FUNDAMENTALS OF NOISE CONTROL ENGINEERING

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PREFACE

This reference is based on proven noise control technologies which have evolved from the inception of the Occupational Safety and Health Act (OSHA) of 1970 to the present time. Much of the noise control referenced in the text was legislated during the 1970s. Today OSHA no longer enforces engineering controls to meet the law. However, the law has never been revised to show this. Employees today demand a quiet environment and are aware of detrimental impact of excessive noise on their health. Communities are also demanding an acceptable acoustical environment.

We have found that emphasis on engineering control of noise has changed very little since the 1970s even though the enforcement of regulations has. Hopefully, this reference will give you a broad understanding of how noise control engineering has evolved and how you can apply the fundamentals of noise control engineering in your profession.

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1
THE IMPORTANCE OF NOISE CONTROL

American industry has three motives to reduce workplace sound levels:

1. To prevent hearing loss
2. To insure a pleasant working environment for employees
3. To comply with OSHA regulations

HEARING LOSS

It is estimated that between 8.7 and 11.1 million Americans suffered a permanent hearing disability.[1] The quality of life of these individuals is generally significantly degraded because of their reduced ability to carry out communications in their business and personal lives. It is well established that prolonged exposure to excessive noise levels will result in a permanent hearing loss. The probability of incurring a hearing loss greater than 25 dB ranges from 18% for exposure to 90 dBA to 70% for exposure to 115 dBA for a working lifetime of 40 years. An industry is held responsible for hearing loss incurred by employees which is attributable to noise exposure associated with their jobs, and is legally liable to compensate employees when hearing loss is identified. With 75% of the nation's workforce exposed to sound levels above 85 dBA, potential worker's compensation liability for hearing loss has been estimated to be on the order of $12 billion.

WORKERS COMPENSATION PROGRAMS AND CLAIMS

Richard E. Ginnold, Associate Professor, School for Workers, University of Wisconsin - Extension compiled an update of Workers Compensation Programs.[2] The study was published by the U.S. Environmental Protection Agency.

The following is a summary of the findings of the study:

1) While occupational hearing loss was found compensable in key cases 30 years ago and is covered in most state statutes, only nine states compensate more than a token number of hearing loss claims. Over 70% of the country's manufacturing workers live in 41 states which pay few or no claims.

2) Of the states compensating few or no claims, nine have statutory requirements of wage loss or total medical impairment (almost impossible to obtain under current medical standards). Another 32 states have few or no claims because of a variety of factors such as 6-month waiting periods before filing after leaving the noise environment (usually after retirement), restrictive impairment formulas, severe filing deadlines, lack of worker choice of physician, or deductions for aging.

3) The maximum benefit for total loss in both ears varies greatly between states, ranging from $8,000 in New Jersey to $135,000 in the FEC program. The average maximum benefit for the 50 states is $21,700. However, maximum benefit levels should not be considered in isolation. Many states with high benefits pay few or no claims. In addition, an average award of around $2,000-$2,500 is much lower than the maximum benefit.

4) In 1977, the total number of claims paid has been estimated at 6,095 for the 50 states, totalling approximately $13 million in payments. For the federal programs there were 2,300 estimated claims paid amounting to $17.6 million. It should be noted that the numbers of claims have been rising at 20-30% per year in the highest claim states, California and New Jersey, and in the FEC program.

5) A 10-year claims projection, assuming at a minimum 10% per year increases in the filing of claims, shows state claims of almost 16,000 and federal claims totalling nearly 6,000 in 1987. The total claims bill in 1987 would be $156 million for both programs. The 10-year benefits total for state and federal programs is projected at $835 million.

ENVIRONMENT OF THE WORKPLACE

The concern for worker welfare extends beyond the risk of hearing damage to other physiological and psychological effects, including annoyance. It is simply unpleasant to work in a noisy environment. Studies have indicated that workers are both less happy and less productive in areas of high ambient noise when compared to similar jobs in quieter workplaces. A NIOSH study showed that the increase in overall absenteeism among workers in noisy areas as compared with non-noisy areas is on the order of 1.23 workers per hundred per day. At a $9.00 basic wage, this represents an average of $230 per worker per year.

OSHA REGULATION

Title 29 CFE, Section 1910.95 of the Williams-Steiger Occupational Safety and Health Act of 1970 (Public Law 91-596) pertains to the protection of workers from potentially hazardous occupational noise. The regulation established a maximum noise level of 90 dBA for a continuous 8-hour exposure during a working day. Higher sound levels are allowed for shorter exposure times. The Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor was created for the purpose of implementing and enforcing the law.

ENVIRONMENTAL NOISE

The national concern for the wide-spread adverse effects of environmental noise has created a demand for the development of community noise control programs. At the present time however, there is no universal criterion for defining excessive sound for its properties are unlike those of any other pollutant; a sound leaves

no residue and becomes noise only when it is "undesired" and causes unpleasant psychological or physiological reactions.

The sources of sound are as complex as the effect of their sounds. The important problem here is the audio-visual sensing factor. The roar of Niagara Falls is a beauty of nature, and therefore, accepted, but the startle of thunder is not so regarded. The noise of the subway is not happily received by a nearby resident but it is probably most acceptable to the commuter who thought he had missed his train.

Americans' foremost complaint about their neighborhoods is noise. In a national survey of housing conditions by HUD, street noise was cited by 34% of the 60,000 respondents as a "condition existing in this neighborhood," 60% of those reporting the condition felt that street noise was "disturbing, harmful, or dangerous," and 18% of those reporting the condition felt that "it is so objectionable" that they would "like to move."

According to a Census Bureau study, 49.2% of American households feel their neighborhoods are too noisy. By contrast, only about a third as many—12.1 million compared to 34.9 million—feel crime in their neighborhoods is high enough to be considered an undesirable condition.

A result of increasing public concern about community noise is the growing amount of government activity in noise. Twenty-three states have enacted enabling legislation for noise control and have a combined budget of over $1,000,000. On the municipal level, there are now well over 1,200 noise regulations. This government activity represents nearly a 300% increase in legislative activity since 1970.

THE ROLE OF THE NOISE CONTROL ENGINEER

Noise control is not a new field. There have been many fine theoretical texts written about the importance of noise, but until recently much of the emphasis has been on architectural accoustics and aeronautics. This text is aimed at presenting a practical approach for solving noise control problems. You will play the role of the environmental noise control consultant. Through Job Simulation Experiences you will learn how to solve most noise problems

involved in designing a new, quiet industrial or power plant. The techniques used can be applied to any complex. Emphasis is placed on not only the technical areas, but also on the management of a noise control program.

Throughout this book you will be involved in the design of a new industrial plant. Since an industrial plant contains both process, power generation, and office areas, you will gain a broad exposure to noise control problems. In your role as a noise control consultant you may be a private practitioner or may work for a firm. In any case, the main areas that you will be dealing with are:

- Noise radiated to nearby residences
- Noise exposure of operating personnel
- Noise in offices, conference rooms, etc.

Each category will be evaluated based on different noise control objectives:

- Residential noise objectives are based on community standards and local ordinances.
- Employee exposure noise objectives are based on OSHA and hearing loss criteria.
- Office and administrative noise objectives are based on noise criteria for interior spaces.

NOISE CONTROL IN NEW PLANT DESIGN

Table 1.1 summarizes the major activities of the noise control engineer associated with the design of a new industrial plant.

There are three main noise objectives which should be equally weighed during the design phase of a new facility:

- *Technical Proficiency* – The noise control design should meet established criteria, including all applicable legislation (OSHA, local ