessments of the benefits change with:

- different ways of defining the benefits (such as different "fences")
- specific variables (such as "worker mobility") and assumptions.

Toward these ends, we present here the results of some exemplary calculations of the likely magnitude of hearing conservation and some other benefits. These calculations are based on the noise exposure data developed by BBN. Additionally, the hearing impairment estimates utilize:

- the "equal energy rule" to compute equivalent continuous exposures for workers who spend portions of their working life at different noise levels, and
- relationships between noise exposure and hearing impairment derived from Baughn[1]
- the age distribution of workers in 19 industries in 1970*

Important qualifications and assumptions for these calculations are listed below in Section 5.1.4 and will be elaborated in more detail in the Appendix to this report.

---

[1]Baughn, W. L.: Relation Between Daily Noise Exposure and Hearing Loss Based on the Evaluation of 6835 Industrial Noise Exposure Cases, AMRL-TR-73-53, NTIS, Springfield, Virginia (1973).

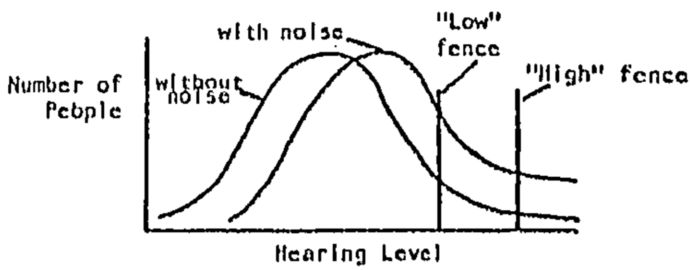
*There are many differences between our calculations and those presented in the Inflationary Impact Statement (IIS). Our use of an appropriate age cross-section of the population, for example, enables us to determine the numbers of people experiencing different degrees of hearing impairment at any one time in the future.

5.1 Hearing Conservation*

5.1.1 Measures for Defining Benefit

The Concept of "Fences"

The measures used for defining hearing impairment have given rise to great confusion, some of which is reflected in the IIS. Fundamental to a proper understanding of hearing conservation benefits is an appreciation of the fact that noise causes a change from one population distribution of hearing levels to another:



Essentially the entire population of workers has worse hearing because of the influence of noise. Those which, without noise, might have had excellent hearing are shifted so that they have less than excellent hearing. Those which without noise, would have had only fair or poor hearing have their hearing handicaps increased.

The usual practice in the past--and that used in the IIS--has been to draw a single line, or "fence", at a particular hearing level**and determine the number of people moved from one side of the fence to the other side of the fence by the influence of noise. This procedure has been misleading because many have interpreted numbers of people crossing the single fence as the total numbers of people "harmed" by a particular noise exposure--and hence potentially benefited by noise control.

*For a discussion on the discounting of hearing conservation benefits see P.5-43.
**Most commonly, the fence is drawn at 25 dB averaged at .5, 1, 2 kHz Re: ISO

This difficulty can be mostly overcome if, instead of using a single fence, a series of fences is used to describe the spectrum of hearing impairment experienced by the population under the influence of noise. In our work, we have chosen to use fences at 20, 25, and 50 dB* to determine the numbers of people who are placed into 20-25, 25-50, and over 50 dB "hearing level categories" because of the influence of noise.** Thus we determine the changes in the numbers of people experiencing what might be described as "mild", "moderate" and "severe" hearing impairment for different noise control standards and compliance scenarios.

Equilibrium vs. Pre-Equilibrium Benefits

There is another feature of hearing conservation benefits which is fundamental for purposes of definition. The population distribution of hearing levels at any one time reflects not only present noise exposures but noise exposures which have been experienced over the entire period of the population's work history. In the case of workers in their sixties, this history covers forty years or more. Therefore, it must be expected that even if full compliance with a 90 dBA or an 85 dBA regulation could be achieved at once by the end of today, the full equilibrium change in the population distribution of hearing levels would not be seen for at least forty years into the future. Figures 5.1 and 5.2 show the approximate rate at which the benefits of 90 and 85 dBA regulations (measured as the numbers of people prevented from being in different hearing level ranges at any one time) approach their ultimate equilibrium values. (Equilibrium is achieved somewhat more rapidly for the milder categories of hearing impairment because younger age groups contribute somewhat more to these groups and young populations come to equilibrium faster.)

---

*Averaged at .5, 1, 2 kHz Re: ISO. Throughout this discussion, unless otherwise stated, hearing levels are expressed for the average of these three frequencies.

**In all cases in this work the numbers of people in those categories due to noise is after subtraction of the people who would be in the same categories because of presbycusis alone.

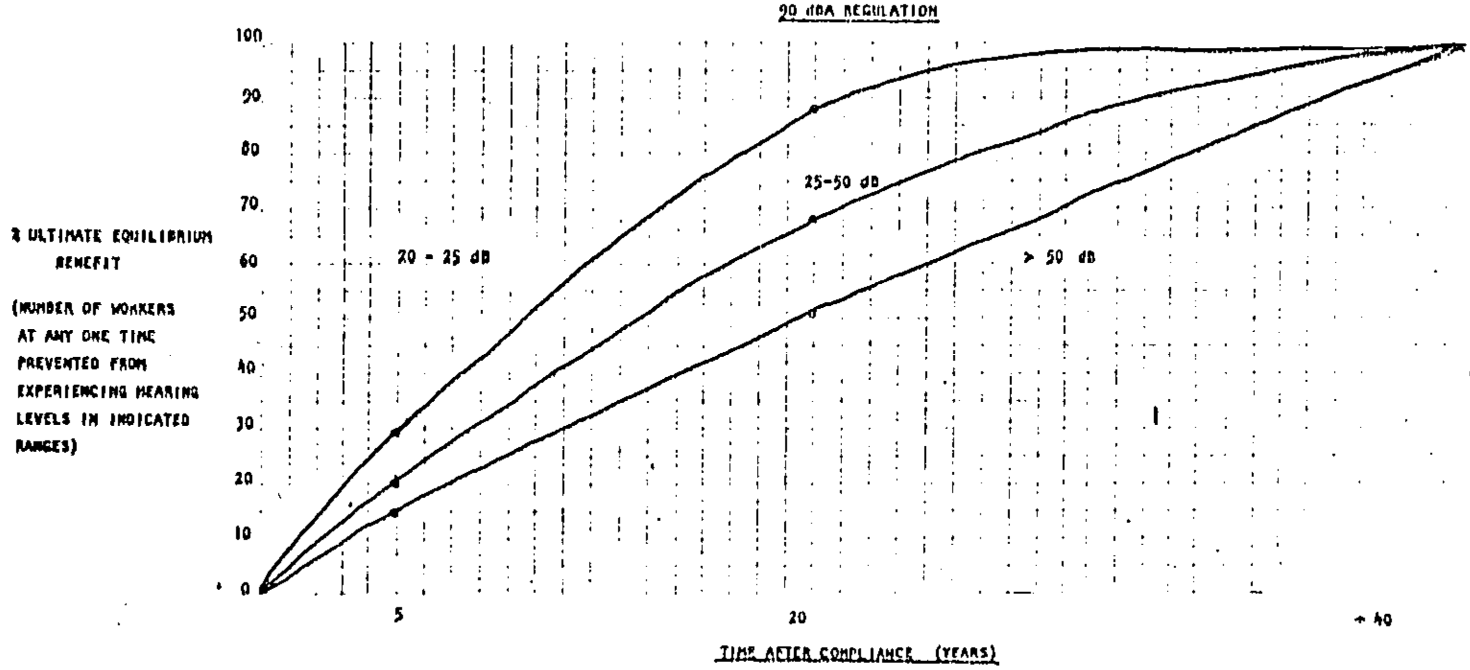
The effect of including the "mild" 20-25 dB (.5, 1, 2) hearing impairment category will be qualitatively similar to the result of using a 25 dB fence for hearing levels defined by 1, 2, 3 kHz frequencies.

Figure 5.2

HEARING CONSERVATION BENEFIT AT

DIFFERENT TIMES AFTER COMPLIANCE

90 dBA REGULATION



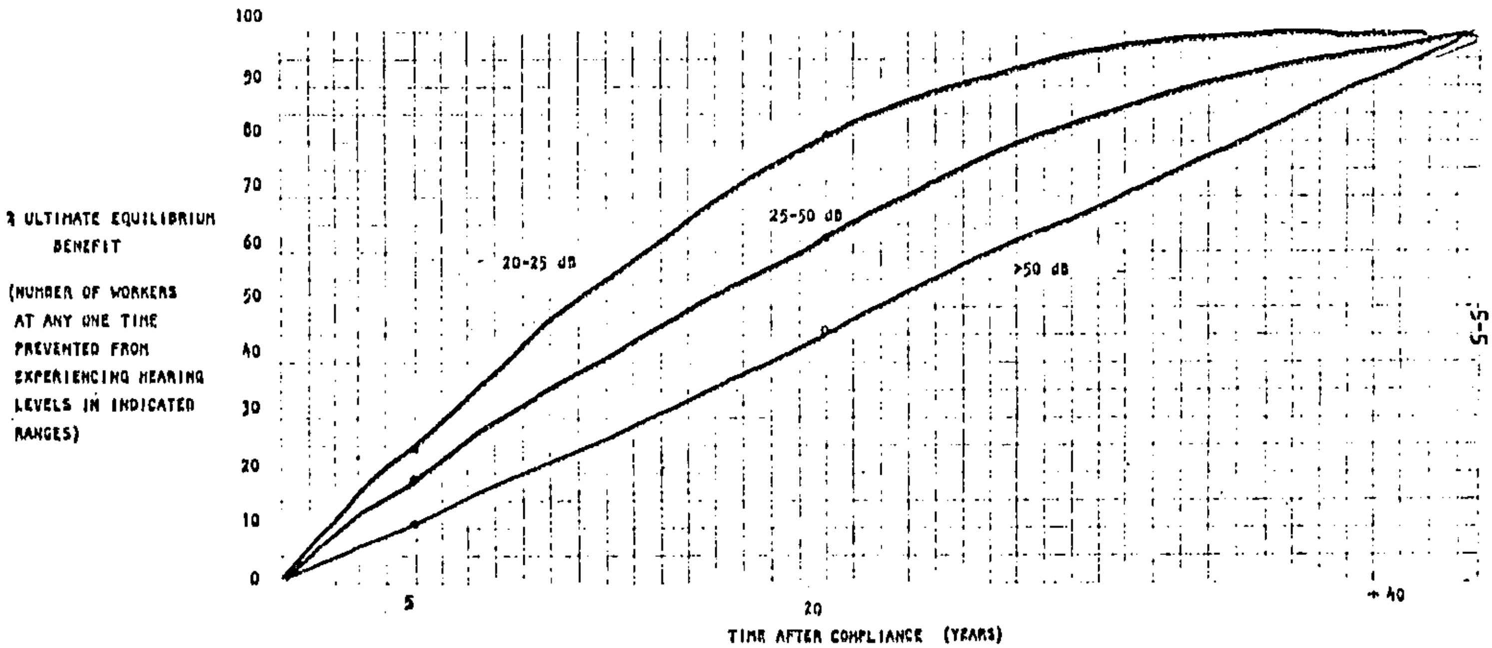
5-4

Figure 5.2

HEARING CONSERVATION BENEFIT AT

DIFFERENT TIMES AFTER COMPLIANCE

85 dBA REGULATION



5-5

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"Stock" and "Flow" Measures of Hearing Conservation Benefit

We have dealt with this equilibrium/pre-equilibrium problem in the following way:

- Ultimate equilibrium benefits are expressed with a "flow" concept--the number of people at any one time after equilibrium who have been prevented from experiencing various degrees of impairment (20-25 dB, 25-50 dB, over 50 dB) by the noise regulation and compliance scenario under study.
- Pre-equilibrium benefits are expressed with a "stock" concept--the number of person-years of impairment in the three hearing level categories prevented by the compliance scenario before the establishment of the 40-year equilibrium.

The latter measure of benefits can be appropriately compared with the present value of total compliance costs computed in the "Cost" section above, since both are "stock" measures of cumulative effects over the same time period.* The former measure, showing the ultimate flow of benefits at equilibrium, should be compared with the ultimate flow of compliance costs for maintenance and replacement of noise controls in the far future.

Table 5.1 shows hearing conservation benefits of different compliance scenarios expressed with these two measures. It may be noted that the "85 dBA (5 years)" compliance scenario and the "90 dBA (5 years), 85 dBA (10 years)" scenarios have the same ultimate equilibrium benefit because the final compliance level of 85 dBA is the same. However, the five-year delay in implementation of 85 dBA compliance between the two scenarios is reflected in the larger pre-equilibrium benefit (in person-years) of the 85 dBA (5 years) scenario.

*For purposes of comparison, "equilibrium" in the calculations is assumed to occur at exactly 40 years after initial compliance is complete (year 45 in Figure 4.3 of the "Cost" section).

Table 5.1

RELATIONSHIP BETWEEN TWO MEASURES OF HEARING CONSERVATION BENEFITS

	Equilibrium Measure	Pre-equilibrium Measure
Compliance Scenarios	Millions of Workers Prevented From Experience Hearing Levels Greater Than 25 dB At Any One Time After Ultimate Equilibrium	Millions of Person-Years of Impairment Over 25 dB Prevented Before Establishment Of Ultimate Equilibrium
Present Exposures Unchanged	0	0
Comply 90 dBA within 5 yrs.	.77	18
Comply 90 dBA within 5 yrs.; Comply 85 dBA within 10 yrs.	1.35	28
Comply 85 dBA within 5 yrs.	1.35	30

Hearing Impairment Within Different Hearing Level Categories

For simplicity, in Table 5.1 and some other tables we have presented results using only the "over 25 dB" hearing level category--which is the sum of "25-50 dB" and "over 50 dB" categories. As per our earlier discussion, for ultimate policy purposes it must be borne in mind that hearing impairment is a continuum. Figure 5.3 shows the results of expressing the ultimate equilibrium benefits in our three designated hearing level ranges. It can be seen that of the hearing impairment over 25 dB prevented by either the 85 dBA or the 90 dBA regulations, approximately 15% represents hearing impairment in the severe "over 50 dB" category.* Further, the number of people prevented from experiencing 20-25 dB hearing levels is approximately 1/3 as large as the number of people prevented from experiencing hearing levels over 25 dB.

5.1.2 Factors Affecting the Benefit Calculations

Other than the noise standard level and compliance scenarios (which will be covered below) the major variable of importance in determining the level of benefits expected from noise control is worker mobility. The dose-response curves** for noise-induced hearing damage are such that the larger the mobility of the working population--that is, the more that the noise exposure of a given job is spread among a larger population by job exchange--the larger the hearing impairment effect of that job on the population as a whole. Although a particular job-exchange between worker "A" in a noisy job and worker "B" in a quiet job will certainly reduce the probability that worker "A" will cross any given "fence" of hearing level, <u>in general</u> the increase in the probability that worker "B" will cross the fence because of the job-exchange <u>more than compensates</u> on a population basis for the benefit received by "A". As can be seen in Figure 5.4, this is true*** whatever hearing level category is examined and the differences between calculations based on different indexes of job mobility are very substantial.

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*The policy maker may choose to value the prevention of impairment over 50 dB more highly than the prevention of impairment in the 20-25 dB or 25-50 dB categories.

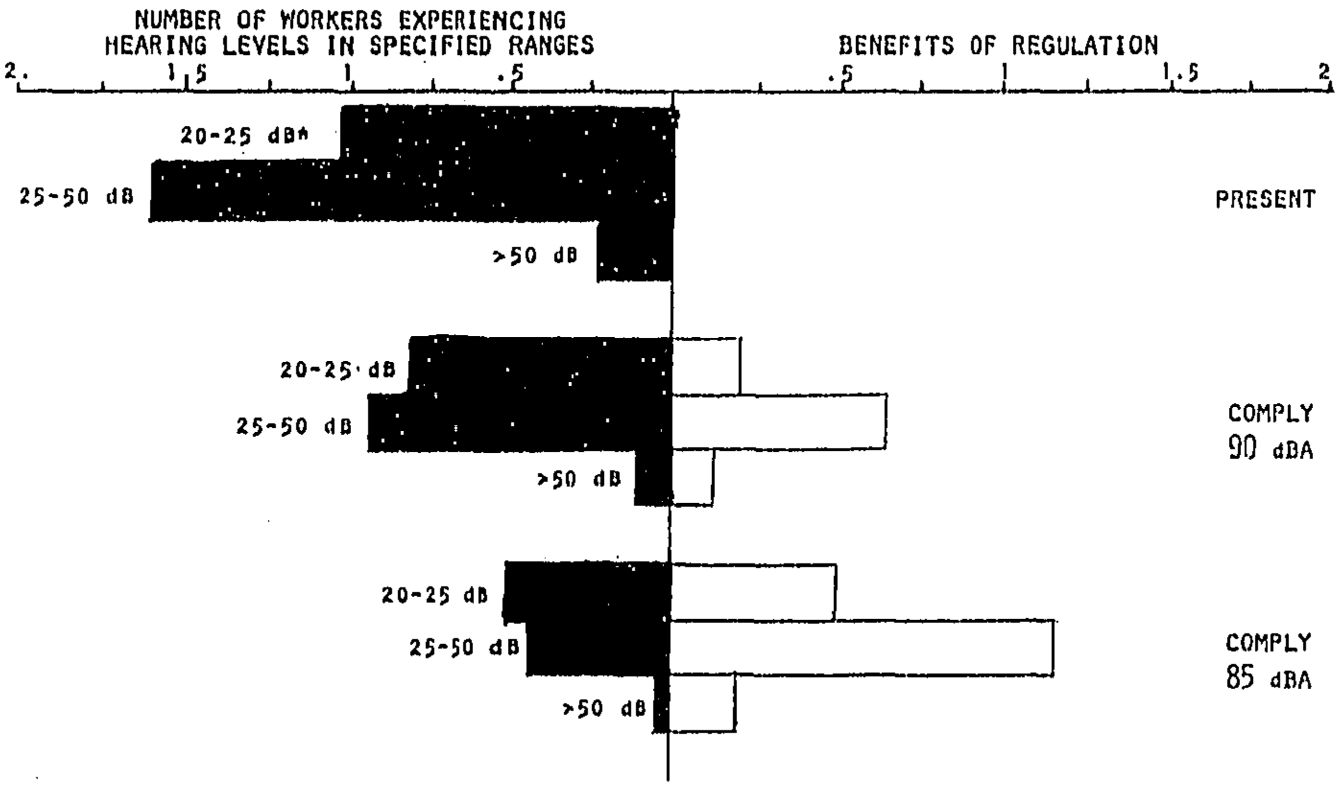
**That is, the relationship between noise "dose" and hearing impairment "response".

***At least for the Baughn damage-risk data. Calculations based on the Robinson data are expected to be similar but this requires confirmation in future work. The worker mobility calculations for the HS are defective in that they seem to neglect all the hearing damage produced in workers who stay at any one noisy job less than 3 years.

FIGURE 5.3

HEARING CONSERVATION BENEFITS, AS DEFINED BY DIFFERENT "FENCES", FOR DIFFERENT COMPLIANCE LEVELS

(IN MILLIONS OF WORKERS AT EQUILIBRIUM)



* ALL HEARING LEVELS ARE AVERAGES AT .5, 1, 2 KHz RE: ISO.

EFFECT OF WORKER MOBILITY ON THE NUMBER OF WORKERS EXPERIENCING HEARING LEVELS OVER 25dB AT ANY ONE TIME AFTER THE ESTABLISHMENT OF EQUILIBRIUM

(IN MILLIONS OF WORKERS)

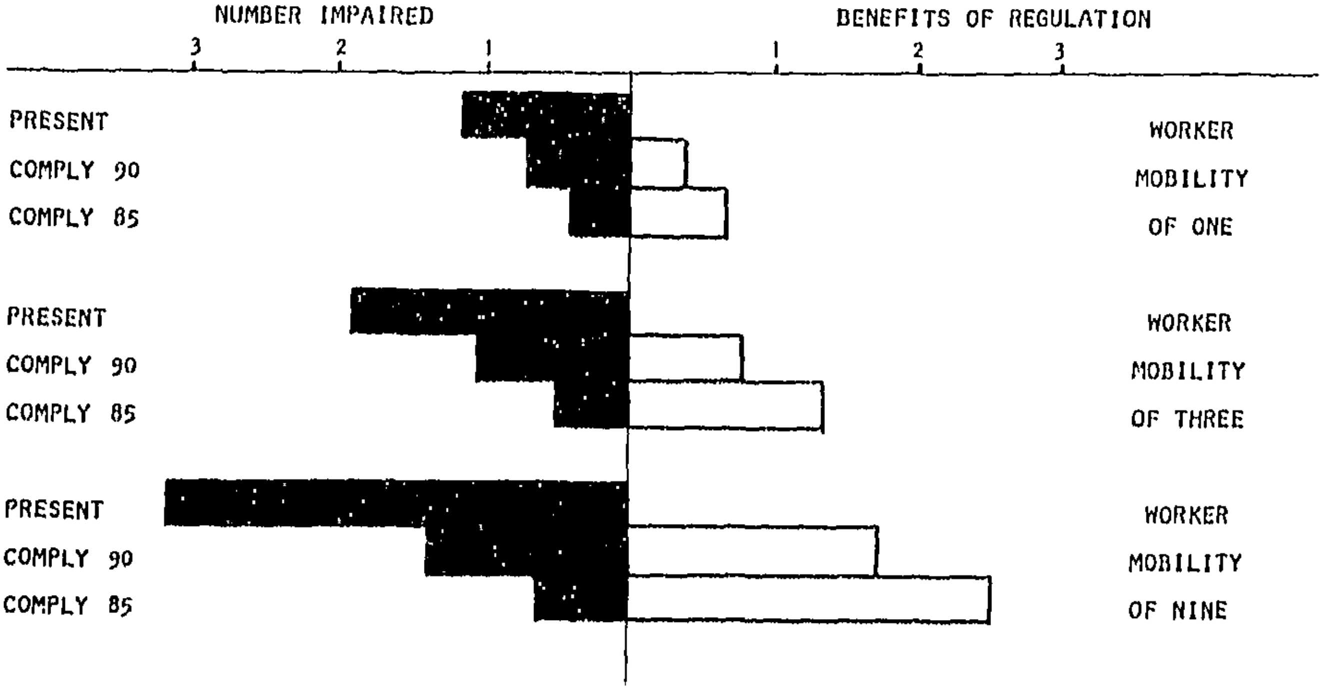


FIGURE 5.4

For our calculations (except where otherwise stated) we have chosen to use a job mobility index of 3--meaning, on average that workers of all ages in noisy jobs (greater than 80 dBA) have spent an average of 1/3 of their working lives at the noise level of their present job and 2/3 of their working lives at quiet jobs, (80 dBA). Precise determination of the actual job mobility of workers in noisy jobs is exceedingly difficult from available information, but data shown in Table 5.2 indicates that, on average, the general population of all employees has spent approximately 1/3 of their working time on jobs at their present establishment.

5.1.3 Benefits of Different Compliance Scenarios

The Effect of Standard Compliance Level on Ultimate Equilibrium Benefits

Table 5.3 shows the effect of various standard compliance levels on the magnitude of the equilibrium flow of benefits within different hearing level categories. The expected benefits of an 85 dBA regulation are substantially larger than the expected benefits of a 90 dBA regulation. An 85 dBA regulation will produce nearly a 90% reduction in the number of workers in the "severe" (over 50 dB) hearing impairment category due to noise*, whereas a 90 dBA regulation will produce a reduction of only about 50%. Similar results can be seen for the 25-50 dB category. Further, for the milder 20-25 category the benefits of the 85 dBA regulation increase proportionally more than the benefits of the 90 dBA regulation.

Benefits of the Different Compliance Scenarios

Figure 5.5, similar to the illustrations in the cost section, diagrams the scenarios for which we have computed benefits. Figure 5.6 shows a "stock" measure (person years > 25 dB) of those benefits for the first forty years after initial compliance (corresponding to the period from year five to year forty-five on Figure 5.5). It can be seen that the two-step "90 (5 year), 85 (10 year)" scenario produces about 93% of the person-years of hearing conservation benefit over 25 dB as the 85 (5 year) scenario. We should note, however, that because of the more rapid equilibration of the 20-25 dB

*"due to noise" means that the total numbers given for present exposures are the additional numbers of people in each hearing level category after subtraction of the numbers of people in each category due to presbycusis alone.

impairment category (see Figures 5.1 and 5.2) the five year delay will produce a somewhat smaller proportion of the benefit in the 20-25 dB range (i.e. < 93%).

Table 5.2

PROXY MEASURE OF WORKER
MOBILITY FOR DIFFERENT AGE GROUPS*

	A	B	A ÷ B
Age	Average Number of Years Since Age 18	Average Job Tenure in Years at Current Establishment	Measure of Worker Mobility
20-24	4	1.69	2.37
25-34	11.5	3.84	2.99
35-44	21.5	7.27	2.96
45-54	31.5	11.23	2.80
55-64	41.5	14.41	2.88
over 65	50	16.05	3.12

*Based on data from "Job Tenure of Workers" January 1973, Special Labor Force Report 172, Table A, Age: Tenure of Current Job, January, 1973.

CAVEAT: A number of factors will tend to make these all-employee averages over- and under-estimate the effective job mobility of noise-exposed workers for hearing impairment calculations:

Factor tending to produce lower effective job mobility than indicated by the all-industry averages:

--A worker transferring from a noisy job at one establishment to a similarly noisy job in another establishment is counted as having moved for purposes of the data. However, since such a worker's noise exposure has not changed, no job mobility has occurred for the purpose of computing hearing impairment impact.

Factor tending to produce higher effective job mobility than indicated by the all-industry averages:

--A worker transferring from a noisy job to a quiet job at the same establishment is not counted as having moved for purposes of the data. However, since such a worker's noise exposure has changed, job mobility has occurred for the purposes of computing hearing impairment impact.

Factor producing a bias of uncertain direction:

--Noise-exposed workers may have higher or lower average job mobility than the average of all employees.

TABLE 5.3

EQUILIBRIUM* BENEFITS
OF DIFFERENT COMPLIANCE LEVELS

Workers In Each Hearing Level Range/100 Jobs
In All Industry Due to Noise**

	Hearing Impairment With No Change In Exposures	Benefits Achieved by Compliance to Specified Levels			
		90 dBA	87.5 dBA	85 dBA	82.5 dBA
20-25 dB***					
No. of Workers Per 100 Jobs	6.98	1.48	2.22	3.37	5.00
% of Reduction In No. of Workers		21.3	31.8	48.3	71.6
25-50 dB***					
No. of Workers Per 100 Jobs	11.33	4.65	6.13	7.99	9.49
% of Reduction In No. of Workers		41.0	54.1	70.5	83.8
> 50 dB***					
No. of Workers Per 100 Jobs	1.597	.753	.985	1.391	1.453
% of Reduction In No. of Workers		47.1	61.7	87.1	90.9

*Ultimate Equilibrium greater than 40 years after compliance

**After subtraction of presbycusis

***(.5, 1, 2 KHz) Re: ISO

COMPLIANCE SCENARIOS

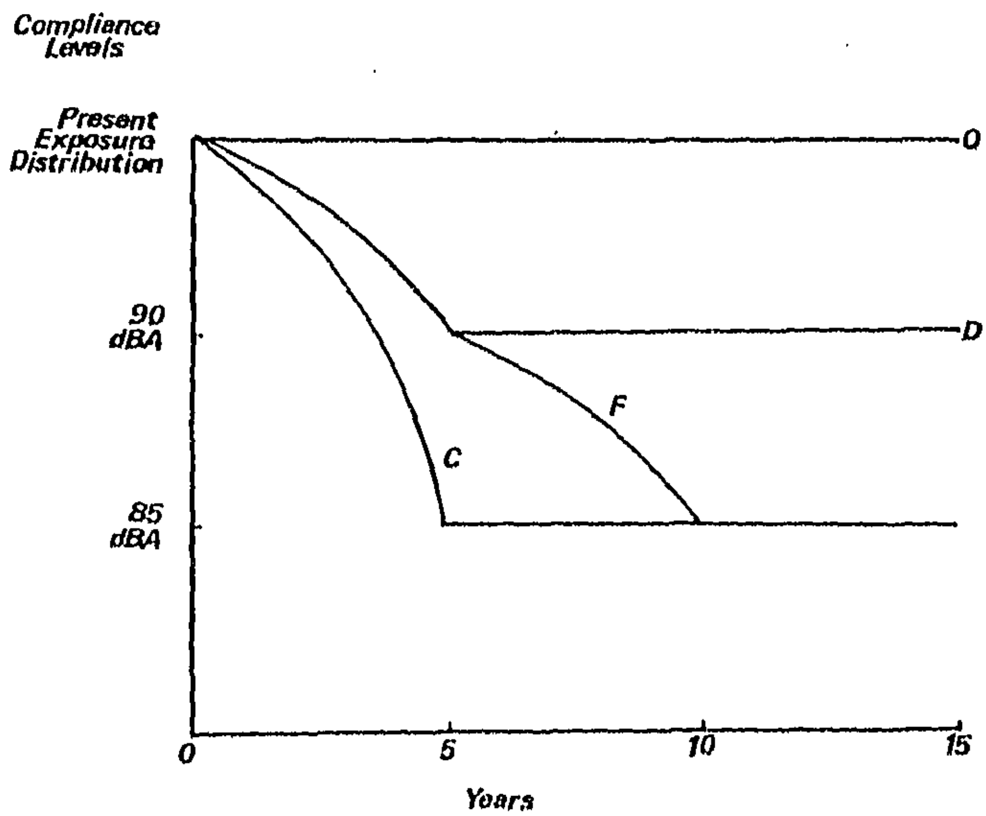


FIGURE 5.5

HEARING CONSERVATION BENEFITS

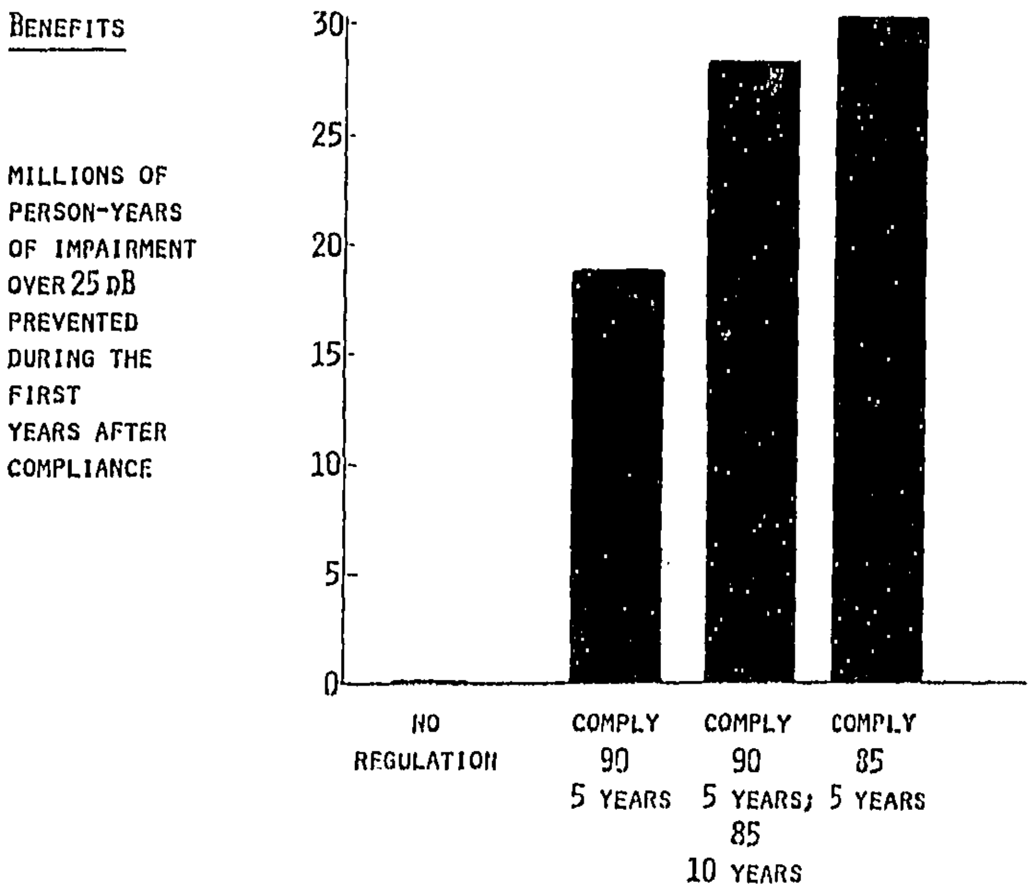


FIGURE 5.6

Benefits of Different Compliance Scenarios in Different Industries

As will be discussed in more detail in the Appendix, the BBN data on current noise exposures in individual industries must be regarded as provisional--although they represent the best information available. Based on this data, Table 5.4 presents the results of calculations of the expected benefit produced by implementing the various compliance scenarios in different industries. It is possible that if the underlying data are confirmed and adjusted where necessary, similar calculations might help form the basis for rational choices between different compliance scenarios for different industries.

TABLE 5.4
PERSON-YEARS OF NOISE-INDUCED IMPAIRMENT OVER 25 dB
DURING THE FIRST FORTY YEARS AFTER ATTAINMENT OF YEAR-FIVE COMPLIANCE
(IN MILLIONS OF PERSON-YEARS)

			Hearing Impairment Prevented By Different Compliance Scenarios			
	Compliance Scenario*		0	D	F	C
SIC	INDUSTRY	Impairment With No Changes In Exposures	Present	90 (5yr)	90 (5yr), 85 (10yr)	85 (5yr)
20	Food and Kindred Products	3.97	0	.783	1.418	1.551
21	Tobacco Manufacturers	.158	0	.036	.050	.053
22	Textile Mill Products	11.41	0	3.47	4.78	5.03
23	Apparel & Other Textile Products	.96	0	.017	.058	.068
24	Lumber and Wood Products	10.16	0	3.29	4.46	4.66
25	Furniture and Fixtures	1.95	0	.277	.602	.676
26	Paper and Allied Products	2.23	0	.300	.714	.807
27	Printing and Publishing	2.71	0	.201	.722	.851
28	Chemicals and Allied Products	3.66	0	.766	1.316	1.429
29	Petroleum and Coal Products	2.11	0	.702	.917	.955
30	Rubber and Plastic Products	1.87	0	.296	.570	.630
31	Leather and Leather Products	.197	0	.004	.011	.013
32	Stone, Clay & Glass Products	1.60	0	.309	.476	.513
33	Primary Metal Industries	13.15	0	3.89	5.42	5.72
34	Fabricated Metal Products	5.06	0	1.254	1.92	2.05
35	Machinery, except Electrical	4.90	0	1.147	1.757	1.885
36	Electrical Equipment & Supplies	.90	0	.070	.208	.242
37	Transportation Equipment	3.75	0	.846	1.373	1.482
49	Electric, Gas & Sanitary Services	4.03	0	.417	1.221	1.412
ALL INDUSTRY TOTAL		74.75	0	17.98	27.94	29.99

* Year-Five Compliance corresponds to Year-Five on Figures 4.2 C,D, and F.
** See Figure 4.3 for a graphical representation of the lettered compliance scenarios.

5.1.4 Assumptions and Limitations of the Calculations

Time does not permit a full exposition here of all the appropriate caveats with respect to basic data, assumptions, and detailed methodology for the results presented above. In this section we shall list some of these features which will be covered in more depth in the Appendix.

- Uncertainties in the BBN exposure data by industry
  - --Small sample size within industries, possibly unrepresentative
  - --Failure to use objective instrumentation for noise measurement
  - --Expression of employee exposures in terms of a 5 dBA time-exposure trading rule, necessitating an uncertain adjustment of the data for industries where noise intensity fluctuates during the day and the appropriate 3 dBA trading rule would give a substantially different equivalent continuous exposure value.
- Procedural Assumptions
  - --The Baughn damage-risk data for predicting hearing impairment.
  - --The equal energy rule for calculating equivalent continuous noise exposures for populations with varying exposures through working life.
  - --The age distribution of the worker population in the 19 industries in 1970 (considered, for the calculation to be unchangingly representative of the age distribution of the worker population into the far future).
  - --The number of production workers employed will be constant over the next forty years at levels corresponding to 1974 average employment in each industry.
  - --Exclusion from consideration of people who have left the workforce but who may bear hearing impairment caused by work through their retirement years.
  - --Worker mobility of 3 for all age groups and all industries. No distinction between male and female workers (who may differ substantially in average mobility).
  - --Definition of "compliance" with a specified exposure level as bringing all employees above that level exactly down to that level. (In other words, for "compliance with 90 dBA" calculations, it was assumed that the effect of a 90 dBA regulation would be on balance to bring all workers with exposures above 90 dBA to 90 dBA).

Although there are a number of areas where the existing calculations can be refined, we believe that such refinements will not substantially alter the conclusions.

5.2 Other Benefits

Hearing conservation is the benefit of noise control about which we have the most information and which we can quantify with greatest confidence. However, it is by no means likely to be the only benefit. Although the other benefits of noise control cannot be assessed with the same accuracy as hearing impairment, some "best expected value" or other treatment of these benefits is essential for the proper assessment of the social efficacy of alternative noise standards.

5.2.1 Absenteeism Costs Saved

Noise as a Factor That Influences Absenteeism--Data Sources

The extensive literature on industrial absenteeism and its control includes numerous attempts to define causes of absence in an effort to reduce absenteeism at its source. Among the factors which some experts believe contribute to high absenteeism are the physical characteristics of the work environment, including dust, heat, fumes, and noise.[1] An increased tendency toward absenteeism may result from workers' psychological aversion to returning each day to an unpleasant environment, as well as from any physiological effects to which noise contributed.

Until recently, there have been no data which link occupational noise exposure to absenteeism with sufficient controls to insure significance. This is because of the close association between noise exposure and other characteristics of the work population in noisy jobs (such as age, experience, socio-economic status, other exposures on the job, etc.). One study, prepared by the Raytheon Service Company and completed in May 1975, compared accident, illness, and absence rates for workers in a boiler manufacturing plant who were exposed to high (95 dBA or higher) and low (80 dBA or lower) noise before and after a hearing conservation program had been instituted.* The basic objective of the study was to determine if the increased frequency of

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[1] John M. Knight, How to Reduce Absenteeism, American Foundrymen's Society, 1973, p. 11; Donald L. Hawk, "Absenteeism and Turnover", Personnel Journal, Vol. 55, No. 6 (June 1976), p. 295.

*The Raytheon study was sponsored by the National Institute for Occupational Safety and Health under Contract No. CDC-99-74-28. A condensed version of the final report, entitled "The Influence of a Company Hearing Conservation Program on Extra-Auditory Problems of Workers", prepared by Dr. Alexander Cohen of NIOSH was used for this study.

absences (and injury and illness) observed in a previous study among workers exposed to high noise would show a significantly lower absence (and injury and illness) rate after implementing a hearing conservation program involving the use of hearing protectors. Workers in both high and low noise groups were made part of the program. If excessive noise were a factor contributing to increased absenteeism, then it would be expected that absences would decrease after the noise levels were reduced.

The absenteeism data collected over two 2-year periods (before and after hearing conservation) were compared separately for high and low noise groups. The high noise group exhibited a median reduction in the total days absent over the 2 years during the program from 19.7 to 7.3 days per worker.[1] The average reduction in total days absence within the high noise group was from 30.1 to 15.0 days per worker. Both the average and median reductions in medical days lost per worker (after the reduction in noise exposure) were by 50% or more.

While the Raytheon study made serious efforts at control for outside influences, the results are tempered by various methodological considerations and other factors. The limitations of this study are discussed below.

In the high noise group, 60 out of 417 workers did not use hearing protectors during the conservation program. Yet absences among non-users went down almost as much as among users. The study suggests that this result could be attributable to several factors:

1) The "Hawthorne" effect created by increased management interest in employee health and safety caused increased employee attendance.[2]

2) The method for rating use or non-use of hearing protectors by workers had methodological shortcomings. This classification was made by three levels of supervisors (plant safety engineering staff, line foremen, and research study staff) rather than workers themselves.

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[1] Cohen, op. cit., pp. 12, 14a.

[2] Cohen, op. cit., pp. 18, 25.

In addition, the judgments were made at the end of the 2-3 year program as to the use or non-use over the entire period.[1] Therefore, more workers in the high noise group could have used ear protection than were given credit for by the rating system used. Audiometric test data collected after the hearing conservation period suggest a more wide-spread use of hearing protectors than the ratings would indicate. No signs of further deterioration in the hearing of the high noise group was observed after the 3-5 years between pre-hearing and post-hearing conservation audiograms

Estimates of Reduced Absenteeism Due to Noise

Methodology

Raytheon and CPS data were used to compute the potential realizable reduction of medical absences due to noise per manufacturing production worker. An assumption was made that the Raytheon experience would represent an upper bound for absenteeism reduction. The CPS data was used to estimate noise-related absence based on actual medical and non-medical absences of the two SIC industries with the highest and lowest absence rates per worker per year. The equation in Table 5.5 was developed in order to compare the more general CPS data with the noise-specific Raytheon data.

In order to arrive at a best guess of the likely effects of noise on medical absences, it is necessary to know the relationship of the Raytheon absence experience to the absence in the manufacturing sector. For this purpose, we utilized absence data summarized from the 1972 Current Population Survey (CPS) of households conducted by the Bureau of the Census for the Bureau of Labor Statistics. It is the only source of systematic national data on job absences by industry and worker characteristics.[2] While data from employers would be preferable, fewer than two-fifths of all workers are employed in firms which keep absence records.[3] Therefore, the CPS data, available by 2-digit SIC codes, were utilized in the following estimates.

[1] Cohen, op. cit., pp. 7, 23.

[2] The data have been summarized and analyzed by Janice Neipert Hedges, "Absence from Work--a Look at Some National Data," Monthly Labor Review, Vol. 96, No. 7

[3] Ibid., p. 25.

Table 5.5

Equation for Total Reduced Medical Absenteeism Due to Noise (Per Worker Per Year)

$A = (f_1)\ (f_2)\ (f_3)\ (f_4)\alpha$

where

- α = reported average yearly absences of full-time production workers in the manufacturing sector, based upon 1972-1973 data.
- f_1 = realizable fractional reduction of absenteeism due only to noise.
- f_2 = average fraction of medical absence due to noise.
- $(f_1)\ (f_2)$ = realizable reduction in medical absence due to noise.
- f_3 = fraction of the average total unscheduled absences attributable to illness or injury related (medical) causes.
- f_4 = correction factor for the difference between the rates of medical absences of production workers and non-production workers.

$(f_1)(f_2)$

To establish the realizable reduction in medical absence due to noise $(f_1)(f_2)$ for the manufacturing sector, the assumption for the upper bound is the 50% reduction found for the Raytheon population. For the lower bound, the assumptions differ for absences of less than one week and absences of one week or longer (taken from CPS data). Noise exposure can be expected to have a larger impact on shorter medical absences because of the annoyance factor and potential decrease in well-being on the job. In the case of medical absences of one week or more, a lower fraction of days would be attributable to noise (1/20). Noise itself may not be the direct cause of the week-long absence but may cause a worker who is already absent for four days to remain absent for a fifth day, thereby placing the reported absence into the week-or-more category.

$\underline{f_3}$

The fraction of the average total unscheduled absences attributable to medical causes (f_3) differs from miscellaneous causes such as family business and responsibilities, jury duty and funeral leave. For absences of one week or more, where data were available only for total absences, the assumption is that for the upper bound 90% of long-term absences are medical. For the lower bound the assumption is that the same fraction of week-or-more absences are medical as for absences of less than one week. (This fraction is 2.9/4.7).

$\underline{f_4}$

Regarding the correction factor accounting for the difference between the rates of medical absences of production workers and non-production workers (f_4), the assumption is that production workers have twice the long-term absence rate (one week or longer) as non-production workers. This approximation is supported by data on absence rates by occupation, found in Appendix

Table 5.6 illustrates the above procedures used to compute preventable noise-related absences based on Raytheon and CPS recorded absence data. The annual per-worker preventable absence derived from the Raytheon study is 6.2 days (median) and 4.8 (average). Based on Current Population Survey data, the maximum estimate for the manufacturing industries with potentially high and low absence rates is 3.9 days and .8 per worker respectively. The CPS calculations could be applied as well to SIC industries between these ranges.

The Raytheon and CPS absence data are not strictly comparable without an adjustment because the Raytheon figures are the absence prevented by bringing down the noise-exposed population to below 80 dBA, while the estimates based on the CPS data assume a reduction from present exposure to 85 dBA. The adjustment is made later in the text.

Table 5.6

REDUCED MEDICAL ABSENTEEISM DUE TO NOISE
(PER WORKER, PER YEAR)

a	$f_1 \times f_2$	f_3	f_4	days absent per worker preventable
Raytheon production workers [a] full time medical absences/year				(by reducing exposure to below 80 dBA)
9.85	$\frac{12.4}{19.7}$ (median)	1	1	6.2
9.85	$\frac{15.0}{30.1}$ (avg.)	1	1	4.8
manufacturing (avg. 20 SIC) [b] full time medical absences number of absences less than one week				(by reducing exposure to 85 dBA)
2.9	$\frac{15.0}{30.1}$ upper bound	1	$\frac{3.4}{2.9}$ = 1.7	
2.9	$\frac{1}{5}$ lower bound	1	$\frac{3.4}{2.9}$ = .7	
20 SIC codes, total workers [b] full (and part) [c] time medical and non-medical absences numbers of absences of one week or more duration				upper 3.9 lower .8
4.1 (SIC 21) upper bound	$\frac{15.0}{30.1}$	$\frac{9}{10}$	$\frac{3.4}{2.9}$ = 2.2	
1.8 (SIC 27) lower bound	$\frac{1}{20}$	$\frac{2.9}{4.7}$	$\frac{3.4}{2.9}$ = .1	

Sources:

[a] Alexander Cohen, "The Influence of a Company Hearing Conservation Program on Extra-Auditory Problems in Workers," paper condensed from final report prepared by the Raytheon Service Company in May 1975, from a study sponsored by the National Institute for Occupational Safety and Health.

[b] Janice Neipert Hedges, "Absence from Work: A Look at Some National Data," Monthly Labor Review, Vol. 96, No. 7 (July 1973), p. 27. Based on Bureau of Census data from 1972 Current Population Survey.

[c] We assume part time workers do not contribute significantly to long-term absence rates.

Calculation Results

The Raytheon average annual absence rate of 4.8 should be considered in a proper context both because of the limitations of the study as mentioned previously and because the Raytheon population excludes workers exposed to noise levels between 80 dBA and 95 dBA. Absence rates for workers exposed within this range are uncertain. While one can postulate that less noisy environments may contribute to less noise-related absence, the exact relationship has not been suggested. Because 4.8 days may be a relative overestimate for lower noise levels, we have assumed a halving of this rate for every 5 dBA reduction in exposure lower than 97.5 dBA (see Table 5.7).

Effects of a 90 dBA Standard

Worker days saved (in thousands) =

(	1196.70	x	3.1	) +	(	1538.07	x	0.7	)
	Workers at 97.5 brought to 90 dBA		Days saved per worker			Workers at 92.5 brought to 90 dBA		Days saved per worker	

= 4,786.419 days
(38,291.4 hours)

Effects of an 85 dBA Standard

Worker days saved (in thousands) =

(	1196.70	x	3.9	) +	(	1538.07	x	1.55	) +	(	1840.96	x	0.35)
	Workers at 97.5 brought to 85 dBA		Days saved per worker			Workers at 92.5 brought to 85 dBA		Days saved per worker			Workers at 87.5 brought to 85 dBA		Days saved per worker

= 7,695.48 days
(61,563.8 hours)

These data are presented in columns 2 and 3 of Table 4, along with cost data (columns 4 and 5).

Table 5.7

CALCULATION OF PERSON DAYS SAVED PER WORKER
EXPOSED AT DIFFERENT LEVELS (BASED ON RAYTHEON STUDY)

Exposure Before Regulation	Population Exposed* (Thousands)	Days Saved Per Worker Per Year By Reduction To Less Than 80 dBA			
97.5	1196.70	4.8			
			> 2.4	3.1	3.95
92.5	1538.07	2.4			
			> 0.7		
90		1.7			
			> 0.5	0.85	
87.5	1840.96	1.2			
			> 0.35		
85		0.85			
<80		∿ 0			

*See Appendix.

Using the low and high estimates for days saved based on the CPS data yields comparable data, also found in Table 5.8 since the estimates 3.9 and 0.8 were made for the savings of bringing the present exposed population to 85 dBA, the entries for CPS data are simply in the ratio of 3.9/3.95 and 0.8/3.95 where 3.95 is the days saved in bringing the Raytheon population down to 85 dBA. (See Table 5.7).

It should also be noted that the Raytheon experience is based on the use of hearing protectors and not engineering or administrative controls. Consequently, decreases in absence rates as a result of compliance with engineering or administrative controls may differ from those experienced as a result of hearing protectors use. It can be postulated that engineering controls, which eliminate the presumed discomfort associated with hearing protectors, would decrease absences even more than hearing protectors. The Raytheon study suggests the possibility that hearing protectors may, under certain circumstances, actually <u>increase</u> absenteeism. The median absence rate of the group of workers exposed to 80 dBA or lower increased by 68% after the use of hearing protectors.[1]

Table 5.8 utilizes preventable absences due to noise for the two sets of estimates to compute total annual savings for proposed 90 dBA and 85 dBA regulations. The <u>wage rate</u> is used as the <u>lower</u> bound because it represents: (1) the value of the last unit of labor assuming profit maximizing behavior on the part of firms in the industry and, (2) it ignores the costs of worker training and fringe benefits. The <u>value added per production hour</u> is an <u>upper</u> bound because it is an average, not marginal, concept of the value added per production worker and includes the contribution of other factors of production.

It would be unrealistic to use only the wage rate as a proxy for lost production for the following reasons:

- The marginal productivity theory of labor has two simplifying assumptions which must be further considered if the wage rate is used to approximate the cost to society of the output lost due to unscheduled noise-related absences: (1) workers are assumed to be perfectly interchangeable and of equal efficiency,

[1] Cohen, <u>op. cit.</u>, p. 13a.

Table 5.8

COMPUTATION OF ANNUAL ABSENTEEISM SAVINGS UNDER DIFFERENT REGULATIONS

Standards	Medical Absence Due To Noise		Absenteeism Savings	
	Eight Hour Days Saved Per Year (In Millions)	Person-hours Saved Per Year (In Millions)	Total 1971 Production Worker Wages (Inflated to 1975, $ million) 1 hr = $5.54	Total 1971 Value Added Per Prod. Worker (Inflated to 1975, $million) 1 hr = $20.28
Estimate Based on Absence Reported In Raytheon Data				
90 dBA Std.	4.785	38.29	212.1	776.5
85 dBA Std.	7.695	61.56	341.04	1,248.4
Estimates Based on Absence Reported In CPS Data				
upper bound - 90 dBA Std.	4.725	37.80	209.4	766.6
85 dBA Std.	7.598	60.78	336.7	1,232.6
lower bound - 90 dBA Std.	.950	7.60	42.9	154.1
85 dBA Std.	1.558	12.47	69.1	252.8

and (2) there is total absence of monopsony power in the labor markets. To the extent that real world considerations deviate from the simplifying assumptions, the wage rate would underestimate the cost of lost output.

- absenteeism is also used in this report as a surrogate for decreased productivity for those workers who are physically present but because of the high noise levels are not working efficiently.
- unscheduled noise-related absences of key personnel may disrupt normal production processes, thus imposing additional costs on the firm.
- loss of skilled personnel may be accelerated by higher turnover and early retirement.

Because of the above factors, both the wage rate and the value added per production hour are included in our calculation as bounds of the savings from reduced absenteeism.

After calculating the annual savings from reduced noise-related absences, these estimates were computed for a 20 and 40 year total savings. (See Table 5.9.) It was assumed that the annual savings would remain the same. Each year was discounted to present value at a 7% discount rate and the total savings added for 20 and 40 years respectively. The differences in savings between a 90 dBA and 85 dBA standard for each compliance period were also computed.

The benefits of prevented absenteeism, using both the lower bound of wage rate and the upper bound of value added, are substantial. Low and high present-value estimates for savings arising from a 90 dBA standard are $0.6 billion and $10 billion respectively over 40 years. For an 85 dBA standard, the low and high estimates are $0.9 billion and $17 billion respectively. The variation between low and high savings results from a five-fold difference in the estimates of days lost due to noise and a three-fold difference in alternative valuations of the lost output per hour to society. Eighty percent of the total savings is captured by the end of the first 20 years of compliance.

Table 5.9

NET SAVINGS OF ABSENTEEISM
UNDER 90 dBA AND 85 dBA REGULATIONS
(DISCOUNTED TO PRESENT VALUE)

Standards	$ Billions					
	Annual Savings		Savings Over First 20 Years After Compliance		Savings Over First 40 Years After Compliance	
	Wages	Value Added	Wages	Value Added	Wages	Value Added
Estimate Based on Raytheon Data						
90 dBA Standard	.21	.78	2.26	8.22	2.84	*10.33
85 dBA Standard	.34	1.25	3.64	13.23	4.58	16.65
Benefits of 85 dBA Over 90 dBA	.13	.47	1.38	5.01	1.74	6.32
Estimates Based on CPS Data						
Upper Bound:						
90 dBA Standard	.21	.77	2.21	8.12	2.78	10.22
85 dBA Standard	.34	1.23	3.56	13.08	4.48	16.46
Benefits of 85 dBA Over 90 dBA	.13	.46	1.35	4.96	1.70	6.24
Lower Bound:						
90 dBA Standard	.043	.16	.47	1.64	*.59	2.07
85 dBA Standard	.069	.25	.72	2.66	.91	3.35
Benefits of 85 dBA over 90 dBA	.026	.09	.25	1.02	.32	1.28

*The entries in the boxes are the high and low cost estimates for savings over 40 years arising from a 90 dBA standard. The entries in the inverted triangles are the corresponding estimates for an 85 dBA standard.

For the purposes of estimating most-likely values for calculating the benefit deriving from reduced absence, we use the arithmetic mean of our low and high estimates, which also represents half the savings predicted from generalizing the Raytheon results. Thus, $5.5 billion is the expected benefit for a 90 dBA standard, and $8.8 billion corresponds to an 85 dBA standard, all discounted to present value at 7%.

The calculation of the 20 and 40 year savings, stated in 1975 dollars, are based on the assumption that compliance with either a 90 dBA or 85 dBA standard would begin immediately after the effective date of the regulation. For compliance scenarios which delay compliance 5 years after the regulation takes effect, the absenteeism benefits are reduced by approximately 29%. For the 90 dBA standard with a 5 year delay the benefits are $3.9 billion and for 85 dBA, $6.3 billion. For 10 and 15 year delays in compliance, the reduced benefits are $2.8 and $2.0 billion for 90 dBA respectively and $4.5 and $3.2 billion for 85 dBA respectively.

5.2.2 Workers' Compensation Costs Saved

Noise induced hearing loss has been a much controverted workers' compensation issue in the last two decades. This is in part because it heralded broad inclusion of occupational diseases into the compensation system and because employers and carriers feared large costs if all employees with moderate hearing loss filed claims for workers' compensation. Though far from being realized, these potential costs are realistic and must be included in any calculations of future benefits derived from the OSHA standard.

The discussion below will include the following: 1) the total potential future loss to the society assuming that all those workers who would otherwise be impaired would have made claims for workers' compensation after 20 and 40 years of compliance with a 90 dBA or 85 dBA standard, 2) an estimate of the current rate at which qualified workers' do in fact receive compensation, utilizing trends in the rate of increase among states, 3) various characteristics of workers' compensation statutes and/or hearing loss formulae which might cause an increase or decrease in the number of claims compensated, 4) other calculations of costs for hearing loss, and 5) other noise-related compensation costs associated with hearing loss.

Potential Workers' Compensation Benefits

It should be noted that the workers' compensation claims are a one-time cost, even if in reality the claims may be spaced over a variety of different times. For the purpose of our calculations we have computed the potential benefits (compensation costs saved) based on previously described hearing loss* which assumes a total capture (i.e., a total claiming) of workers' compensation awards. However, because of variations in the age and mobility into and out of the workforce, we have assumed that workers would have received compensation payments only after they leave the workforce. Under a 90 dBA standard, workers in the impaired population leave the workforce at a rate of 2.7% per year and under an 85 dBA standard, at 2.8% per year.** Thus, at the end of 40 years compliance, all presently impaired workers leave the workforce and would have received compensation were it not for the standard. In addition, a small number of new workers who enter the workforce shortly after the standard takes effect would leave

*See Section 5.1.

**The .1% difference in the two rates is due to the increased age of benefited workers in the workforce at an 85 dBA standard.

the workforce after 40 years and also would have been eligible for compensation. The magnitude of this potential benefit is to be found in Table 5.10 under the conditions of compliance with 90 dBA and 85 dBA.

These estimates of workers' compensation savings may be a substantial underestimation of the total number of workers who might, in fact, be eligible for compensation for noise-induced hearing damage at sometime in their careers. The rapid advance in presbycusis-related hearing loss tends to reduce the difference between noise-exposed and unexposed groups at advanced age, leading to a smaller estimate of workers eligible for compensation than if the estimate were made at a point some years prior to retirement.

Our calculations are based on no change in present compensation schedules, which may offset to some degree the inevitable fact that not all workers who will be handicapped for compensation purposes will receive payment. In computing the total potential awards made for partial occupational hearing loss, we utilized a maximum income benefit of $19,000 for loss of hearing in both ears as of January 1, 1976.[1] This was derived from an average of the maximum benefits of the ten states with the largest number of production workers. Compensation awards for moderate hearing impairment (10 dB shift over the 25 dB fence) and severe hearing impairment (35 dB shift over the 25 dB fence) were calculated using the number of workers prevented from crossing the 25 dB threshold at a 90 dBA regulation and 85 dBA regulation. For compensation calculations, "handicap" is measured as 1-1/2 percent for each dB loss between average hearing levels of 26 dB and 92 dB, 15% handicap equaling $2,850/worker and 35% handicap equaling $6,650/worker. Implicit in these calculations is a hearing loss compensation formula of .5, 1,000 and 2,000 Hz averaged over 25 dB.

The total potential savings in workers' compensation benefits that will accrue from either a 90 or 85 dBA standard are small ($.28 billion and $.53 billion respectively) when compared to the capital and maintenance costs of compliance. It is clear that the savings from the workers' compensation payments alone cannot serve as an adequate economic incentive for industries to voluntarily reduce the level of noise exposure in the workplace.

[1] Chamber of Commerce of the U.S., Analysis of Workmen's Compensation Laws, Washington, D.C., 1976.

Table 5.10

Total Potential Workers Compensation Payments Saved for Hearing Loss In Both Ears*

($ billions)

Discounted to Present Value

Standards	$ Billions	
	Savings Over First 20 Years After Compliance	Savings Over First 40 Years After Compliance
90 dBA Standard	.16	.28
85 dBA Standard	.31	.53
Benefits of 85 dBA over 90 dBA	.15	.25

Estimate of Trends in Current Compensation Awards

Traditionally, the number and size of annual workers' compensation claims for hearing loss have been small as compared to other types of disability payments. However, with an increased awareness on the part of employees about health hazards on the job, the number of compensated hearing loss cases is on the increase. Understanding the rate at which claims are presently compensated is useful as one benchmark for potential future increases in hearing loss compensation benefits. Few states keep detailed statistics on workers' compensation claims or awards. Two states (New York and Wisconsin) compute awards data in comparable form. Table 5.11 shows their annual number of hearing loss awards (cases closed by the state workers' compensation board) and trends from 1970 to 1975. During this period, both states had fairly conservative compensation statutes. Both required a six-month waiting

*This assumes that workers would have received compensation payments only after they leave the workforce.

Table 5.11

TRENDS IN WORKERS' COMPENSATION CLAIMS FOR OCCUPATIONAL HEARING LOSS 1970-1975

Year	No. of Compensation Cases Closed		Yearly % Change	
	New York*	Wisconsin**	New York	Wisconsin
1970	101	57	-	-
1971	106	55	05	- 04
1972	165	82	56	49
1973	227	82	38	00
1974		83		01
1975		151		82
Yearly Average	150	85	33	26

*See Appendix E-1 for complete data on New York compensation cases closed.

**See Appendix E-2 for complete data on Wisconsin compensation cases closed.

period prior to filing a claim and used a .5, 1,000, and 2,000 Hz formula averaged over 25 dB. The annual number of cases compensated during this period rose well over 100% in each state. The average annual rate of increase for these two states was approximately 30%.* Assuming no further increase in the rate, by the end of a 40 year compliance period the number of awards will be substantially greater than at the present time.

Clearly, individual States vary in the number of hearing loss awards made annually. The numbers are affected by the size of the population exposed to noise within each state, the extent of worker awareness of noise-induced hearing loss compensation coverage and other job health issues, and the compensation formula used to compute impairment. Trend estimates, as tempered by various factors in the 50 workers' compensation statutes and hearing loss formula, may be responsible for both increases or decreases in current claims among the different states. They indicate the possible extent to which the real world differs from the formula assumed for the benefit calculations above.

Factors Which Decrease Estimates of Compensation Benefits

Historically workers' compensation statutes have included several blanket exemptions. As of the end of 1975, three states (New Jersey, South Carolina, and Texas) had elective coverage, and approximately one-fourth (1/4) of the states had exemptions based upon the size of the establishment.[1]

The following limitations apply specifically to noise-induced hearing loss:[2]

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*This trend is suggestive of several California data which indicate a 27% increase from fiscal year 1974-75 to fiscal year 1975-76 in the number of claims filed. (See Appendix E-3.)

[1] A.S. Hribal and G.M. Minor, "Workers' Compensation-1975 Enactments", Monthly Labor Review, Vol. 99, No. 1 (January 1976), p. 30.

[2] These comparative hearing loss requirements are derived from Meyer S. Fox, M.D., "Workmen's Compensation and Medical-Legal Aspects of the Occupational Noise Problem," in Proceedings of the Workshop on Industrial Hearing Conservation, sponsored by the National Association of Hearing and Speech Agencies, Washington, D.C., 1971, pp. 19-20. Wherever possible, more recent (1975) statutory changes are noted.

- Occupational hearing loss due to continuous noise (as opposed to accident or trauma-induced noise) may not be compensable.*

- An employee may be required to leave work for six months before filing a claim for hearing loss compensation.** In theory, this can occur through transfer to a non-noisy job, permanent layoff or retirement. In practice, claims are generally not filed until retirement. This may reduce the number of claims because a percentage of workers either die before retirement or lose contact with their plant during the waiting period.[1]

- The use of a higher threshold than 25 dB to determine hearing impairment will lower the number of compensable claims. For example, Wisconsin utilizes a 35 dB threshold for beginning hearing loss.

- A number of states either deduct or allow for possible deduction of 1/2 decibel per year beginning at around age 40 for hearing loss due to age (presbycusis). Thus, at retirement age of 65 or over, a worker with moderate hearing loss (35-40 dB) might not be considered impaired after the presbycusis has been deducted. This deduction also results in a reduction of the number of severe impairment claims.

- A few states compensate for <u>total</u> hearing loss only.*** "Total loss" may range from 50% to 100% impairment.

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*The 1970 data indicate this to be true for Alabama, Colorado, Idaho, Indiana, Iowa, Louisiana, Nebraska, New Mexico, Vermont, and Wyoming. In 1975 Colorado and Louisiana changed from elective Workers' Compensation to compulsory Workers' Compensation.

**The 1970 data indicate this to be true for Louisiana, Maine, Missouri, New York, North Carolina, Rhode Island, and Utah. In Wisconsin, the waiting period was recently reduced to two months.

***The 1970 data indicate that these states are Massachusetts, Michigan, Ohio, and Pennsylvania.

[1]Richard Ginnold, "Workman's Compensation for Hearing Loss in Wisconsin", 25 Labor Law Journal, 693-694 (November, 1974).

Factors Which Increase Estimates of Compensation Benefits

- The state of California, whose manufacturing workforce totals 8% of all U.S. manufacturing workers, utilizes 3,000 Hz in its hearing loss formula. Wisconsin also computes hearing handicap using 3,000 Hz.
- The Fowler-Sabine, or AMA rule, which utilizes .5, 1, 2, and 4 Hz relatively weighted, may increase the number of claims slightly. Hearing at 4,000 Hz is considered by some experts to contribute to speech intelligibility.*
- The traditional impairment formula of 1.5% compensation for each dB loss beyond 25 dB (up to 92 dB for 100% loss) may be modified. For example, Wisconsin now allows for 1.75% compensation for each dB loss.

It should be noted that a combination of the above factors is the ultimate determinant of the hearing loss formula of any given state, and hence, of workers' compensation claims levels. Although no attempt has been made in this study to analyze the extent of these individual statutory effects, their aggregate impact is expected to continue. This is due in large measure to increasing attention focused on the worker compensation system as a result of the 1972 report of the National Commission on State Workmen's Compensation Laws. With the threat of federal intervention, 49 states enacted in 1975 nearly 300 amendments to their compensation statutes in order to conform with federal guidelines, including the recent changes described above.[1] This trend is likely to continue in the near future, with hearing loss requirements receiving more attention once the OSHA noise exposure standard is promulgated.

*The 1970 data indicate that Kansas uses this formula to compute hearing loss.

[1] Aribal and Minor, "Workers' Compensation", p. 30.

Alternative Calculations of Costs for Noise-induced Hearing Loss

The workers' compensation system was designed to spread the costs of work related injuries among employers, thereby reducing their individual risk of large payments. In exchange for guaranteed payments, workers give up their right to sue their employers under common law, except where a specific injury or illness is not covered by the workers' compensation system. This exception is noteworthy in the area of occupational hearing loss, particularly because the variables of state impairment formulae may exclude certain types and degrees of hearing loss from the workers' compensation system. For example, in those states where only total impairment is compensable, workers must go to court to receive damages for partial hearing loss.

Court awarded damages are considered by some to be a better indicator of the real value society places on harm, in part because they include compensation for such non-pecuniary damage as pain and suffering and loss of enjoyment of life. These items are not usually calculated into workers' compensation awards. When juries do return damage awards in hearing loss cases, the awards can be substantially larger than workers' compensation might otherwise provide. For example, one case for partial hearing loss (approximately 35 dB) brought a jury award of $30,000.[1] While this study does not attempt to estimate the extent of court awards for occupational hearing loss, this form of compensation should be recognized as an alternative approach to estimating the benefits derivable from reducing the amount of hearing loss in the workplace.

Another indicator of the potential social cost of hearing loss is the "purchase cost" of hearing. This measure is often used to estimate what the "market" price of a difficult-to-quantify item would be. The questions "what would you pay to have normal hearing?" or "what would you pay not to work in high noise?" illustrate the method by which the purchase cost of hearing loss and high noise would be estimated. Factors such as annoyance and frustration

[1] John Shoop v. U.S. Steel Corp., Docket No. 3615 (Ct. of Common Pleas, Allegheny County, Pa. 1972). The case was dismissed in 1975 after the Pennsylvania Supreme Court brought a similar case within the scope of workers' compensation. See Hinkle v. H. J. Heinz, 337 A. 2d 907 (May 1975).

with unintelligible speech and often-associated social stigma are implicit in such estimates.

Taken together, court awarded damages and purchase costs suggest that workers' compensation benefits may be an inadequate estimate of the true cost of noise-induced hearing loss. Workers' compensation awards do serve, however, as a minimal measure for direct hearing loss costs.

Other Noise-Related Compensation Costs

Distinct from types of compensation costs for occupational hearing loss (such as worker's compensation, court awarded damages and purchase cost) are compensation to workers for indirect effects of noise exposure in the workplace. One potential effect of excessive noise is an increase in the number of industrial accidents due to the masking of warning signals and an increase in momentary gaps or errors in performance.

The Raytheon study, discussed in Section 5.2.1, also measured the change in the number of job injuries among workers exposed to 95 dBA and higher after the initiation of a hearing conservation program. The results indicate that the number of injuries went down 39% after the program, which included the use of hearing protectors.[1] The number of job injuries among workers in the low noise group remained constant after the program. This finding contradicts the view that hearing protectors increase the number of industrial accidents. Thus, a reduction in the number of noise-induced industrial injuries compensated by the workers' compensation system is a benefit which may be significant. For the Raytheon population this number was .75 fewer injuries per worker/ year. Of course, the range of possible injuries and their compensable value will be variable. As a result, no attempt was made to quantify these benefits.

[1] Cohen, op. cit., p. 13a, Table 3.

5.2.3 Cardiovascular/Stress Effects

The major concern over nonauditory health effects from noise arises from the ability of noise under some circumstances to act as a general, nonspecific biological stressor. Other than hearing loss, noise is not suspected of producing any single health problem unique to itself and comparable to the vinyl chloride angiosarcomas, the thalidomide birth defects, or the asbestos mesotheliomas. Rather the effects of noise, if any, are likely to be distributed over a large number of common individual cardiovascular and other maladies whose causation is complex and attributable to other factors as well. Nonetheless, because, in particular, cardiovascular diseases are such a massive problem in our society, even if noise were to increase their frequency or severity by a small percentage in the exposed population, this would be a very substantial adverse impact. Major cardiovascular diseases* account for well over half of all deaths in the United States, currently somewhat over a million people per year.[1] They are also, by far, the most frequent cause of permanent total disability in those under 65, as measured by Social Security awards.[2]

In our earlier work[3] we presented a hypothesis and a detailed analysis of the relevant scientific literature on the relationships between noise exposure, general stress reactions, increased platelet adhesiveness, and long-term cardiovascular degenerative processes. Our conclusion was that some contribution of some level of noise exposure to cardiovascular disease was at least plausible. The reader is referred to our earlier publication for full exposition.

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*Heart attack, stroke, etc.

[1]National Center for Health Statistics. Vital Statistics. Public Health Service (1969).

[2]U. S. Department of Health, Education and Welfare. Occupational Characteristics of Disabled Workers, by Disabling Condition, P. H. S. Publication No. 1531. Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20460 (1967).

[3]EPA 550/9-76-007.

5.2.4 Annoyance as a Social Cost

That noise is, to some degree, a net overall annoyance to industrial workers must be considered reasonably beyond dispute. By and large, it must be supposed that workers exposed to industrial noise in the range under discussion consider it, on balance, unpleasant or annoying. This depression of their quality of life is clearly a social cost. To the degree that workplace noise regulations may reduce this social cost, the reductions should enter into an assessment of the overall costs and benefits of these social policies. In our earlier work[1] we offered some procedures for arriving at an approximate monetary valuation of the reduction in annoyance produced by particular noise regulations. Unfortunately, to this date we have not had time to update these calculations using current BBN data on estimated noise exposures.

[1]EPA 550/9-76-007.

NOTE TO SECTION 5 ON DISCOUNTING NON-MONETARY BENEFITS

The purpose of this note is to address the problem of "discounting" hearing conservation benefits. There are three different approaches to the discounting of non-monetizable benefits:

- discount hearing conservation benefits at the same discount rate used in the monetary benefit or cost calculations;
- discount the hearing conservation benefits but at a lower discount rate than that used in the monetary benefit or cost calculations;
- do not discount hearing conservation benefits at all.

The first approach would apply the traditional present discounted value criterion (see Section 4.1) to non-market items. The approach has the advantage of allowing parallel treatment of all costs and benefits.

If the discount rate is 7%, then one year of hearing impairment prevented today would be equivalent to 1.4 years of hearing impairment prevented in five years, or two years of hearing impairment prevented in 10 years, or 7.7 years of hearing impairment prevented in 30 years. Thus, any positive discount rate would value one year of hearing impairment saved in an early year higher than one year of impairment saved in later years.

The second approach would allow for discounting of non-monetizable benefits, but at a lower discount rate. This approach can be defended in terms of a belief that certain amenities, such as hearing, become more valuable relative to other goods in this society as time passes and the standard of living improves.

The following relationship would separate the factors affecting the present value of hearing impairment prevented:

$$\frac{x(1 + c)^n}{(1 + r)^n}$$

where:

x = metric expressed in years of hearing impairment prevented

c = increase in value of hearing impairment prevented

r = discount rate

For small values of r and c, this is equivalent to:

$$\frac{x}{(1 + r - c)^n}$$

Thus, the "effective" discount rate (r-c) will be less than the discount rate used for monetary benefit or cost calculations.

The third approach would not discount non-monetizable benefits. This result can be reached through any of three pathways.

First, there is a question of the appropriateness of applying a discount rate to consequences of an action which has significant effects on future generations.* Clearly, any positive rate of discount will discriminate in favor of choices that involve adverse impacts on later generations but not on earlier ones. Because the benefits of noise control extend beyond the costs of the current generation, a similar situation is presented. If the decision-maker is concerned with intergenerational equity then an argument could be made that the appropriate social rate of discount is zero (Ø).**

*A complete adoption of this argument might not allow for discounting of costs where the benefits are received currently and the costs are incurred in later generations. For a more complete discussion, see National Academy of Sciences, Decision Making for Regulating Chemicals in the Environment, Appendix H, p. 177.

**See Schulze, W. (1974), "Social Welfare Functions for the Future", American Economist 18(1): 70-81; Page, T. (1975), Equitable Use of the Resource Base, unpublished paper.

Secondly, the issue of monetizing the value of human life or health and the issue of whether or how to discount non-monetary benefits are not strictly separable issues. Discounting non-monetary benefits is a backhanded way of attaching monetary characteristics to non-monetary goods. Implicit in discounting is the notion that the goods at any one time can be traded off for equivalent goods at another time. In reality, few markets exist for this direct trade. The market exists only through the monetary exchange system which has a pathway which is clearly subject to the discounting process.

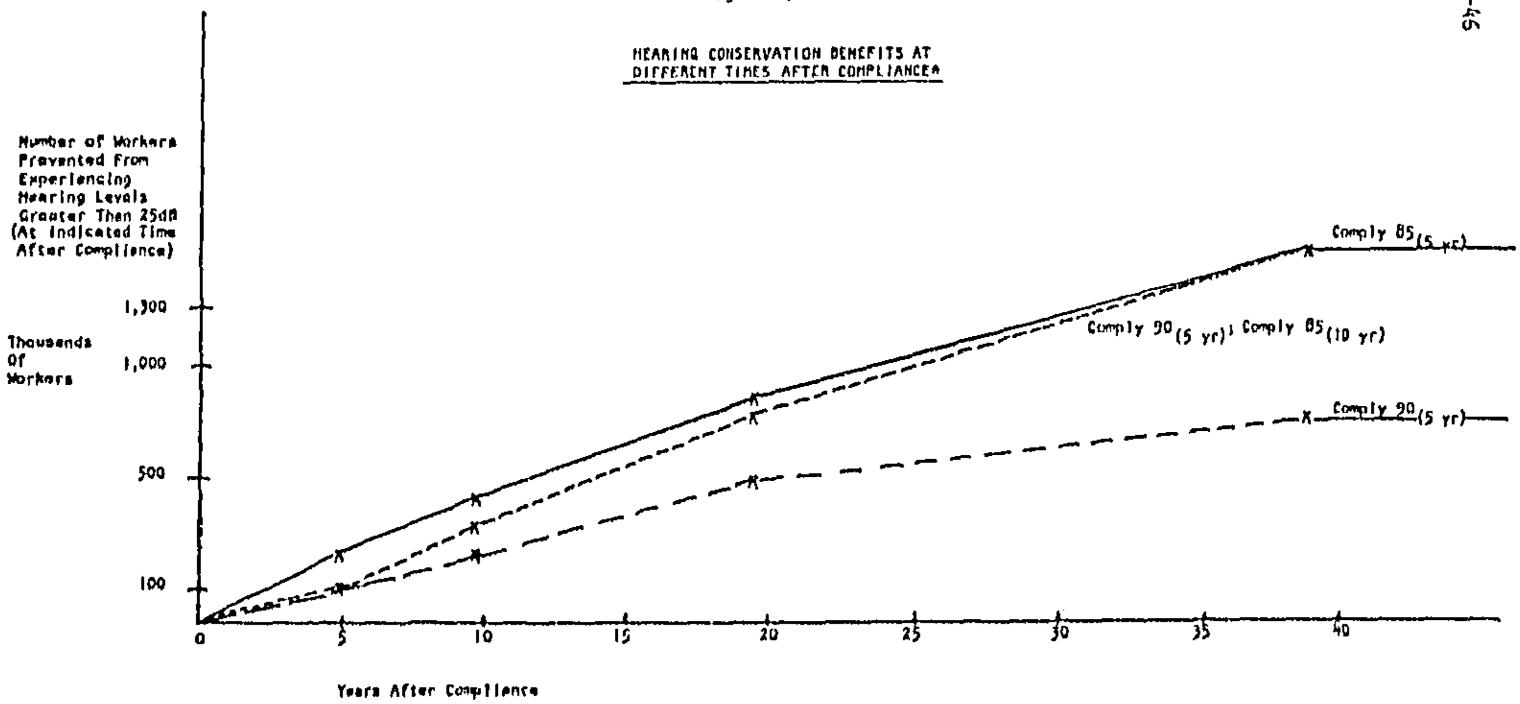
Finally, the "benefit" of removing a person now from risk of future damage, which is irreversible, inevitable and non-arrestable once the risk exposure occurs, can be viewed as a *present* benefit--and quantified, for example, as the benefit of removing those presently at risk from future harm.

We chose not to apply a discount rate for hearing conservation benefits, not because we are certain that it should be zero, but because we believe the decision-maker should resolve the question himself. To aid in this exercise, we present the time flow of benefits. Figure 5.8 is a graphical analysis of when the years of hearing impairment prevented would occur.* This presentation will facilitate the discounting of hearing conservation benefits should the reader decide discounting (and at what rate) is appropriate.

*Figure 5.8 is an adaptation of Figure 5.1 and Figure 5.2 of the Main Report.

Figure 5.8

HEARING CONSERVATION BENEFITS AT DIFFERENT TIMES AFTER COMPLIANCE*



*Assumes Workforce of 14,475,000 Production Workers

6. COST/BENEFIT

In the two previous sections we have made various estimates of the magnitude of different kinds of costs and benefits. In this section we bring the two sides of the analysis together in order to help clarify the relationship between the costs expended by firms on noise control and the benefits accruing to workers and firms under different compliance scenarios.

6.1 Cost/Benefit comparisons excluding all benefits except hearing conservation.

For simplicity we shall make some initial incomplete comparisons among compliance scenarios utilizing only the hearing conservation benefits expressed as person-years of impairment over 25 dB. As has been covered earlier, the number of person-years of impairment over 25 dB is not a complete measure of total hearing conservation benefits but it can serve here as an approximate index for purposes of illustrating the types of comparisons which can be made.

Figure 6.1 is from the cost section (Section 4), and shows the discounted before-tax costs of compliance of the scenarios for which benefit calculations have been made. Figure 6.2 presents data from the benefit section within the same format. Figure 6.3 shows the results of dividing the cost estimates in Figure 6.1 by the benefit estimates in Figure 6.2. These numbers represent the dollars expended to save each person-year of hearing impairment over 25 dB under the different scenarios, relative to the case case of no change in present exposures.*

The primary conclusion from Figure 6.3 is that the total cost/benefit

* It is also possible to compute the incremental costs/benefits of going from one compliance scenario to another. These are:

[Present exposures] to [90 (5 years)]: $790
[90 (5 years)] to [90 (5 years), 85 (10 years)]: $760
[90 (5 years), 85 (10 years)] to [85 (5 years)]: $1,910
[90 (5 years)] to [85 (5 years)]: $900

measure used does not differ appreciably for the three compliance scenarios shown. As a first approximation, therefore, it seems that the cost/effectiveness for hearing conservation of the noise control expenditures needed to bring present exposures down to 85 dBA in five or ten years is similar to the cost-effectiveness of the expenditures needed to bring present exposures down to 90 dBA.

Another kind of comparison can be made with these data. The ratio of the benefits of the two-step "90 (5 years), 85 (10 years)" scenario to the benefits of the one-step "85 (5 years)" scenario is approximately 28 million person-years/30 million person-years--or 93% of the benefits of one-step compliance scenario. On the other hand, the ratio between the cost figures is somewhat less, $21.2 billion/$25.1 billion--or 84% of the costs of one-step compliance. The difference is not overwhelmingly impressive, but it is possible that the delay scenario is worthy of consideration for some noisy, economically hard-pressed industries where a somewhat larger proportion of the benefits may be captured for a lower proportion of the costs.

Cost/benefit comparisons of these same types can also be done on an industry-by-industry basis--although, because of the possible inaccuracies in the disaggregated data such comparisons are subject to much larger uncertainties than all-industry aggregate comparisons. Table 6.1 shows the results of dividing the estimates of costs for each industry (Table 4.2) by the estimates of benefits for industry (Table 5.4.) for three compliance scenarios. The data tend to suggest a wide variation in the relative cost-effectiveness of noise control investments in different industries. Should such differences persist after confirmation of the underlying data, they can form part of the basis for selection of different compliance scenarios and other noise abatement policies for different economic sectors. Possible policy options in response to such differences will be discussed in Section 8 below.

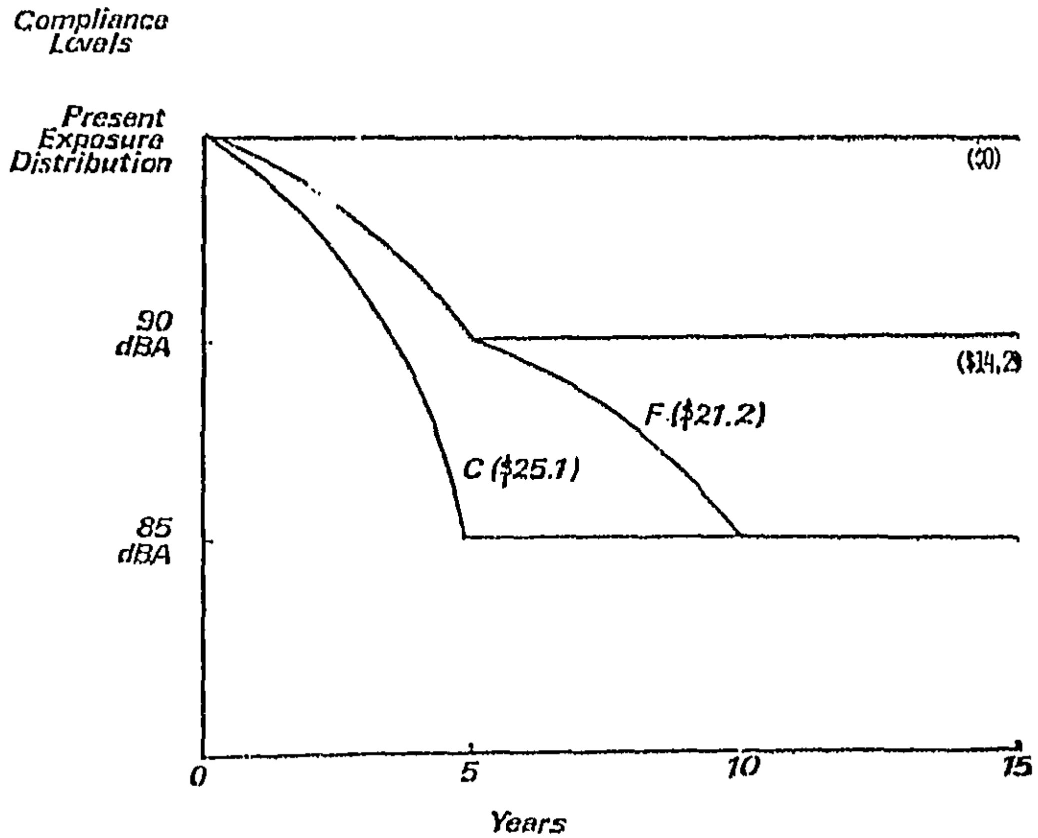
6.2 Approaches to a more comprehensive cost/benefit analysis

The uppermost line on Figure 6.4 is another presentation of the same data derived in the previous section. The lower lines indicate how the analysis changes as cost reductions to firms from absenteeism, tax savings,* and additional types of benefits (cardiovascular/stress effects, annoyance costs) are brought into the cost/benefit calculus. It is clear that these additional considerations all take the analysis in the direction of incurring less cost per unit of benefit borne by the firms.

---

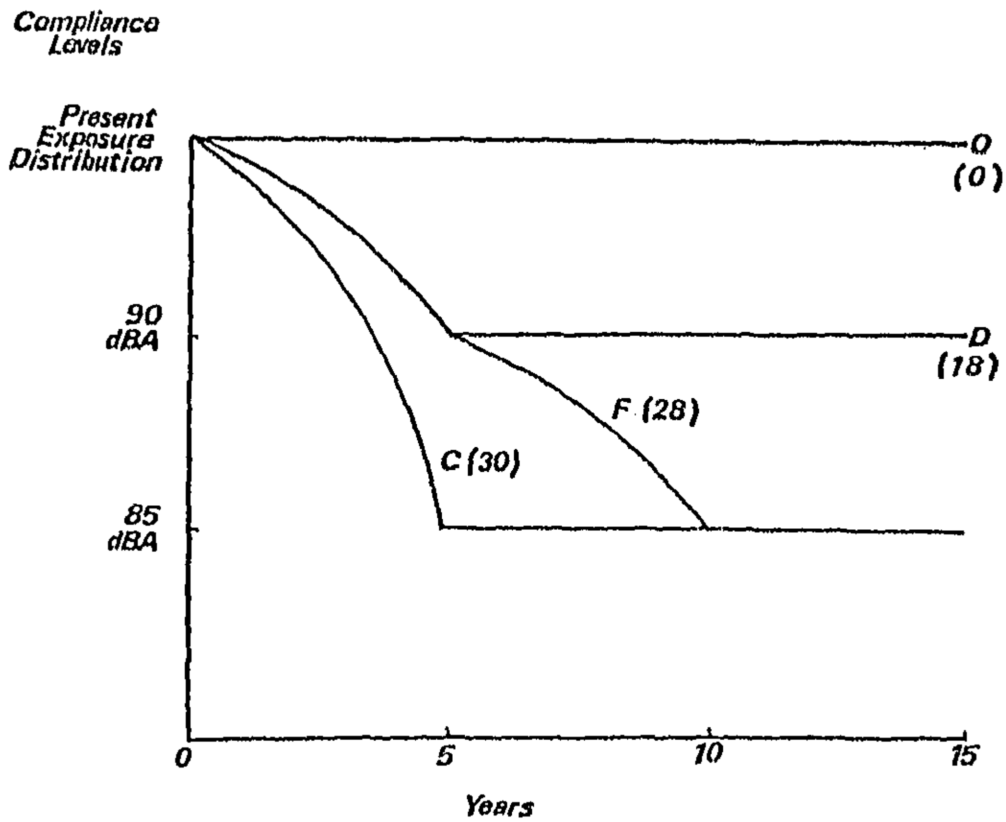
* It must be remembered that the tax savings do not really abolish half the costs, as might be inferred from the diagram, but merely re-distribute them to governmental entities. Still the tax savings represent real reductions in the net costs which must be borne by firms.

FIGURE 6.1
COMPLIANCE SCENARIOS



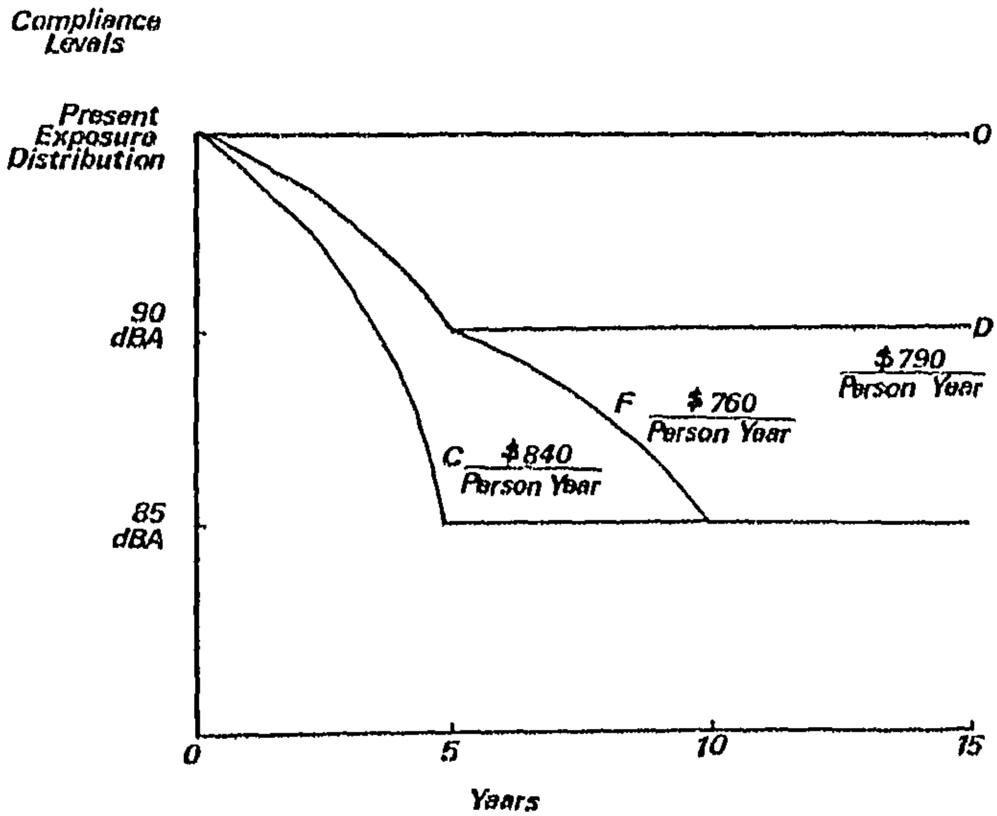
DISCOUNTED PRESENTED VALUE COST (BILLIONS OF DOLLARS)
BEFORE TAX EFFECT

FIGURE 6.2
COMPLIANCE SCENARIOS



Hearing Conservation Benefits, Expressed in Millions of Person-Years of Impairment Over 25dB, During the First Forty Years After Compliance

FIGURE 6.3
COMPLIANCE SCENARIOS



COST BENEFIT ANALYSIS

- Hearing Conservation Benefit Only
- Dollars per Person-Year of Impairment Over 25 dB

TABLE 6.1

TOTAL COST*/PARTIAL BENEFIT OVER FORTY-FIVE YEARS

			$Total Cost / Prevented Person-Year Over 25 dB		
Compliance Scenario**		0	D	F	C
SIC	INDUSTRY	Present	90 (5yr)	90 (5yr) 85 (10yr)	85 (5yr)
20	Food and Kindred Products	0/0	990	1,220	1,400
21	Tobacco Manufacturers	0/0	1,690	2,260	2,680
22	Textile Mill Products	0/0	450	560	660
23	Apparel & Other Textile Products	0/0	0	220	300
24	Lumber and Wood Products	0/0	290	300	330
25	Furniture and Fixtures	0/0	1,760	930	890
26	Paper and Allied Products	0/0	900	510	520
27	Printing and Publishing	0/0	3,160	1,700	1,830
28	Chemicals and Allied Products	0/0	540	520	590
29	Petroleum and Coal Products	0/0	340	340	370
30	Rubber and Plastic Products	0/0	520	470	530
31	Leather and Leather Products	0/0	0	790	1,040
32	Stone, Clay & Glass Products	0/0	740	870	1,010
33	Primary Metal Industries	0/0	484	592	691
34	Fabricated Metal Products	0/0	1,410	1,030	1,030
35	Machinery, except Electrical	0/0	2,570	1,990	2,020
36	Electrical Equipment & Supplies	0/0	2,800	1,880	2,070
37	Transportation Equipment	0/0	1,070	900	960
49	Electric, Gas & Sanitary Services	0/0	1,860	920	940
ALL INDUSTRY AVERAGE		0/0	$ 790	$ 760	$840

* Based on BBN Data

** See Figure 4.3 for a graphical representation of the lettered compliance scenarios

APPROACHES TO A MORE COMPREHENSIVE
COST-BENEFIT ANALYSIS

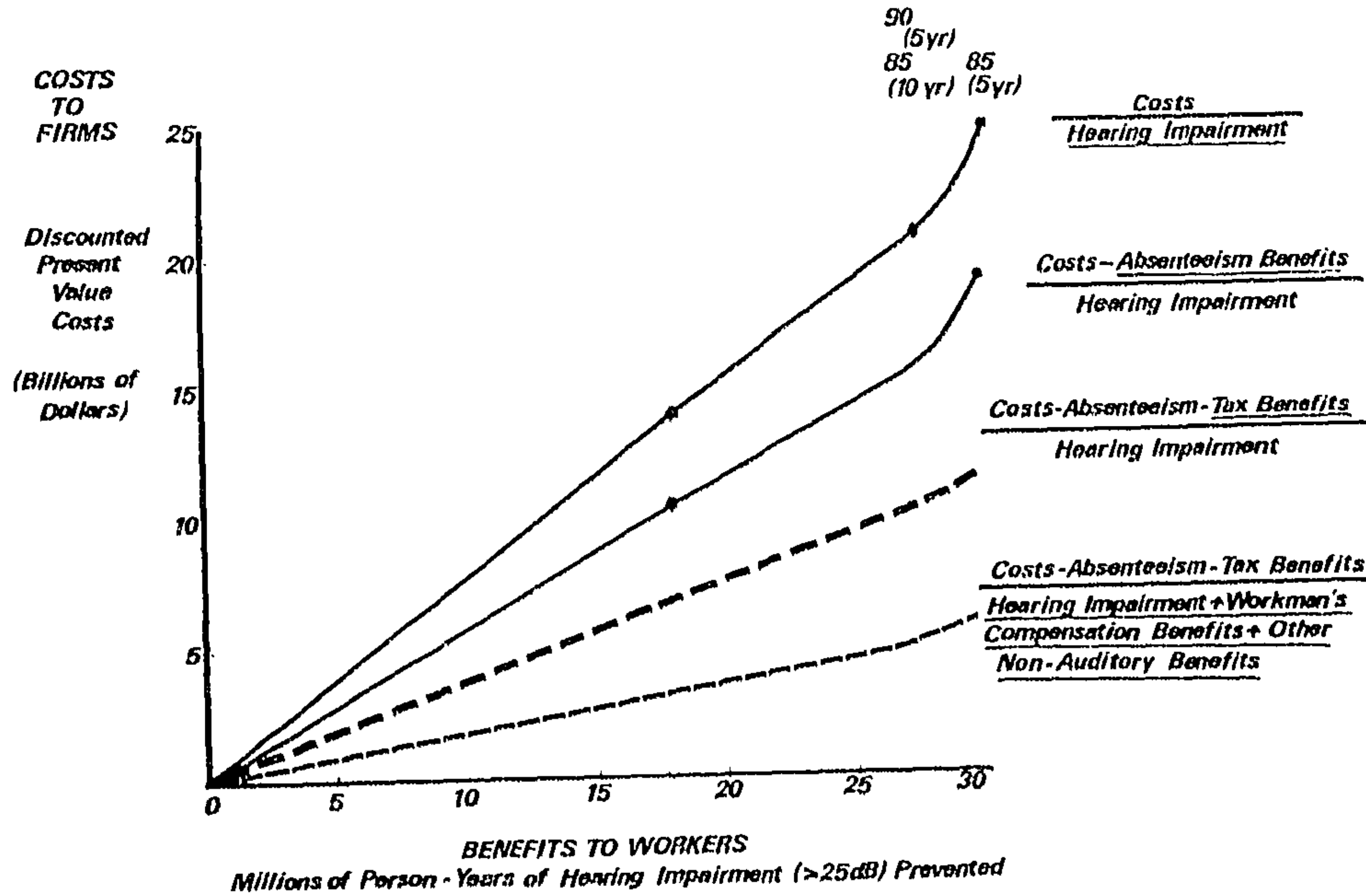


FIGURE 6.4

6-8

7. LEGAL ISSUES RELATED TO THE WORKPLACE NOISE STANDARD

7.1 The Feasibility Concept and OSHA Regulation

7.1.1 In The Standard-Setting Context

Within the OSHAct the term "feasibility" is only mentioned once, in Section 6(b)(5), which specifies that in setting standards OSHA must

> set the standard which most adequately assures, *to the extent feasible*, on the basis of the *best available evidence*, that *no* employee will suffer *material impairment* of health or functional capacity even if such employee has regular exposure to the hazard dealt with by such standard *for the period of his working life*.

In fact, however, the concept of feasibility pervades the decision-making process in a variety of contexts. The appropriateness of considering feasibility, and the appropriate definition of the term, are important legal matters currently in issue which have special relevance for the workplace noise standard.

The scope of the term feasibility as used in the Act has been definitively interpreted through caselaw as encompassing both technological and economic considerations.* The parameters of what "feasible" actually means in practice have also been specified by the courts. Standards can therefore be feasible even if:

1) They are financially burdensome to employers,
2) They affect profit margins adversely,
3) They put individual employers out of business
4) They require improvements in existing technologies or the development of new technologies.

Standards come closer to infeasibility if only a few firms in an industry

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*See Industrial Union Department, AFL-CIO v. Hodgson, 499 F. 2d. 467 (D.C. Cir. 1974) and AFL-CIO v. Brennan, 530 F. 2d 109 (3d Cir. 1975). Both cases establish this point, relying primarily on the legislative history of the OSHAct as justification for their position.

can achieve them or if they drastically change the competitive position of the industry. They would appear, from the cases, to be infeasible if they cripple or eliminate an entire industry.*

7.1.2 In Variance Proceedings

The purpose of the variance provisions in the OSHAct is to impart a degree of flexibility into the compliance scheme so as to legalize legitimate reasons for non-compliance in individual cases. In one case, a permanent variance will be issued when the employer establishes workplace conditions which are "as safe and healthful" as those specified in regulations, even though they are different (Section 6(d)). In another case, temporary variances will be granted when an employer is "unable" to comply (Sections 6(b)(6)(A) and (B)). Thus, questions of "feasibility" enter into the equation only with respect to temporary variances.

In a variance proceeding the inability (or infeasibility) to comply cannot be based on grounds of economic hardship. This fact can easily be inferred from the Act, as it specifies only a limited number of acceptable explanations for non-compliance: unavailability of professional or technical personnel, materials, or equipment, or lack of time to complete necessary alterations.

The variance mechanism is important in the noise standard context for two reasons. First, it provides temporary relief from a "technology-forcing" standard. As mentioned above with reference to standard-setting, a standard which effectively demands the development or adapting of new technologies can be legally "feasible". The variance mechanism makes such a standard practicable as well, especially during the initial period when

*This discussion is a distillation of the IUD case, the vinyl chloride standard case, The Society of the Plastics Industry, Inc. v. OSHA 509 F. 2d 1301 (2nd Cir. 1975), and International Harvester Co. v. Ruckelshaus 478 F. 2d 615 (D.C. Cir. 1973), which considered the competitive climate in the automobile industry and its effect on the feasibility of air pollution standards.

technological changes must occur. Second, the criteria for granting variances indicate that although "feasibility" considerations in OSHA decision-making go beyond the standard-setting context, economic feasibility need not continually be taken into account. Once the initial economic feasibility of the standard is established, this argument is not, at least with respect to variances, an acceptable excuse for non-compliance.

7.1.3 In Abatement Agreements

Abatement agreements are generally entered into by OSHA and a company after that company has been cited for violation of a standard. This procedure derives from Section 9(a) of the OSHAct which specifies that the citation establish a "reasonable" time for abatement. Violations of such agreements can be assessed penalties under Section 17(d) of not more than $1,000 per day.*

The issue of feasibility--both economic and technological--arises in abatement agreements by virtue of the requirement that their time period be reasonable. Evidence concerning the economic hardship represented by a certain abatement schedule is, thus, admissible in Review Commission hearings contesting the appropriateness of the abatement schedule specified in a citation. (This fact was agreed to by all the commissioners in the recent Review Commission decision dealing with economic feasibility in citations, Continental Can--see discussion below.)

The fact that economic considerations may be taken into account in fashioning abatement periods is important for the noise standard in the following ways. First it provides an additional mechanism by which to mitigate hardships on an individual employer basis. Moreover, abatement

*Variations on this basic theme also occur. For instance, the much-publicized American Can abatement agreement (April 1974) was a stipulated settlement of three citations which were contested by the company. OSHA in that case agreed to refrain from further action on the citations in exchange for the promise to reduce noise exposure. Another noise reduction arrangement was made on a national level between OSHA and the National Concrete Masonry Association, under which compliance with the standard was to be achieved by December 31, 1976.

agreements, especially those implemented on a national industry level, may be a particularly useful tool in combination with an industry-specific standard.

7.1.4 In Citation Contests: Continental Can and the Feasibility of Engineering Controls for Noise Abatement

Both the current and proposed noise standards call for engineering controls as the primary means of compliance, except to the extent that such controls are not feasible, in which case personal protective equipment will be permitted. Infeasibility of engineering controls may thus be a good defense to a noise citation. This question was the primary point in issue in the recent Continental Can litigation (4 OSHC 1541). Continental Can was cited for violation of the noise standard and pleaded in its defense:

1) That even if engineering controls were installed on all cited machines, the factory noise levels would still not be within allowable limits and that therefore it should be relieved of its responsibility to institute engineering controls at all and allowed instead to use hearing protectors exclusively;
2) Even assuming engineering controls were required to reduce noise as far as possible, they were infeasible in this case due to their excessive cost; and
3) The burden of proof was in any case on OSHA to establish both technological and economic feasibility.

The Commission ruling in this case, if upheld on appeal, will have important implications for the design of the noise standard and its enforcement. First, it should be made clear that the decision in no way eliminates the duty of the employer to implement engineering controls first to the extent that they are feasible even though such controls cannot reduce noise levels sufficiently. Protective devices are still to be considered a second resort. The most novel aspect of the case, however, is its holding that economic factors are to be taken in account in reaching a determination as to the feasibility of engineering controls. The majority commissioners argue for this posture based largely on the IUD case (discussed above) which allowed economic factors to be considered in setting feasible health and safety standards. Their position is that "feasible" when written into a promulgated standard should be interpreted just as it has been when written into the Act. The dissent in the case argues that "feasible" as used in a duly promulgated standard only means technical, not economic, feasibility and that Congress did not intend citation contests to be a case-by-case economic impact assessment. The last important holding in the case was that the burden of proof was on OSHA to establish both economic and technical feasibility of engineering controls. (This point was objected to by the dissent as well.)

Going beyond the Commission's determination of legal principles, it is important to consider its factual findings as to feasibility. In Continental Can, engineering controls were found infeasible on the following uncontradicted evidence introduced by the company: $32,000,000 capital expenditure to reduce all plants' noise levels to 90 dBA via engineering controls vs. $100,000 to do so via personal protective devices.* By way of contrast, in another decision (Carnation Co. OSHRC Docket No. 8165, November 25, 1975) engineering controls were deemed feasible at a cost of $2.1 million when annual net income of the company was $79.6 million. The mode of decision-making specified by the Commission to reach such decisions is an analysis in which "all the relevant cost and benefit factors" are weighed, taking care to distinguish between hazards such as noise which are not life-threatening and other hazards which might be.

If Continental Can remains good law on appeal, it is clear that OSHA must devise methods to meet its burden of proving the economic and technical feasibility of engineering controls. This may perhaps best be accomplished on an industry rather than on a firm level. Feasibility on an industry level can be established:

1) by setting industry-specific standards supported by solid cost data, and
2) by negotiating industry-wide abatement agreements such as that concluded with the Concrete Masonry Association.

*The company did not claim that a $32 million expenditure would "seriously jeopardize its financial condition." This is currently the only grounds allowed in the OSHA Field Operations Manual for considering economic cost.

Given the fact that various court cases have specifically stated that a feasible standard may be burdensome or put individual employers out of business, the determination of feasibility for an industry taken as a whole may go far toward shifting the burden of proof from OSHA in individual cases.

7.2 Industry-Specific Standards

The option of drafting OSHA workplace noise requirements in an industry-specific manner has been considered by OSHA and generally advocated by EPA throughout the examination of the proposed noise standard. Nevertheless, this option has been less than thoroughly analyzed thus far. There are essentially three ways by which the problem of differentiating among industries could be approached. First, the mandated noise level itself could vary according to industry, e.g. 90 dBA for some SIC codes, 85 for others, 80 for others, etc. Second, a single uniform standard could be promulgated, but industry compliance time scenarios varied, e.g. an 85 dBA standard with 1, 2, 5, 10, or 15 year compliance periods, depending on the industry. Lastly, the mode of compliance could vary by industry. For example, exclusive use of engineering control might be required for some industries and hearing protectors allowed to varying degrees in others, depending on the feasibility of engineering controls. The legality, desirability, and practicality of these options will be the subject of the following analysis.

The basic legality of industry-specificity in standard setting is well established, both in the OSHA context and in other regulatory systems. In addition, its feasibility is demonstrated by current practice. EPA has, for example, promulgated many industry-specific requirements in both the air and water pollution areas. Differentiation among industries will also be the basis for energy-use reduction requirements authorized by the 1975 Energy Policy Conservation Act. Even OSHA has in the past employed this approach, as illustrated by its Occupational Safety and Health Standards for special industries: paper pulp, textiles, bakeries, laundries, telecommunications, etc.*

*See 29 C.F.R. Chapter XVII, Parts 1910, 261-275.

Although these examples attest to the general feasibility of regulating industry by industry, they do not bear close analogy to the noise situation to the extent that they concern different hazards in different industries. The closest resemblance to the noise case--a single hazard pervasive across industries--is posed by the asbestos standard set by OSHA. The industry difference problem was addressed head-on by the court in the challenge to that standard (IUD, supra). One of the points in issue concerned the effective date of the regulation--which was to be uniform for all industries. OSHA had promulgated a 5-fiber standard for all industries which was to be reduced to 2-fibers for all industries after 4 years. Evidence was introduced showing that many industries could have complied well within the allowable 4 years. NIOSH had, on the basis of this evidence, recommended varying standards depending on industry compliance capability. Nevertheless, OSHA promulgated a uniform standard, largely for reasons of practical administration.

The D.C. Circuit Court, while upholding the general standards, remanded for clarification or reconsideration, the part making the standard uniform. In so doing, it made several very important points concerning industry-specific standards. First, the court chided OSHA for not seeking out and introducing more information showing inter- and intra-industry differences. Second, it maintained that industry-specific standards "would not appear to create opportunities for employers in one industry to challenge their standards on the grounds that standards for another industry were less demanding" (except if the industries were directly competing). Lastly, the court refused to accept OSHA's cryptic reference to reasons of practical administration as justification for uniformity. Its specific statement on the subject is as follows:

> It is possible that the Secretary failed to pursue this point because he interpreted the statute to require a single uniform standard for reasons of practical administration. If so, we disagree. The statutory scheme is generally calculated to give the Secretary broad responsibility for determining when standards are required and what those standards should be. If the Secretary determines that meaningful distinctions between the compliance capabilities of various industries can be defined, he is authorized to structure the standards accordingly.

It is noteworthy that to this point in the consideration of the noise standard OSHA has rejected the option of industry-specific standards for two reasons: administrative impracticability, and inequitable treatment of workers in industries with less strict standards.* With respect to difficulties in administration, this argument against industry-specificity seems to have been largely disposed of by the IUD case, unless OSHA soon compiles detailed evidence to substantiate its claim on this point. Given the paucity of analysis performed to date concerning this option, one might even argue that is is legally incumbent upon OSHA to consider industry-specific standards more fully.**

With respect to the equity or unequal treatment problem, a variety of issues deserve further mention. The problem of unequal treatment of employers in various industries which arises as a result of an industry-specific standard was addressed directly in the case of the asbestos standard. The court's statement on this point is quoted above. Although the court clearly approved such an approach, one industry-specific standard which concerned it was the effect on competition which such a standard might create. Reference was made, however, to other major cases*** which found competitive problems of this sort generally applicable at the intra- rather than inter-industry level. In the OSHA context, it has been maintained previously, hardships on the intra-industry level may be dealt with by a variety of means (e.g. variances, abatement agreements). Thus the competition issue (on either an intra- or inter-industry level) should not be a pressing concern. The IUD court said as much:

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*40 Fed. Reg. 12366 (March, 1975).

**Without such analysis OSHA faces a formidable legal challenge to its standard and potential remand 1) on the basis of the IUD remand in a similar situation, or 2) on the basis of NEPA (and CEQ and DOL implementing regulations) which calls for a "detailed assessment of alternatives." A beginning toward industry-by-industry analysis and establishing the "meaningful distinctions" between industries is, however, made by the BBN analysis and the CPA work considering cost and compliance capabilities according to 19 SIC code industries.

***International Harvester Co. v. Ruckelshaus 478 F. 2d 615 (D.C. Cir. 1973) and Portland Cement Association v. Ruckelshaus, 486 F. 2d 375 (D.C. Cir. 1973).

> The only relevant question [in a challenge by employers in one industry] would be whether the time schedule established for each industry would be feasible for that industry; therefore, comparisons with . . . a different industry would be pointless unless the two industries were in competition with one another.

Similarly, the legal problems created by workers in one industry complaining of unequal treatment from an industry-specific standard do not appear especially severe. One could simply apply the court's reasoning in IUD concerning employers to the employees' context, and this might prove a sufficient answer. Moreover, if in answer to such complaints OSHA were to set a uniform, less protective standard rather than one which is selectively strict according to industry compliance capability, its action would in this case be open to characterization as equally unprotective treatment for all. It is, therefore, entirely possible (given the wide variation among industries) that an industry-specific standard, drafted according to considerations of individual industry feasibility, could be, in the aggregate, more protective of workers than a single uniform standard which would, legally, have to meet the feasibility test with respect to the lowest common denominator of industries.*

A last "equity" question to be considered is the efficient allocation of resources to effectuate mandated social goals. Put more concretely, if the goals of general economic feasibility and worker protection are both present in the OSHAct, the most efficient way to achieve them both may be to vary the mandated levels of noise protection (beyond a certain minimum which should be universal) according to the feasibility of achieving greater levels of protection. In short, it may be most "equitable" to impose very strict standards for industries capable of meeting them economically feasibly.

*The Constitutional problems of equal protection which might arise in this situation are not especially troublesome. The appropriate test to be applied would be whether there were a rational basis for distinctions among industries. The stricter justification for legislative action, "compelling governmental interest" is only applied where there is a "suspect" classification (industry differences are not) or where a "fundamental right" is involved. If workers' (or public) health were to gain judicial recognition as a fundamental right, an industry-specific standard which in effect granted unequal treatment might be forbidden, but this is not the present state of the law.

7.3 Conclusions

It is apparent that the discussion to date concerning industry-specific standards has been deficient in its depth and seriousness. OSHA's examination of this alternative has been rather cursory and its reasons for rejection conclusory. A fuller consideration of this option is clearly required by existing legal authority: 1) NEPA and its implementing regulations, which unambiguously outline the alternatives section of an impact statement and 2) the Industrial Union case, which held that industry-specificity in health standards must be explored before a uniform standard can be set. Part of this analysis has been attempted in this report.

Moreover, on the basis of the OSHAct itself, past agency actions under it, and the relevant caselaw, it appears that OSHA has perfect legal competence to promulgate regulations in the industry-specific form. The Industrial Union case made it clear that an inequity in treatment of different industries is not a legal impediment; and administrative difficulty is similarly not a persuasive legal argument without some data to support this assertion. Moreover, the existence of a group of industry-specific standards currently in force attests to both the legality and practicability of this option.

This being the case, the key to the analysis of industry-specific standards is whether "meaningful distinctions" exist among industries sufficient to justify different basic standards, different compliance periods, or different modes of compliance. The distinctions which must exist essentially concern the "feasibility" of stricter standards for some. Thus, to quote the IUD court, the final "relevant question" is feasibility.

The feasibility of differing compliance scenarios according to industry has in part been demonstrated by the earlier analysis in this report. The problem of feasibility of compliance on a firm-by-firm basis (a consideration necessary if the Continental Can decision is upheld) has yet to be satisfactorily resolved.

Part of the solution to the individual firm feasibility problem lies in sound use of existing mechanisms allowing regulatory flexibility--variances and abatement agreements. The solution to the additional problem of OSHA's legal burden to prove such feasibility on a case-by-case basis may again lie in an industry-level approach. If feasible industry-specific standards are promulgated and upheld, and if feasible abatement agreements or industry-level abatement guidelines are adopted, the effective burden of proof may shift from OSHA to firms to prove that their case is compelling enough to warrant an exception to the general industry rule.

7.4 Ethyl Corporation v. EPA

The Ethyl Corporation litigation was a contest of the regulations by which EPA sought to reduce lead content in gasoline. The case has major significance for environmental or health regulatory agencies in general, but it is of more limited relevance with respect to the OSHA workplace noise standard. The primary issue in Ethyl Corp. was the authority of EPA to regulate when such action was based only on a finding that lead additives represented a "significant risk of harm" rather than on proof of actual harm. (The statutory direction in the Clean Air Act allows the agency to control or prohibit fuel additives which "will endanger the public health or welfare.") The D.C. Court of Appeals upheld EPA's action, affirming its right to take preventive measures based on its assessment of risk even in a situation where conclusive factual findings were difficult if not impossible to obtain due to the scientific uncertainties surrounding the issue. A second important point in issue was whether EPA could justifiably regulate the lead content in gasoline even though the lead additives increased the potential harm only incrementally in that other sources of lead presumably contributed the major portion of human exposure. Again, EPA's authority in this regard was confirmed.

In an important respect the Ethyl Corp. situation does not bear close analogy to workplace noise control, since in the latter case the adverse effects of noise exposure on hearing are relatively well documented and understood. (On the other hand, when considering the non-auditory effects of noise, the question of an agency's authority to guard against uncertain potential harm is certainly cogent.) However, the issue of cumulative detrimental effect, the second major point in Ethyl Corp., is significant in the noise context. The clear message of Ethyl Corp. is that regulatory agencies have the responsibility to reduce to the extent feasible those hazards which fall within their jurisdiction even though there may be significant causative factors which lie beyond their control. With respect to the noise standard, this point is relevant to the problems of presbycusis and especially sensitive individuals. The Ethyl Corp. rationale would seem, in these contexts, to indicate that OSHA may design its standard so as to prevent in unusually situated individuals a cumulatively induced handicap, irrespective of the fact that the workplace exposure may only represent an incremental addition to the handicap's causation.

8. POLICY ISSUES AND A CHOICE OF COMPLIANCE SCENARIOS

8.1 Recapitulation of Findings

- Although there are uncertainties in the underlying data and there are major methodological flaws in the BBN cost analysis, we believe that we have demonstrated that a proper methodological treatment yields (after-tax effects) costs of the same magnitude. Furthermore, we believe that the BBN estimates do provide a rational basis for the adoption of an occupational noise exposure regulation.

- An analysis of the compliance costs of an industry-by-industry basis tends to suggest a potential wide variation among industries in the economic burden to comply with a 90 dBA or an 85 dBA standard. This variation could form part of the basis for meaningful distinctions among industries in selecting different compliance scenarios. However, in order to provide a rational basis for setting an industry-by-industry standard (should that be desired) the BBN cost estimates need to be confirmed and adjusted, where necessary.

- The magnitude of the effect that discounting has on compliance costs and the practical considerations making immediate compliance not feasible, suggest the consideration of alternative compliance scenarios with different time-phasing for compliance.

- It is likely that about half of the net costs of the regulation on industry will be borne indirectly by governments in the form of tax reductions.

- The BBN estimate of noise exposure in individual industries must be regarded as highly preliminary and subject to error. Properly interpreted, however, they can: (1) form the basis for assessments of the <u>overall</u> hearing conservation benefits likely to be produced by compliance with different noise regulations under different assumptions, and (2) give some indication of how much the hearing conservation benefits of noise control may <u>vary among industries</u>. The data for specific industries need to be critically assessed, however.

- <u>Ultimate Equilibrium Flow of Benefits</u>

  If present exposures remain unchanged, approximately 1.9 million workers will experience hearing levels above 25 dB due to industrial noise at any one time (after subtraction of the workers who will be over 25 dB due to presbycusis alone). The implementation of a 90 dBA standard will reduce the number over 25 dB by about 770,000 and the implementation of an 85 dBA standard will reduce the number over 25 dB by about 1,350,000.

  Of this hearing impairment over 25 dB which is prevented, approximately 15% represents hearing impairment in the "severe" over 50 dB category. In addition, the number of people prevented from experiencing 20-25 dB hearing levels is approximately one-third as large as the number of people prevented from experiencing hearing levels over 25 dB.

- <u>Pre-Equilibrium Benefits of Different Compliance Scenarios</u>

  Compliance with a 90 dBA standard within five years will prevent about 18 million person-years of impairment over 25 dB prior to equilibrium (at year 45). Compliance with an 85 dBA standard within five years will prevent about 30 million person-years of impairment over 25 dB in the same time period. A two-step compliance scenario with compliance to 90 dBA within five years and compliance to 85 dBA within ten years will prevent about 28 million person-years of impairment over 25 dB prior to equilibrium.

- <u>Worker's Compensation</u>

  The total potential savings in worker's compensation benefits that will accrue from <u>either</u> a 90 or 85 dBA standard are small ($.28 billion and $.53 billion, respectively) when compared to the capital and maintenance costs of compliance. It is clear that the savings from the worker's compensation payments alone cannot serve as an adequate economic incentive for industries to voluntarily reduce the level of noise exposure in the workplace.

- Absenteeism

  The benefits of prevented absenteeism are substantial. For the 90 dBA standard with a five-year delay, the expected benefits are $3.9 billion and for 85 dBA, $6.3 billion.

- Other Benefits (reduction in cardiovascular disease processes, and in annoyance) are plausible and, though of uncertain magnitude, must be included in any complete assessment of benefits.

- Cost/Benefit

  Cost/benefit comparisons excluding all benefits except pre-equilibrium hearing conservation indicate that:
  -- Cost/effectiveness for hearing conservation of the noise control expenditures to reach 85 dBA in five years is similar to the cost/effectiveness of the noise control expenditures needed to reach 90 dBA in five years. For the 85 dBA regulation, $840 present value would be spent to prevent each person-year of impairment over 25 dB, and for the 90 dBA regulation $790 would be spent for each person-year over 25 dB prevented.
  -- The "two-step" scenario (compliance with 90 dBA in five years, compliance with 85 dBA within ten years) has a slightly better cost/benefit ratio ($760/person-year over 25 dB prevented) than the other scenarios.
  -- The data tend to suggest wide variation in the cost/benefit ratios for the different compliance scenarios in different industries.

- Inclusion of absenteeism benefits, tax benefits, worker's compensation and other non-auditory benefits, all move the cost/benefit ratio in the direction of providing more benefits to workers at lower costs to firms.

8.2 Identification of the Issues in Conflict

There are important technical issues in conflict such as the definition of material impairment, the time-intensity trade-off rule, and the data most suitable for quantifying the relationship between noise exposure and hearing impairment. However, controversy surrounding these issues tends to obfuscate the more basic policy-determining questions. The basic issues are:

- the extent to which OSHA should, under its mandate, impose costs on industry and society in order to benefit workers,
- the choice of time frames for compliance,
- the mix of engineering controls, administrative controls, hearing conservation programs, and
- the desirability of industry-specific standards.

It is hoped that this writing has helped to distinguish the technical and scientific bases for policy choices from the legal, economic and practical bases.

8.3 Discussion of the Basic Issues

The Extent to which OSHA should, under its mandate, impose Costs on Industry and Society in order to benefit Workers

Since there would be substantial hearing loss in the work force with either a 90 dBA or an 85 dBA standard, there is a firm evidentiary basis for OSHA, under its mandate, to promulgate an occupational noise exposure regulation.* The *technological feasibility* of using engineering controls to achieve the proposed alternative standards has been emphasized by BBN, although some industries may need to supplement those controls by other compliance methods during the initial phase of compliance. *Economic feasibility* remains a thornier issue.

OSHA would be well-advised to pursue cost-effective means of implementing a noise regulation, and the directive for an Inflationary Impact

*On the benefit side, there may be justification for adoption of an even lower noise exposure level.

statement does require an analysis of the economic effects of a proposed standard. However, a cost-benefit analysis is neither the required nor most desirable approach for policy guidance. Cost-benefit analysis is inappropriate for dealing with issues comparing incomensurables such as workers' hearing and capital costs (See section 2). The fear of the Council on Wage and Price Stability that costs of regulation will far *exceed* the benefits is inappropriately put. The costs can not be directly compared to the benefits since there is no theoretically correct way to monetize all the benefits of hearing conservation. The issue is whether the costs are *justified* by the benefits (See section 5 for discussion of the appropriate quanification of benefits). Our earlier presentation of costs and benefits (derived from a proper treatment of the data contained in the Inflationary Impact statement) do indicate that a noise regulation for industry as a whole is justified. The exact form of the regulation will be discussed in the subsection entitled, "The Choice of Compliance Scenarios".

The Choice of Time Frame for Compliance

We have shown that a slight delay in compliance times will reduce the firm's effective costs of compliance and not be very harmful to workers (See Figures 4.3 and 5.6). In addition, a delay in compliance may allow new technology to develop in the noise control field and in severely noise-impacted industries. Thirdly, delaying the compliance period will allow a firm more flexibility in obtaining the necessary capital funds, accoustical materials, and technical expertise needed for compliance. At the same time, the dangers of a delayed compliance scenario must be recognized, particularly delays by those firms lacking good faith. A two-step scenario(which mandates interim compliance with a noise level higher than the final level required)should be seriously considered in cases where a one-step, but lengthy delay scenario would appear to be more cost-effective.* (See further discussion in the section entitled, "The Choice of Compliance Scenarios".)

The Mix of Engineering Controls, Administrative Controls, and Hearing Conservation Programs

The mixture of engineering controls, administrative controls, and personal hearing protectors, must be most carefully addressed. The success of a variety of types of engineering controls is fairly well-documented. However, the success of administrative and personal hearing protection approaches is seriously questioned [1,2]. In industrial field conditions, it was revealed that the field-tested ear plug did not offer the protection indicated in the available literature.[1] We are not unmindful of some evidence that indicates success; we merely wish to point out that the reliability of this form of noise control is highly uncertain and varies with the particular case. In another recently published report by NIOSH entitled "A Survey of Hearing Conservation Programs in Industry"[2], it was revealed that administrative controls had seldom been used with much success. Here too we find that the reliability of a noise control measure other than engineering controls depends very much on the particular program. It must be recognized that "feasibility" (required by the OSH Act) must not only refer to feasibility of engineering controls, but also the feasibility of hearing protectors being *effective*. A more expensive but reliable engineering

*Abatement agreements providing long time periods for compliance have met with mixed success (Bureau of Natural Affairs Inc., Occupational Safety and Health Reporter, vol. 6, no. 14, p. 402, September 2, 1976). If, after claiming to have done all within its power, a firm concludes it can not comply and has done nothing, no disciplinary action appears to be possible under the law. Therefore unless compliance activity can be effectively monitored, only short delays between interim compliance steps seem to be justified for either abatement agreements or compliance scenarios.

[1] M. Padilla, "Ear Plug Performance in Industrial Field Conditions", Sound and Variation (May 1976), pp.33-6.

[2] M.E. Schmidek et. al., Survey of Hearing Conservation Programs in Industry, NIOSH No. 75-178, June 1975.

control may be preferable to a cheap but unreliable hearing protection approach--if the latter's feasibility is highly uncertain. It is worth pointing out that in the NIOSH study mentioned above, 80% of the hearing test facilities failed to meet the ANSI criteria for audiometer performance or limits for background noise levels.[1]

The Desirability of Industry-Specific Standards

There appears to be a rational basis for setting industry specific standards should that be desired. In Tables 8.1, 8.2, and 8.3, we compare the benefits, costs, and costs per benefit for three different compliance scenarios on an industry basis. Should the policy maker wish to derive the maximum hearing protection per dollar expended by industry, he may wish to impose different burdens on the different industries. The criteria for this undertaking may include health, economic, and technological factors. On the health side it must be recognized that solutions which may not be health-effective approaches in the long term (e.g. hearing protectors or some administrative controls) may suffice for an interim period. This would lessen compliance costs for the firm and encourage better technological solutions in the long run. Both costs, "profitability", and cost/benefit data should be considered on the economic side. The possible promulgation of machinery standards (by EPA), the availability of government assistance in Research and Development and possibility of technological innovation enter into the technological factor.

8.4 External Factors Which May Ultimately Bear on a Choice of Compliance Scenarios

Before discussing a choice of compliance scenarios, three additional factors important for ultimate policy formulation will be discussed.

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[1] Ibid.

Table 8.1

COMPARISON OF BENEFITS, COSTS AND COST/BENEFIT FOR
COMPLIANCE SCENARIO 90 (5 year)

SIC	INDUSTRY	BENEFITS*	COSTS**	COST/BENEFIT***
20	Food and Kindred Products	.783	777	990
21*	Tobacco Manufacturers	.036	61	1,690
22	Textile Mill Products	3.47	1,560	450
23	Apparel & Other Textile Products	.017	0	0
24	Lumber and Wood Products	3.29	945	290
25	Furniture and Fixtures	.277	480	1,760
26	Paper and Allied Products	.300	270	900
27	Printing and Publishing	.201	635	3,160
28	Chemicals and Allied Products	.766	412	540
29	Petroleum and Coal Products	.702	236	340
30	Rubber and Plastic Products	.296	155	520
31	Leather and Leather Products	.004	0	0
32	Stone, Clay & Glass Products	.309	230	740
33	Primary Metal Industries	3.89	1,884	484
34	Fabricated Metal Products	1.254	1,762	1,410
35	Machinery, except Electrical	1.147	2,951	2,570
36	Electrical Equipment & Supplies	.070	196	2,000
37	Transportation Equipment	.846	905	1,070
49	Electric, Gas & Sanitary Services	.417	777	1,860
				$ 790 (ALL INDUSTRY AVERAGE)

*Noise-induced hearing impairment over 25 dB over 45 years in millions of person-years
**Total discounted compliance costs over 45 years (millions of dollars, present value)
***Cost in dollars per prevented person-year over 25 dB

Table 8.2

COMPARISON OF BENEFITS, COSTS AND COST/BENEFIT FOR
COMPLIANCE SCENARIO 90(5 year), 85(10 year)

SIC	INDUSTRY	BENEFITS*	COSTS**	COST/BENEFIT***
20	Food and Kindred Products	1.418	1,730	1,220
21	Tobacco Manufacturers	.050	113	2,260
22	Textile Mill Products	4.78	2,700	560
23	Apparel & Other Textile Products	.058	13	220
24	Lumber and Wood Products	4.46	1,327	300
25	Furniture and Fixtures	.602	560	930
26	Paper and Allied Products	.714	365	510
27	Printing and Publishing	.722	1,224	1,700
28	Chemicals and Allied Products	1.316	689	520
29	Petroleum and Coal Products	.917	310	340
30	Rubber and Plastic Products	.570	268	470
31	Leather and Leather Products	.011	9	790
32	Stone, Clay & Glass Products	.476	416	870
33	Primary Metal Industries	5.42	3,211	592
34	Fabricated Metal Products	1.92	1,983	1,030
35	Machinery, except Electrical	1.757	3,501	1,990
36	Electrical Equipment & Supplies	.208	391	1,880
37	Transportation Equipment	1.373	1,234	900
49	Electric, Gas & Sanitary Services	1.221	1,128	920
				$ 760 (ALL INDUSTRY AVERAGE)

*Noise-induced hearing impairment over 25 dB over 45 years in millions of person-years.
**Total discounted compliance costs over 45 years (millions of dollars, present value)
***Cost in dollars per prevented person-year over 25 dB

Table 8.3

COMPARISON OF BENEFITS, COSTS AND COST/BENEFIT FOR COMPLIANCE SCENARIO 85 (5 year)

SIC	INDUSTRY	BENEFITS*	COSTS**	COST/BENEFIT***
20	Food and Kindred Products	1.551	2,264	1,400
21	Tobacco Manufacturers	.053	142	2,680
22	Textile Mill Products	5.03	3,339	660
23	Apparel & Other Textile Products	.068	20	300
24	Lumber and Wood Products	4.66	1,541	330
25	Furniture and Fixtures	.676	602	890
26	Paper and Allied Products	.807	419	520
27	Printing and Publishing	.851	1,555	1,830
28	Chemicals and Allied Products	1.429	845	590
29	Petroleum and Coal Products	.955	351	370
30	Rubber and Plastic Products	.630	331	530
31	Leather and Leather Products	.013	14	1,040
32	Stone, Clay & Glass Products	.513	520	1,010
33	Primary Metal Industries	5.72	3,954	691
34	Fabricated Metal Products	2.05	2,109	1,030
35	Machinery, except Electrical	1.885	3,812	2,020
36	Electrical Equipment & Supplies	.242	500	2,070
37	Transportation Equipment	1.482	1,419	960
49	Electric, Gas & Sanitary Services	1.412	1,325	940
				$ 840 (ALL INDUSTRY AVERAGE)

*Noise-induced hearing impairment over 25 dB over 45 years in millions of person-years.
**Total discounted compliance costs over 45 years (millions of dollars, present value)
***Cost in dollars per prevented person-year over 25 dB

Tax Alternatives

In our calculation of the costs associated with the workplace noise standard (Section 4.1), we discussed the after-tax impact of the capital and maintenance costs for purchases of noise abatement equipment. That discussion assumed that such capital expenditures would in most cases qualify for two existing tax benefits: the depreciation deduction (Section 167) and the investment tax credit (Section 38). These benefits, of course, pass on some of the costs to the government and the general taxpayer population.

The current tax code provides other benefits to investments in environmental control technologies which are, however, unavailable in the noise context. These arise from Section 169, which allows rapid amortization of a "certified pollution control facility". Such facilities are considered to be plant or equipment installed for the reduction of air or water pollution.

One alternative to be considered for reducing workplace noise is a simple amendment to the defitional section of I.R.C. 169 (169(d)) which would include noise abatement devices within the meaning of the term "pollution control facility".* Such an amendment would presumably provide an additional incentive to firms to make investments in noise control; however, the size of the increment is not certain given the fact that the investment credit would then be unavailable. For those particular expenditures, moreover, although the tax mechanism may be efficacious as a policy tool, it is not clear that as a matter of social policy the shifting of costs which tax benefits entail is necessarily desirable. One must balance,

---

*Amendments to Section 169(d):

For purposes of this section--

1) The term "certified pollution control facility" means a new identifiable treatment facility...to abate or control *noise* water or atmospheric pollution...

B) the Federal certifying authority has certified...*(iii) as being in compliance with the Occupational Safety and Health Act or the Noise Control Act...*

3) The term "Federal certifying authority" means...*in the case of noise pollution the Environmental Protection Agency or the Department of Labor.*

among other things, decreased noise pollution or reduced financial burdens on small or marginal firms against, for instance, an equally-reduced cost to large and/or healthy firms which amounts to a public subsidy. No particular course of action is recommended here, other than a suggestion that this option may merit further consideration.

EPA Machinery Regulations

The desirability of shifting the burden from firm to the manufacturer of noisy machinery through a mechanism such as EPA machinery regulation needs to be considered. (See testimony of Mr. Charles Elkins of the EPA.)

The Desirability of Encouraging Government Intervention Through Support of Industrial Research and Development

It is interesting to note that those industries with severe noise problems are often those with the lowest measures of Research and Development intensity. Table 8.4 illustrates the relationship between high noise levels and low Research and Development expenditures.

Measures of R&D intensity, by industry, 1961-72

Industry	Mean over the 1961-72 period		
	R&D scientists & engineers per 1,000 employees	Total funds for R&D as a percent of net sales[11]	Company funds for R&D as a percent of net sales[11]
Group I			
Chemicals & allied products	37.0	4.0	3.5
Machinery	25.9	3.9	3.1
Electrical equipment & communications	47.2	8.5	3.6
Aircraft & missiles	80.6	20.9	3.5
Professional & scientific instruments	33.9	5.9	4.1
Mean for group I	47.1	8.2	3.5
Group II			
Petroleum refining & extraction	15.0	0.9	0.9
Rubber products	17.0	2.0	1.7
Stone, clay & glass products	10.7	1.6	1.5
Fabricated metal products	12.0	1.3	1.2
Motor vehicles & other transportation equipment	19.4	3.3	2.5
Mean for group II	10.4	1.9	1.6
Group III			
Food & kindred products	7.2	0.4	0.4
Textiles & apparel	3.1	0.5	0.5
Lumber, wood products & furniture	4.7	0.5	0.4
Paper & allied products	6.5	0.9	0.8
Primary metals	5.6	0.8	0.8
Mean for group III	6.0	0.6	0.6

[15] For further information on R&D in small companies, see Thomas Hogan and John Chirichiello, "The Role of Research and Development in Small Firms", in *The Vital Majority: Small Business in the American Economy*, Small Business Administration, 1974.

[11] Total net sales by Group I industries over the entire 1961-72 period were only 25 percent larger than sales by industries in Group II and approximately 50 percent larger than those of Group III industries.

Source:
Science Indicators 1974, National Science Board 1975.

It also should be realized that federal support for Industrial Research and Development is lowest in those industries with severe noise problems, (Table 8.5).

Table 8.5
Federal funds as a percentage of total industrial R&D expenditures, by industry, 1973

Industry	Percent
Aircraft and missiles	78
Electrical equipment & communication	50
Professional & scientific instruments	20
Motor vehicles and other transportation equipment	17
Machinery	16
Rubber products	12
Chemicals and allied products	10
Fabricated metal products	5
Primary metals	4
Petroleum refining and extraction	3
Stone, clay, and glass products	2
Textiles and apparel	2
Food and kindred products	1
Paper and allied products	1

[1] Federal support for nonmanufacturing industries amounted to 56 percent of their total R&D expenditures in 1973.

Source: Science Indicators 1974, National Science Board 1975.

Thus, the ultimate compliance scenario should reflect the desirability of encouraging government intervention in the Industrial Research and Development of those industries most severely impacted.

8.5 The Choice of Compliance Scenarios

The form of the standard must reflect not only the best available technological and scientific information, but must also consider the administrative burdens of setting the standard and enforcing the law. In Section 7 we raised important issues likely to surface in legal challenges to whatever standard is promulgated and enforced. The challenges may differ as to technological versus economic feasibility, who proves something as opposed to what needs to be proved; and whether the challenge is to a broad-based standard, an industry-specific standard, or to the particular burden placed on an individual firm.

The facts would appear to mandate an ultimate compliance with an 85 dBA standard in all industries.

Considerations of both costs and realiability support the preference of engineering controls as the primary compliance strategy, supplemented by personal hearing protectors and some administrative controls (such as the running of night or weekend shifts) in the interim phase of compliance. Some industries may be harder hit. Government policies favoring further cost-sharing by society through tax changes and government participation in research and development should be considered if engineering controls impose a particularly severe burden on a substantial number of industries.

A slight delay in compliance time (less than five years) is probably inevitable. If a longer delay is deemed desirable, the standard ought to require compliance with an 85 dBA standard in no longer than 10 years, with an interim compliance with 90 dBA at no later than five years.

There are differences between industries in the economic burden likely to be imposed. The factors which can be used to differentiate industries in order to promulgate industry-specific standards, which differ in compliance times, in certain cases are:

- cost/benefit ratio
- cost per measure of industry profitability
- the likelihood of a technological breakthrough
- the existence of government assistance
- the likely effectiveness of proposed machinery regulations
- OSHA enforcement priorities vis-a-vis industries, and
- OSHA abatement and variance posture.

In sum, we believe that there is sufficient evidence in the record to justify setting an occupational noise exposure regulation. It would not be beneficial to wait until more evidence is required. The form of the standard must be such that the regulation is enforceable and likely to elicit an effective response by those regulated. The regulation must be of the form that can be effectively administered. The damage resulting from further delay in the setting of a standard is substantial and warrants prompt and deliberate action.

APPENDICES

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APPENDIX A: METHODOLOGY OF COST CALCULATIONS

1. COST ESTIMATES IN THE AGGREGATE

1.1 Computing Discounted Present Value of BBN Capital Costs

Table A1 illustrates how the discounted capital costs were computed. For example, BBN's estimate for compliance with an 85 dBA standard ($18,540 million) was broken down in an annual investment schedule for a 5-year compliance period.[1] The annual investment was adjusted for cost reduction due to technological change (3%/year) and a discounted present value adjustment (discount rate of 7%).

TABLE A1

INTERMEDIATE CALCULATIONS FOR COMPLIANCE ALTERNATIVE C.

Dollars in Millions	5 Year Compliance 85 dBA				
Year	Investment Rate*	85 dBA Capital Cost**	Adjustment Technological Change	Present Value Adjustment***	Discounted Capital Cost
1	5%	927	---	---	927
2	12%	2,224.8	.97	.935	2,017.78
3	22%	4,078.8	.94	.873	3,347.14
4	29%	5,376.6	.91	.816	3,992.45
5	32%	5,932.8	.88	.763	3,983.52
	100%	18,540.0			14,267.89

*The investment schedule is from the BBN estimate of the distribution of noise control capital cost over different compliance periods. BBN Report No. 3246, Economic Impact Analysis of Proposed Noise Control Regulation, Figures 3.1, p. 3-35

**BBN estimate total capital cost to comply with an 85 dBA standard is $18,540 million.

***Discount rate of 7%

[1] BBN Report No. 3246, Economic Impact Analysis of Proposed Noise Control Regulation, Figures 3.1, p. 3-35.

1.2 Calculation of Discounted Maintenance Costs.

The discounted maintenance costs were computed by multiplying 5% of <u>existing</u> capital investment by the present value of an annuity at 7% over the entire time-frame. Thus, the discounted maintenance cost for immediate compliance with an 85 dBA standard for the first 20-year time-frame would be:

Capital Cost To Comply With 85 dBA		Annual Maintenance Charge = .05 Capital Cost		PV of Annuity 20 Years at 7%		Discounted Maintenance Cost
18,540	x	.05	x	10.594	=	9820.

The calculations for the discounted maintenance cost for immediate compliance with an 85 dBA standard for the second 25-year time-frame are presented in Table 4.1, footnote 4.

The calculation of the discounted maintenance cost for compliance scenarios of 5 and 10 years take into account the capital investment schedules over the compliance periods. Thus, annual maintenance charges are 5% of the existing stock of capital at the end of the year. After full compliance is reached, the annual maintenance charge is the same dollar amount and only the discount factor varies.

APPENDIX B: DETAILED METHODOLOGY OF THE HEARING CONSERVATION BENEFIT CALCULATIONS

Section 5 of the main text of this report presented the results of some exemplary calculations of the likely magnitude of hearing conservation benefits. This appendix provides a more detailed elaboration of the methods and assumptions used in the hearing conservation computations. Immediately below, we shall delineate how the calculations were done. In general our belief is that although there are a number of simplifying assumptions which could be altered to produce more refined calculations, such refinements would not substantially alter the conclusions.

The calculations were basically done in two steps:

- Definition of exposures and the exposed population. For each compliance scenario, time point, industry, and mobility assumption investigated, this step of the calculation estimated the numbers of workers of different age groups with various equivalent continuous noise exposures (dBA) over their previous working lives since age 18. Toward this end:
  - -- Available exposure data from BBN were adjusted to reflect approximate L_{eq} ("equal energy", "3-dB trading rule") exposures rather than L_{OSHA} ("5-dB trading rule") exposures. (See Section 1.1)
  - -- Exposures were modified, where appropriate, to reflect compliance with postulated regulations, using the assumption that all exposures above a designated standard level would be brought down exactly to the standard level. (See Section 1.2)
  - -- Age X Exposure matrices were constructed, given the approximate age distribution of the workers in the 19 studied Industries in 1970. (See Section 1.3)

-- Utilizing the "equal energy rule", equivalent continuous exposures were calculated for worker populations with changes in their exposure levels over time due to: (1) worker mobility and (2) time after compliance with different noise standards. (See Section 1.4)

- Determination of hearing impairment "risk" and hearing conservation benefit. Given the population exposures defined in the first step, hearing impairment within 20-25 dB, 25-50 dB, and over 50 dB hearing level categories was computed by:

-- Using the observations of Baughn[1] to define relationships between the fraction of people in different hearing level categories at any one time ("risk") and noise exposure for particular age groups. (See Section 2.1)

-- Combining the "risk" relationships (Section 2.1) with the previously defined Age X Exposure matrices (Section 1.4) to compute the number of people in different hearing level categories at any one time. (See Section 2.2)

-- From the numbers of people in particular hearing level categories at various times after compliance, computing the person-years of impairment prevented by different compliance scenarios prior to the attainment of ultimate equilibrium. (See Section 2.3)

1. ESTIMATES OF NOISE EXPOSURE

Assumption #1: BBN Estimates of Occupational Noise Exposure in 10 Industries

Bolt, Beranek, and Newman generously supplied us with a set of their primary data estimating the distribution of noise exposures among production workers in various industries in 1975 (Table B1). These data are (1) more

Based on Information From
Bolt, Beranek, and Newman

TABLE B1

Estimate of the Number of Production Workers Exposed to
Time Weighted Continuous Sound Levels
(In Thousands)

SIC	INDUSTRY	Less Than 80	80-85	85-90	90-95	95-100	100-105	105-110	110-115	TOTAL
20	Food and Kindred Products	640.57	204.99	74.98	168.53	25.80	9.53	0.95	0.95	1,126.3
21	Tobacco Manufacturers	55.50	3.00	0.58	2.88	1.84	---	---	---	63.8
22	Textile Mill Products	77.41	108.89	180.30	153.80	107.52	123.08	---	---	751.0
23	Apparel & Other Textile Products	989.77	27.75	10.28	---	---	---	---	---	1,027.8
24	Lumber and Wood Products	3.97	31.60	41.19	245.85	123.59	5.29	---	---	451.5
25	Furniture and Fixtures	165.92	83.00	74.69	29.60	---	---	---	---	353.2
26	Paper and Allied Products	187.00	109.57	76.38	102.11	1.52	1.30	0.62	---	478.5
27	Printing and Publishing	156.27	177.97	217.06	91.20	---	---	---	---	642.5
28	Chemicals and Allied Products	270.82	92.45	84.28	115.96	3.47	0.22	---	---	567.2
29	Petroleum and Coal Products	10.83	18.07	28.88	28.88	17.32	17.32	---	---	121.3
30	Rubber and Plastic Products	283.88	69.13	54.38	29.81	1.60	1.42	---	---	440.3
31	Leather and Leather Products	206.18	3.82	2.12	---	---	---	---	---	212.2
32	Stone, Clay & Glass Products	354.12	79.78	34.46	2.38	---	12.76	---	---	483.5
33	Primary Metal Industries	178.52	184.04	229.90	188.05	101.61	61.68	---	---	943.8
34	Fabricated Metal Products	516.13	174.61	129.76	68.50	94.47	13.75	0.49	0.09	997.8
35	Machinery, except Electrical	781.78	287.73	157.69	84.54	34.16	26.83	8.93	1.64	1,383.3
36	Electrical Equipment & Supplies	940.60	127.94	54.34	17.40	0.68	1.34	---	---	1,142.3
37	Transportation Equipment	740.23	136.06	119.88	64.48	64.46	8.04	0.55	0.10	1,133.8
49	Electric, Gas & Sanitary Servs.	30.96	140.61	253.87	185.76	---	---	---	---	619.2
	Total	6,590.46	2,069.01	1,825.02	1,579.73	578.12	282.56	11.54	2.78	12,939.3

Total Workforce	12,939,300
Greater than 85	4,321,800
Greater than 90	2,454,640

detailed than those previously published, in that they show the numbers of workers at various levels over 90 dB in individual industries, and (2) do not contain the uncertainty adjustment which BBN applied to the previously published data.*

1.1 Computing L_{eq} Noise Levels for Present Exposures

The figures in Table B1 reflect an estimate of 1975 noise exposures in U.S. industry as determined by BBN under OSHA's current "5-dBA time-intensity trading rule" (Designated as L_{OSHA}). In other words, when BBN found workers with different exposure levels at different times during the working day, equivalent daily continuous exposure levels were estimated by a formula which weighted noise exposures at 95 dB as twice as intense per unit of time as exposures at 90 dB.** Although this bears a good relationship to OSHA's current method of expressing noise exposure, the available evidence*** suggests that an "energy" weighted average ("L_{eq}" as defined by EPA[3], essentially a 3-dBA time-intensity trading rule) is more apprpriate for computing long-term hearing impairment. Unfortunately, underlying data necessary for a precise calculation of L_{eq} were not recorded by BBN. Instead, BBN has suggested the following assumption for roughly estimating L_{eq} exposures from their data for industries characterized primarily by fluctuating noise:

*Because of the uncertainty of the exposure estimates, BBN modified their data be redistributing 1/2 of the workers in each 5-dBA exposure range into the exposure ranges 5-dBA higher and lower than the original exposure range. Example:

	85-90	90-95	95-100
Before adjustment	0	100	0
After adjustment	25	50	25

We believe that the "best expected value" of the exposure distribution is represented by the original data before adjustment, and have therefore based our computations on the uncorrected observations.

**For example, a formula BBN may have implicity used is:

$$L_{OSHA} = 90 + 5(\log_2(\frac{\Sigma z_i 2^{1/5(Y_i - 90)}}{\Sigma z_i}))$$

where z_i is the number of hours at an exposure level of Y_i dBA

***Primarily, the study by Burns and Robinson.[2]

Assumption #2: For industries with primarily fluctuating noise,*

an estimate of the L_{eq} exposure distribution can be generated by shifting half of the workers in an L_{OSHA} exposure distribution to the next higher 5 dBA exposure range. Example:

	85-90	*90-95*	*95-100*
Before adjustment	*100*	*200*	*0*
After adjustment	*50*	*150*	*100*

Table B2 shows the results of applying this procedure to the BBN L_{OSHA} data. Table B3 is a restatement of the data in Table B2 as percentages of the total production workers in each industry. These latter figures serve as the basic exposure estimates for our exemplary calculations.

The gross numbers of workers given in Tables B1 and B2 refer to the population of production workers employed in each industry in the first half of 1975. That particular time period, of course, was a time of deep recession and general employment levels were lower than can be expected for non-recessionary periods in the coming years. Ideally, it would be best to base our benefit calculations on projections of employment in individual industries over the next several decades. Failing that, however, we have elected to use average 1974 employment levels, as they are representative of employment in current times:

Assumption #3: Average Employment in Individual Industries Will Approximate 1974 Employment Levels for the Next Several Decades

To the degree that 1974 employment levels underestimate future employment levels, the benefit estimates will be somewhat underestimated. 1974 employment levels in the indicated industries are shown in Table B4. For the sum of all 19 industries, the difference between 1975 and 1974 is the difference between about 12.9 and 14.5 million production workers.

*SIC's 21, 23, 24, 25, 28, 29, 30, 31, 32, and 33, according to BBN. No adjustment is necessary for other industries, with primarily constant noise.

TABLE B2

Estimates of the Number of Production Workers Exposed to Time Weighted Continuous Sound Levels With L_{EQ} Adjustment for Fluctuating Noise (In Thousands)

Modified from information provided by Bolt, Beranek, and Newman

SIC	INDUSTRY	Less Than 80	80-85	85-90	90-95	95-100	100-105	105-110	110-115
20	Food and Kindred Products	640.57	204.99	74.98	168.53	25.80	9.53	0.95	0.95
21 *	Tobacco Manufacturers	27.75	29.25	1.79	1.73	2.36	0.92	---	---
22	Textile Mill Products	77.41	108.89	180.30	153.80	107.52	123.08	---	---
23 *	Apparel & Other Textile Products	494.89	508.76	19.01	5.14	---	---	---	---
24 *	Lumber and Wood Products	1.99	17.78	36.39	143.2	184.72	64.44	2.64	---
25 *	Furniture and Fixtures	82.96	124.46	78.85	52.14	14.8	---	---	---
26	Paper and Allied Products	187.00	109.57	76.38	102.11	1.52	1.30	0.62	---
27	Printing and Publishing	156.27	177.97	217.06	91.20	---	---	---	---
28 *	Chemicals and Allied Products	135.41	181.63	88.37	100.12	59.72	1.84	0.11	---
29 *	Petroleum and Coal Products	5.42	14.45	23.47	28.88	23.1	17.32	8.66	---
30 *	Rubber and Plastic Products	141.94	176.5	61.76	42.09	15.74	1.55	0.71	---
31 *	Leather and Leather Products	103.09	105.00	2.97	1.06	---	---	---	---
32 *	Stone, Clay & Glass Products	177.06	216.95	57.12	18.42	1.19	6.38	6.38	---
33 *	Primary Metal Industries	89.26	181.28	206.97	208.97	144.84	81.64	30.84	---
34	Fabricated Metal Products	516.13	174.61	129.76	68.50	94.47	13.75	0.49	0.09
35	Machinery, except Electrical	781.78	287.73	157.69	84.54	34.16	26.83	8.93	1.64
36	Electrical Equipment & Supplies	940.60	127.94	54.34	17.40	0.68	1.34	---	---
37	Transportation Equipment	740.23	136.06	119.88	64.48	64.46	8.04	0.55	0.10
49	Electric, Gas & Sanitary Servs.	30.96	148.61	253.87	185.76	---	---	---	---
	TOTAL	5,330.72	3,032.43	1,840.96	1,538.07	775.08	357.96	60.88	2.78
		8,363.15		1,840.96			2,734.77		

*Fluctuating Noise.

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TABLE B3

Estimate of the Percentage of Production Workers Exposed to
Time Weighted Continuous Sound Levels
With L_{EQ} Adjustment for Fluctuating Noise
(In Thousands)

Modified from information
provided by
Bolt, Beranek, and Newman

SIC	INDUSTRY	Less Than 80	80-85	85-90	90-95	95-100	100-105	105-110	110-115
20	Food and Kindred Products	56.87	18.2	6.657	14.963	2.291	0.846	0.084	0.084
21 *	Tobacco Manufacturers	43.495	45.840	2.806	2.712	3.699	1.442	---	---
22	Textile Mill Products	10.309	14.5	24.008	20.479	14.317	16.389	---	---
23 *	Apparel & Other Textile Products	48.150	49.499	1.849	0.5000	---	---	---	---
24 *	Lumber and Wood Products	0.4407	3.979	8.059	31.716	40.913	14.272	0.5047	---
25 *	Furniture and Fixtures	23.488	35.230	22.324	14.762	4.190	---	---	---
26	Paper and Allied Products	39.079	22.9	15.962	21.340	0.318	0.272	0.130	---
27	Printing and Publishing	24.322	27.7	33.784	14.195	---	---	---	---
28 *	Chemicals and Allied Products	23.073	32.022	15.580	17.652	10.529	0.3244	0.0194	---
29 *	Petroleum and Coal Products	4.468	11.913	19.349	23.809	19.044	14.279	7.139	---
30 *	Rubber and Plastic Products	32.237	40.086	14.027	9.559	3.575	0.352	0.161	---
31 *	Leather and Leather Products	48.582	49.402	1.399	0.499	---	---	---	---
32 *	Stone, Clay & Glass Products	36.620	44.870	11.814	3.810	0.246	1.319	1.319	---
33 *	Primary Metal Industries	9.450	19.207	21.929	22.141	15.346	8.650	3.268	---
34	Fabricated Metal Products	51.726	17.5	13.005	6.865	9.468	1.378	0.049	0.009
35	Machinery, except Electrical	56.516	20.8:	11.400	6.111	2.469	1.940	0.646	0.119
36	Electrical Equipment & Supplies	82.343	11.2.	4.757	1.523	0.060	0.117	---	---
37	Transportation Equipment	65.288	12.	10.573	5.687	5.685	0.709	0.049	0.009
49	Electric, Gas & Sanitary Servs.	5.000	24.	41.000	30.000	---	---	---	---
			64.63%	14.23%			21.14%		

*Fluctuating Noise

TABLE B4

1974 EMPLOYMENT LEVELS

SIC	INDUSTRY	THOUSANDS OF PRODUCTION WORKERS IN INDUSTRY IN 1974
20	Food and Kindred Products	1,174
21	Tobacco Manufactuers	65
22	Textile Mill Products	875
23	Apparel & Other Textile Products	1,156
24	Lumber and Wood Products	539
25	Furniture and Fixtures	433
26	Paper and Allied Products	545
27	Printing and Publishing	668
28	Chemicals and Allied Products	616
29	Petroleum and Coal Products	124
30	Rubber and Plastic Products	535
31	Leather and Leather Products	244
32	Stone, Clay & Glass Products	552
33	Primary Metal Industries	1,067
34	Fabricated Metal Products	1,137
35	Machinery, except Electrical	1,483
36	Electrical Equipment & Supplies	1,372
37	Transportation Equipment	1,260
49	Electric, Gas & Sanitary Services	630
	All Industry Total	14,475

1.2. Exposures After the Attainment of Different Compliance Levels

Assumption #4: The effect of "compliance" with a particular standard level (85 or 90 dBA) will be, on balance, to bring all employees above the standard level down to the standard level. Example:*

	80-85	*85*	*85-90*	*90*	*90-95*
Before compliance	*25*		*35*		*40*
After compliance with 90 dBA regulation	*25*		*35*	*40*	
After compliance with 85 dBA regulation	*25*	*75*			

1.3. Age X Exposure Matrices

Both the length of time individuals have been exposed to noise and the magnitude of hearing losses due to presbycusis are related to age. For computations of the hearing impairment experienced by the entire population of workers at any one time-point in the future, it is necessary to:

(1) compute the probability that individuals in each age group will experience different degrees of impairment, and,

(2) multiply the results of (1) by the numbers of individuals in each age group in the population at the designated time-point in the future.

As implied by (2), it would be desirable to base exposure and effect calculations on projections of the age distribution of the population at various times in the future. For simplicity, however, we have elected to assume a constant age distribution similar to the age distribution observed in the 19 industries in the 1970 census:

*The "balance" is between tendencies which produce overcompliance and opposing tendences which produce undercompliance in the industrial population. For discussion see our earlier publication[4], page 2-14.

Assumption #4: The age distribution of the population exposed to noise and experiencing noise-induced hearing impairment will be constant over the next several decades at:

Age	*% of Population*
18-24	*16%*
25-34	*23%*
35-44	*22%*
45-54	*22%*
55-64	*15%*
65+	*2%*

Implicit in Assumption #4 is a complete congruence between the age distributions of the working population exposed to noise and the population experiencing noise-induced hearing impairment at any one time. This is not strictly the case. Older workers who retire from the workforce after noise exposure will experience hearing impairment for the rest of their lives; but because the age distribution in Assumption #4 reflects only the working population, post-retirement individuals and post-retirement hearing impairment will not be included in the benefit computations. For this reason, the results will tend to underestimate the true level of benefits.

In order for Assumption #4 to be combined with the exposure data in Table B3, it is necessary to make two further simplifying assumptions:

Assumption #5: All industries will have identical age distributions, on average, over the next several decades.

Assumption #6: Within each industry, noise exposure is independent of age.

As can be seen in 1970 census data[5] industries can differ in their age distributions. However, it is difficult to know if these inter-industry differences can be expected to persist in consistent fashion over several decades. To the degree that there are consistent inter-industry differences, and to the degree that noise exposure is not independent of age, then there may be additional reasons why the population exposed to noise may differ in age distribution from the population experiencing potential noise-induced hearing damage. Such differences may be expected to have similar effects on the final estimates of benefits as the exclusion of retired workers discussed above.

Given the above assumptions, the exposure distribution for each industry was multiplied by the uniform assumed age distribution to form an Age X Exposure matrix for each industry. Table B5 is the Age X Exposure matrix for the food industry. The food industry's overall exposure distribution from Table B3 can be seen in the column labelled "Total, All Ages" at the extreme right of Table B6. The overall age distribution from Assumption #4 can be seen in the bottom row, labelled "Total, All Exposures."

1.4 Use of the "Equal Energy Rule" to Compute Equivalent Continuous Exposures for Populations With Changing Noise Exposures

The exposures shown in Table B3 are our best estimate of the effective noise dosage produced by particular jobs and received by production workers on any one day in 1975. However, with the passage of years, two kinds of changes in individual workers' exposures occur which must be dealt with in any adequate description of population exposures:

> Worker mobility. Workers in relatively noisy jobs effectively exchange places with workers in relatively quiet jobs. This reduces the effective exposure over time to individuals rotated out of noisy jobs, but increases the total number of workers exposed.
>
> Changes in job noise levels. On compliance with occupational noise regulations, individuals in noisy jobs would experience a change in exposures.

Burns and Robinson,[2] in their study of the effects of occupational noise on hearing of a selected population of workers, found that it was possible to formulate a simple rule for converting exposures which varied in the course of a lifetime to continous exposure levels of equivalent impact on hearing. This is the famous "equal energy rule" --so named because exposures of roughly equivalent energy (with the "A" weighting of different frequencies) were found to have roughly equivalent hearing impairment effects. In more mathematical terms:

TABLE B5

AGE - EXPOSURE MATRIX FOR SIC 20 --FOOD AND KINDRED PRODUCTS*

Exposure Level	Age Group						Total,
	18-24	25-34	35-44	45-54	55-64	65+	All Ages
Less than 80	9.10	13.08	12.51	12.51	8.53	1.14	56.9%
80-85	2.91	4.19	4.00	4.00	2.73	.36	18.2%
85-90	1.06	1.53	1.46	1.46	1.00	.13	6.65%
90-95	2.39	3.44	3.29	3.29	2.24	.30	15.0%
95-100	0.37	0.53	0.50	0.50	0.34	.046	2.29%
100-105	0.14	0.19	0.19	0.19	0.13	.017	0.85%
105-110	0.013	0.019	0.018	0.018	0.013	.0017	0.084%
110-115	0.013	0.019	0.018	0.018	0.013	.0017	0.084%
Total, All Exposure Levels	16%	23%	22%	22%	15%	2%	100%

* All figures are in percent of total workers in the industry.

Assumption #7: For any number of noise exposures for n_i years at Y_i dBA, an equivalent continuous exposure, L_{eq} is given by:

$$L_{eq} = 80 + 10\ log\left(\frac{\Sigma n_i 10^{0.1(Y_i-80)}}{\Sigma n_i}\right)$$

1.4.1 Effective Exposure Changes Due to Worker Mobility

Given Assumption #7 above, and the basic concept of worker mobility as job exchange,* how can mobility be mathematically defined in order to form the basis for computations of (1) equivalent continuous exposures and (2) exposed population size? Consider an individual (A) of age (n) in a job of (Y) dBA daily noise exposure. Imagine that (A) is one of a large group of workers of the same age who have exchanged jobs at defined, regular intervals since beginning work at age 18. Now let us define a worker mobility index "WM" at the time points when exchange is about to occur as the number of intervals which have elapsed for (A) since age 18.** Thus if the intervals are so long that the first job exchange is about to occur (the interval is equal to the job tenure), there is a worker mobility index of 1. If the intervals are shorter, so that more job-exchanges have taken place the job mobility index takes on values greater than 1. In all cases WM can be interpreted either as:

(a) The number of jobs of equal length (A) has held since age 18 (jobs/worker), or

(b) The number of workers who have held the noisy job since (A) was 18 (workers/job), or

(c) $\dfrac{1}{\text{The fraction of each exposed worker's work experience spent in a noisy job.}}$

*No jobs are gained or lost in the process. Implicitly, we consider a substantially full employment situation in which the number of workers is equal to the number of jobs at any one time.

**This is equal to the number of job exchanges which have occurred, considering only the time points when an exchange is due.

Therefore, for a worker mobility index value of 3, the total population which has been exposed is simply three times the number of jobs, and by the equation in Assumption #7 if the "quiet job" exposures were at 80 dBA,* then L_{eq} for that population is:

$$L_{eq(WM3)} = 80 + 10 \log \frac{10^{0.1(Y-80)}+2}{3}$$

Similarly, for a worker mobility of 9, the total population exposed would be nine times the number of jobs and the L_{eq} would be:

$$L_{eq(WM9)} = 80 + 10 \log \frac{10^{0.1(Y-80)}+8}{9}$$

Table B6 shows the L_{eq}'s for various values of Y and worker mobilities of one, three, six, and nine.

TABLE B6

EFFECTIVE EXPOSURES WITH VARIOUS LEVELS OF WORKER MOBILITY

	WM1 L_{eq} With No Job Exchange	WM3 One Third of Each Worker's Work Experience In Noisy Job	WM6 One Sixth of Each Worker's Work Experience In Noisy Job	WM9 One Ninth of Each Worker's Work Experience In Noisy Job
	82.5	81.00	80.5	80.36
	87.5	84.05	82.48	81.80
	92.5	88.19	85.79	84.57
	97.5	92.88	90.09	88.54
	102.5	97.78	94.84	93.15
	107.5	102.74	99.76	98.02
	112.5	107.73	104.73	102.98
Relative size of the exposed population	1	3	6	9

*That exposures for "quiet jobs" average 80 dBA exposure is an assumption we use throughout.

In the main text of our testimony (Section 5.1.2) some evidence is presented which tentatively suggests that worker mobility, defined analogously to the simple case given here, is roughly constant with increasing age and may be approximately equal to three.* For purposes of our computations, except where otherwise stated, we assume a worker mobility value of three. Operationally, the effect of this assumption is to change the "exposure level" column on Age X Exposure matrices (such as Table B5) to the dBA values shown under WM3 on Table B6.

1.4.2 Equivalent Continuous Exposure Levels at Different Times Under Different Compliance Scenarios

Beginning with the time of compliance with either 90 dBA or 85 dBA regulations, the workforce will consist of individuals who have spent various proportions of their working lives under pre-compliance and post-compliance exposure conditions.** The proportion of pre-compliance to post-compliance exposures will vary systematically with

- (a) age--Other things being equal, the workers who are older at any one time will have spent a larger proportion of their working lives under pre-compliance conditions.
- (b) time after compliance--Other things being equal, the proportion of workers' experience under pre-compliance conditions will decrease as more time passes after compliance.

The equation given previously in Assumption #7 allows us to compute equivalent continuous exposures for any individual age group of workers at any time after initial compliance, provided that we make assumptions about (1) the exposure conditions prevailing throughout the entire work history of the workforce prior to compliance,*** (2) the age at which workers enter the workforce. For simplicity, we have chosen to use the following assumptions on these issues for our exemplary calculations:

*Note caveats on Table 5.2, p. 5-12.

**The ultimate equilibrium of pure post-compliance exposure profiles will not be achieved until the entire workforce present at the time of compliance is replaced by new workers--at least forty years after compliance.

***That is, have noise exposures in the past been generally greater, less than or equal to the noise exposures estimated by BBN for 1975?

*Assumption #8: Throughout the entire work history of workers employed at the time of compliance, noise exposures produced by individual jobs will have been constant at levels shown in Table B3.**

Assumption #9: All production workers enter the workforce at age 18 and work continuously thereafter until retirement.

Table B7 shows the equivalent continuous exposure levels computed in this way for the time-point 20 years after compliance with an 85 dBA regulation.

TABLE B7

L_{eq} EXPOSURES TWENTY YEARS AFTER COMPLIANCE WITH AN 85 dBA REGULATION (WORKER MOBILITY OF 3)

Pre-Compliance Exposure Level*	Age Group 18-24	25-34	35-44	45-54	55-64	65-74
81.00	81.00	81.00	81.00	81.00	81.00	81.00
84.05	82.36	82.36	82.54	83.07	83.33	83.47
88.19	82.36	82.36	83.35	85.50	86.31	86.74
92.88	82.36	82.36	85.22	89.22	90.41	91.01
97.78	82.36	82.36	88.46	93.72	95.08	95.74
102.74	82.36	82.36	92.71	98.55	99.97	100.66
107.73	82.36	82.36	97.44	103.49	104.93	105.63
Average No. Years With Pre-Compliance Exposures	0	0	2	12	22	32
No. Years With Post-Compliance Exposures	3	12	20	20	20	20

*Exposure shown are after allowance for a worker mobility index of 3 (See Section 1.4.1. for derivation). With this worker mobility index post-compliance exposure to 85 dBA translates into equivalent continuous exposure to 82.36 dBA.

*As modified, of course, by considerations of worker mobility. Implicitly, also, no effect is assigned to previous programs of audiometry and hearing protector use.

It may be observed that Assumption #8 has the effect of treating "compliance" as a uniform time-point across all industry. It is clear, however, that compliance will be achieved over some finite time period as the investments in noise control are made by different firms in different industries. (In formulating our "compliance scenarios" we have implicitly assumed that the minimum likely time-period for this investment will be five years.) For the benefit computations, we have chosen to date the initiation of "compliance" as beginning all at once at the end of this five-year period.* This procedure will somewhat underestimate the magnitude of pre-equilibrium benefits.

2. ESTIMATES OF HEARING IMPAIRMENT AND HEARING CONSERVATION BENEFIT

The previous section indicated the methodology and assumptions used in estimating equivalent continuous exposures for the population of production workers at various times under different compliance scenarios. In this section we shall set forth our assumptions about the relationships between exposure, age, and hearing impairment, and show our methodology for computing equilibrium and pre-equilibrium hearing conservation benefits.

2.1 Relationships Between Noise Dose and Hearing Impairment Risk for Different Age Groups

All of our computations to-date are based on the Baughn observations of noise-induced hearing impairment among a large group of U.S. automobile workers.[1]

Assumption #10: The Baughn damage-risk data accurately predict the best expected value of noise-induced hearing impairment for the existing population of U.S. workers in all industries.

Use of this particular data set is not without controversy. In our earlier publication** we examined the objections which have been raised to the Baughn

*For the two-step compliance scenario [90 (5 years), 85 (10 years)] for benefit computation "compliance" with 90 occurs all at once at the five year time point, and "compliance" with 85 occurs all at once at the ten year time point.

**Reference 4, pp. 2-17 and 2-18.

data and concluded that despite some uncertainties, the Baughn observations are the most appropriate data-set currently available for estimating likely hearing conservation benefits. That discussion need not be repeated here.

There were three basic steps necessary to convert the Baughn data to a form usable in our calculations:

(1) The total risk* of crossing specific fences (at 20, 25, and 50 dB averaged at .5, 1, 2 KHz RE: ISO) for selected age groups and exposure levels was read from Figures 8, 9 and 11 of Reference 1.

(2) For each age group and fence, the risk of crossing the fence with 80 dBA exposure was subtracted from the risk of crossing the fence at other exposures. The result was the estimate of noise-induced risk after allowance for presbycusis.

Assumption #11: At 80 dBA continuous exposure all hearing impairment is due to presbycusis and none is due to noise.

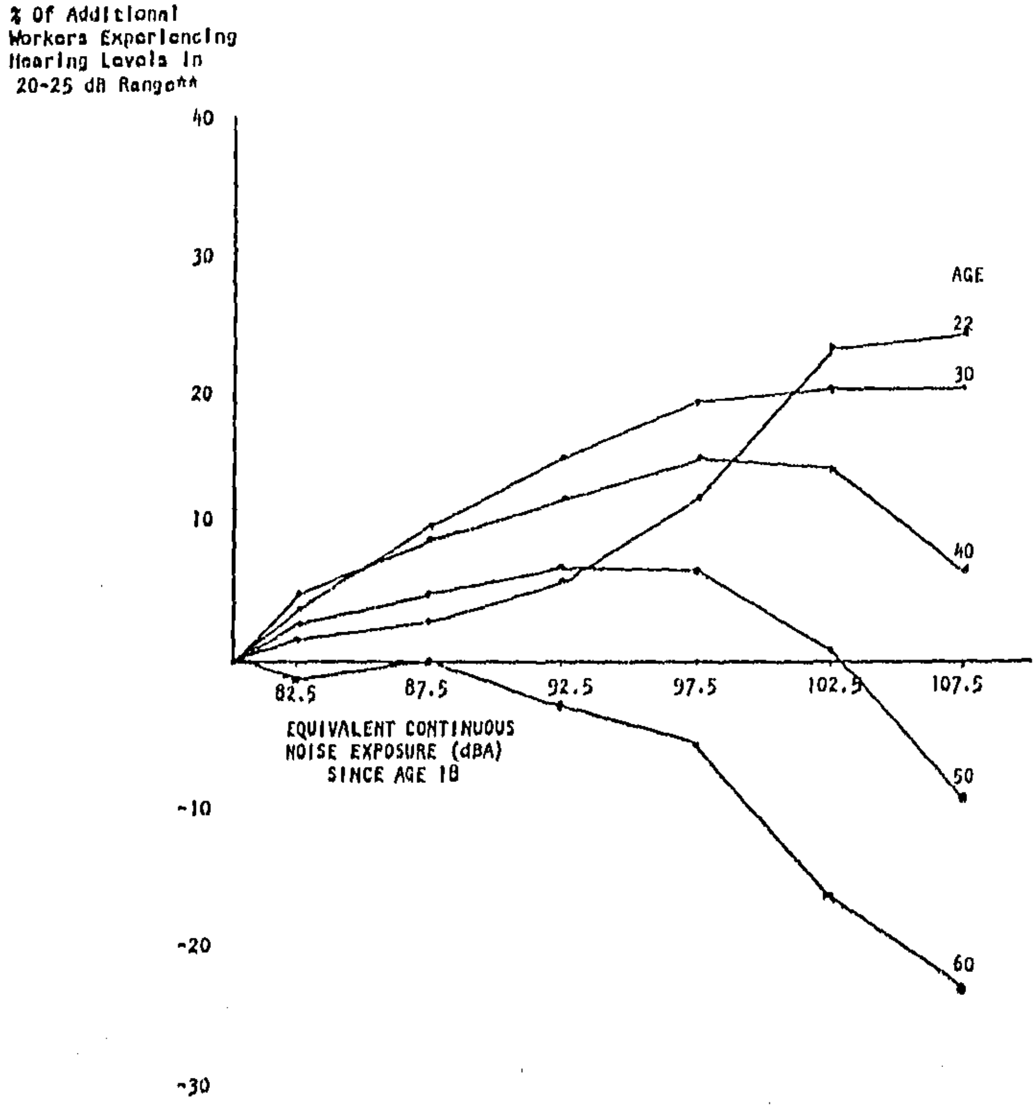
(3) To compute the net change in proportion of people in the 20-25 dB hearing level range, the risk of crossing the 25 dB fence was subtracted from the risk of crossing the 20 dB fence for each age and exposure group. The net change in the proportion of people in the 25-50 dB hearing level range was similarly computed by subtracting the risk of crossing the 50 dB fence from the risk of crossing the 25 dB fence.

The resulting relationships between exposure level and the increase in the proportion of people of specific ages in different hearing level categories are shown graphically in Figures B1 through B3. In some cases (particularly the older age groups for the 20-25 dB hearing level category) it can be seen that the function takes on negative values. In those cases, the influence of noise is to move more people out of the indicated hearing level category (and into categories of worse hearing level) than are being moved in (from categories of better hearing level).

*"Risk" of crossing a fence as used here refers to the proportion of the population expected to cross that fence.

FIGURE B1

BAUGHN DAMAGE-RISK DATA
FOR HEARING LEVELS IN
20-25 dB RANGE*

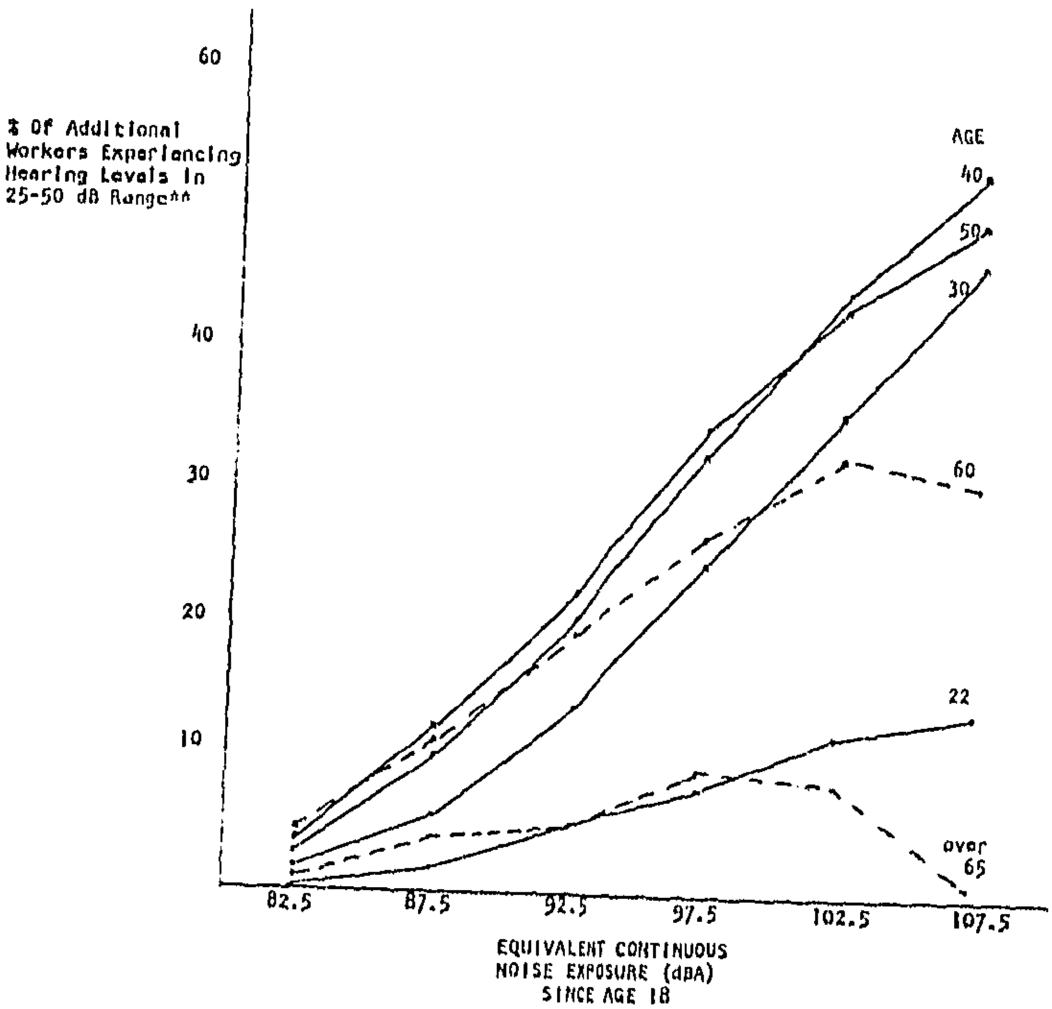


* After subtraction for presbycusis.

** (.5, 1, 2 kHz) Re: ISO.

FIGURE B2

BAUGHN DAMAGE-RISK DATA
FOR HEARING LEVELS IN
25-50 dB RANGE*

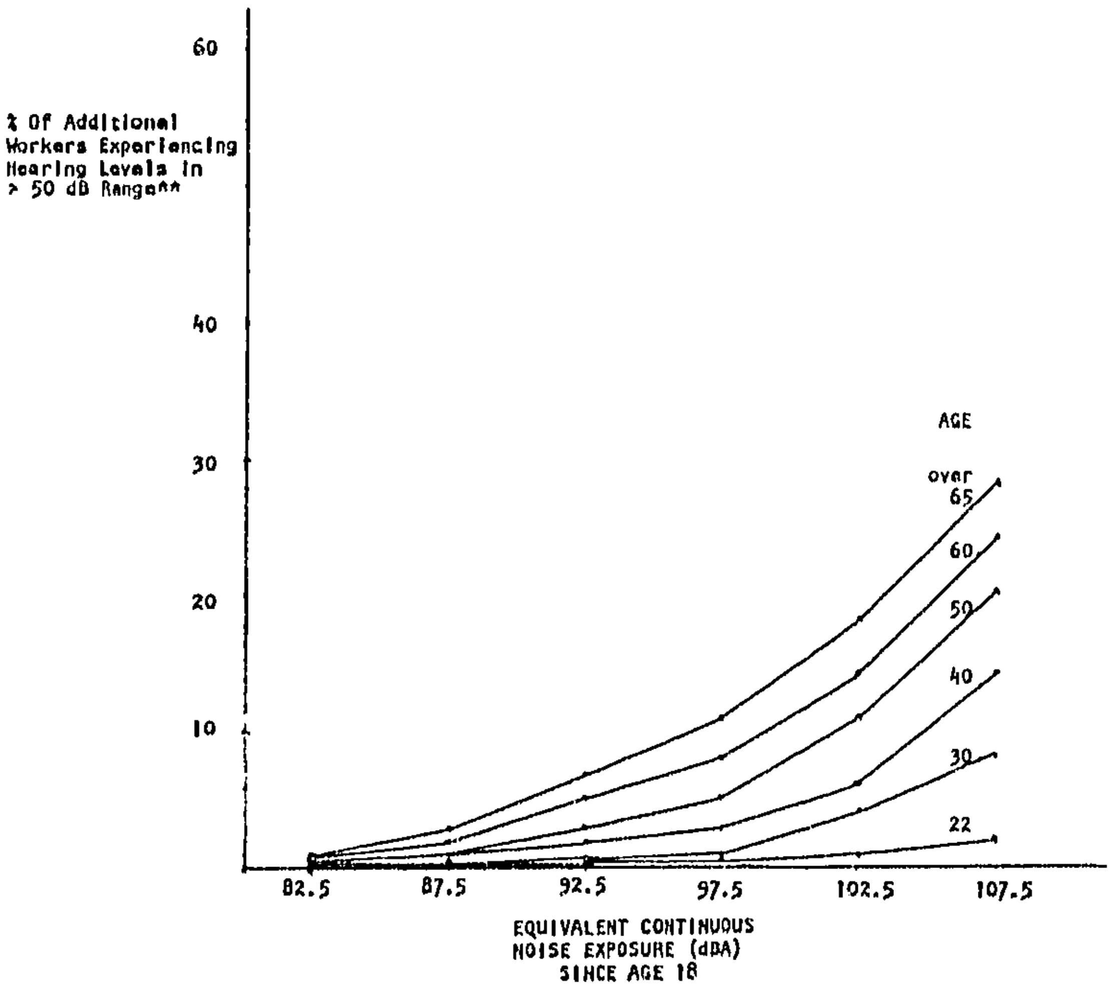


* After subtraction for presbycusis.

** (.5, 1, 2 kHz) Re: 150.

FIGURE B3

BAUGHN DAMAGE-RISK DATA
FOR HEARING LEVELS IN
> 50 dB RANGE*



* After subtraction for presbycusis.

** (.5, 1, 2 kHz) Re: 150.

2.2 Computation of the Number of People in Different Hearing Impairment Categories at Any One Time

Given the relationships shown in Figures B1-B3, for each state of compliance and time-point investigated, a set of three "risk matrices" were derived, consisting of the proportion of each Age X Exposure group moved to each of the three hearing level categories by the influence of occupational noise. For example, the risk matrix for the 25-50 dB hearing level category for the time-point 20 years after compliance with the 85 dBA standard is shown in Table B8.

To compute the numbers of workers experiencing hearing levels in various categories because of the influence of noise at each specific time-point, two additional operations were performed:

(1) The appropriate "risk matrix" was multipled by the appropriate "Age X Exposure matrix" and the worker mobility index,

(2) The resulting numbers of workers experiencing hearing levels in the specified range were summed for all age and exposure groups.

Using these procedures, the numbers of workers in particular hearing level categories were estimated for the various compliance scenarios at time-points 5, 10, 20, and equilibrium (40) years after initial compliance at year 5 in the diagrams in Figure 4.3 of the main text. "Benefits" for each scenario at each time-point were defined as the difference between the predicted number of people with a given level of hearing impairment under the scenario in question and the number which would suffer that impairment under the "0" scenario (no change from present exposures).

2.3 Computation of Pre-equilibrium Person-Years of Impairment Under Different Compliance Scenarios

Ideally it would be desirable to compute a mathematical function which would describe the benefits of each scenario at all time-points from compliance through ultimate equilibrium. Then that function could be integrated over

TABLE B8

"RISK MATRIX"

Proportion of Workers Added to the 25-50 dB Hearing Level Category
By The Influence of Noise
(Time: 20 Years After Compliance with 85 dB Standard, WM3)

Pre-Compliance L_{eq} Exposure Group*	Age Group					
	16-24	25-34	35-44	45-54	55-64	Over 65
Less Than 80	0	0	0	0	0	0
81.00	.001	.0076	.011	.015	.018	.004
84.05	.00236	.0179	.03	.045	.055	.015
88.19	.00236	.0179	.04	.085	.095	.035
92.88	.00236	.0179	.065	.155	.155	.045
97.78	.00236	.0179	.115	.245	.22	.075
102.74	.00236	.0179	.20	.355	.29	.085
107.73	.00236	.0179	.32	.44	.31	.035

*This column is for group identification only. The indicated L_{eq} is after adjustment for worker mobility, but before adjustment for change in exposure due to compliance with the regulation. The risk numbers shown, however, reflect the exposure matrix shown in Table B 7 which does include the L_{eq} exposure reductions attributable to the twenty years of compliance with the regulation.

time to arrive at a precise estimate of the person-years of impairment prevented under each scenario prior to equilibrium. Pending development of such a function however, it is possible to obtain a reasonable approximation of the ultimate result by essentially drawing straight lines between the number of people (P) kept out of each hearing impairment category at the determined time-points (0, 5, 10, 20, and 40 years). Using this procedure, the total number of person-years of impairment in any given hearing level prevented by a particular compliance scenario is given by:

$$\text{Person-Years of Benefit} = (5 \text{ years}) \left(\frac{0 + P_5}{2}\right) + (5 \text{ years}) \left(\frac{P_5 + P_{10}}{2}\right) + (10 \text{ years}) \left(\frac{P_{10} + P_{20}}{2}\right) + (20 \text{ years}) \left(\frac{P_{20} + P_{40}}{2}\right)$$

REFERENCES

1. Baughn, W.L. Relation Between Daily Noise Exposure and Hearing Loss Based on the Evaluation of 6855 Industrial Noise Exposure Cases, Joint EPA/USAF Study, AMRL-TR-73-53 (June 1973).

2. Burns, W., and Robinson, D.W., Hearing and Noise in Industry, Her Majesty's Stationery Office, London England, (1970).

3. EPA, Office of Noise Abatement and Control. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (1974).

4. Hattis, D., et al. Some Considerations in Choosing an Occupational Noise Exposure Regulation, EPA 55079-76-007, (February, 1976).

5. U.S. Bureau of the Census. U.S. Summary, Table 34 "Age of Employed Persons by Detailed Industry, and Sex: 1970", U.S. Government Printing Office, Washington, D.C. 20402.

Appendix C

Rate of Unscheduled Absence for Wage and Salary Workers by Occupation, 1972.

Occupation	Absent Part of Week-Medical Causes	Absent Entire Week-Total Causes
Professional	2.1	1.7
Managerial	1.3	1.5
Clerical	3.0	2.0
Sales	1.5	2.4
Craftsmen	2.1	2.3
Operatives	3.4	3.1
Laborers	3.2	2.7

Source: J.N. Hedges, "Absence from Work--A Look at Some National Data", Monthly Labor Review, Vol. 96, No. 7 (July 1973), p. 28

Appendix D-1

OCCUPATIONAL LOSS OF HEARING1/

Number of Cases and Cost of Compensation

Compensated Cases Closed, New York State, 1959 - 1973

Year of closing	Number of cases	Amount of compensation awarded
1959	70	$ 73,891
1960	69	80,258
1961	185	232,856
1962	110	128,883
1963	77	121,987
1964	84	128,019
1965	82	139,128
1966	54	118,624
1967	90	206,076
1968	105	201,485
1969	67	164,440
1970	101	251,521
1971	106	277,777
1972	165	434,911
1973	227	543,652

1/ Mainly due to continual exposure to loud noise.
Note: Medical and hospital costs are not included in the compensation awarded.

Prepared by: New York State
Workmen's Compensation Board
Administration Division
Office of Research & Statistics
May 18, 1976

Appendix D-2

Occupational Disease
Compensable And Compromise Cases Closed By Worker's Compensation Division
1970-1975
Loss Of Hearing

Nature Of Injury Year	Total No. Of Compensable Cases	Amount Of Indemnity	No. Of Fee Cases	Amount Of Medical Aid	Average Compensation Per Case 1/	Total No. Of Compromise Cases	Amount Of Indemnity	Average Settlement Per Case 2/
Loss Of Hearing Occupational								
1970	40	$ 91,700	2	$ 817	$ 2,321	9	$23,244	$ 2,583
1971	41	90,592	4	1,279	2,725	14	27,083	1,935
1972	60	141,163	7	535	2,429	22	61,259	2,785
1973	54	131,928	8	2,065	2,881	28	67,727	2,419
1974	53	135,203	18	1,630	2,642	30	71,161	2,372
1975	117	247,307	44	4,334	2,213	34	78,195	2,352

1/ Average indemnity payment plus average medical payment.

2/ Includes average compromise payment plus average medical aid.

NOTE: Compensable cases include all cases, except compromise cases, in which indemnity (workmen's compensation) is due and payable.
Compromise cases include all cases in which a compromise of liability under the Workmen's Compensation Act of Wisconsin is made by the employer and the employee. The amount of the compromise settlement includes both indemnity and medical aid.

Prepared by:
Risk Management Section, Research and Statistics Bureau, Department of Industry, Labor, and Human Relations, State of Wisconsin.

APPENDIX D-3

INTERNAL EAR HEARING
WCAB STATISTICAL REPORTS
TABLE 9--INJURIES CLAIMED ON ORIGINAL FILINGS*

Office	Fiscal Year 1974-1975	Fiscal Year 1975-1976
Bakersfield	24	18
Bell Gardens	159	250
Eureka	37	35
Fresno	26	81
Inglewood	57	52
Long Beach	113	161
Los Angeles	119	172
Oakland	91	130
Pomona	72	124
Redding	98	66
Sacramento	85	99
Salinas	8	21
San Bernardino	167	128
San Diego	34	69
San Francisco	80	98
San Jose	33	46
Santa Ana	98	130
Santa Barbara	25	55
Santa Monica	33	59
Santa Rosa	21	40
Stockton	21	38
Van Nuys	137	150
Ventura	64	66
Statewide	1,602	2,028

*Original filings include applications, stipulations with request for award, and requests for approval of C & R.

Prepared by: Workers' Compensation Appeals Board Division of Industrial Accidents, State of California

APPENDIX D-4

TOTAL POTENTIAL WORKERS COMPENSATION PAYMENTS SAVED AT EQUILIBRIUM
BASED ON NUMBER OF WORKERS NO LONGER COMPENSABLE
(Discounted to Present Value)

		25-50 dBA*				> 50 dBA*							
		Present Minus Comply 85		Present Minus Comply 90		Present Minus Comply 85		Present Minus Comply 90		Total Present Minus Comply 85		Total Present Minus Comply 90	
Range Of Years	Year Midpoint	Thousands Of Persons	$ Millions Saved	Thousands Of Persons	$ Millions Saved	Thousands Of Persons	$ Millions Saved	Thousands Of Persons	$ Millions Saved	Total $ Millions Saved	Present Value Of Annuity Of $1	Total $ Millions Saved	Present Value Of Annuity Of $1
0-5	2-1/2	2.4	6.84	1.3	3.71	.3	1.20	.2	1.33	8.04	32.96	5.04	20.66
5-10	7-1/2	7.2	20.52	4.3	12.26	.8	5.32	.4	2.66	25.84	75.76	14.92	43.63
10-15	12-1/2	10.8	30.78	6.2	17.67	1.4	9.31	.6	3.99	40.09	117.22	21.66	45.14
15-20 (20 yr)	17-1/2	14.9	42.47	8.7	24.80	2.0	13.30	1.1	7.32	55.77	82.87 (308.81)	32.12	47.73 (157.16)
20-25	22-1/2	17.8	50.73	10.1	28.76	2.4	15.96	1.3	8.65	66.69	70.69	37.41	39.65
25-30	27-1/2	20.4	58.14	11.3	32.21	3.2	21.28	1.7	11.31	79.42	59.96	43.52	32.86
30-35	32-1/2	23.8	67.83	12.5	35.63	3.8	25.27	2.0	13.30	93.10	49.99	48.93	26.28
35-40	37-1/2	25.3	72.11	13.7	39.05	4.4	29.26	2.3	15.30	101.37	38.82	54.35	20.82
<u>Total Savings</u> Over First 40 Years After Compliance 85											<u>528.27</u>		
After Compliance 90													<u>276.77</u>

*For compensation calculations handicap is measured as 1-1/2 percent for each dB loss between average hearing levels of 26 dB and 92 dB. Based on 10 state average maximum payment of $19,000, 15% handicap (at 25-50 dB) equals $2,850/worker, and 35% handicap (at >50 dB) equals $6,650/worker.

Explanation of Method Used In Deriving Table D-4

Using the number of moderately and severely impaired workers who leave the workforce at years 5, 20, and 40 at 90 and 85 dBA (and hence are prevented from being placed in the compensable category), we have extrapolated to the midpoint years for eight 5-year ranges over a 40-year compliance period. We then multiplied the number of "saved" workers by a hearing impairment payment depending on the severity of hearing loss to obtain the annual workers' compensation savings for the midpoint years. These were totalled to obtain the savings for combined moderate and severe hearing loss for both 90 and 85 dBA standards and discounted using an annuity method to arrive at a 40-year equilibrium total savings.

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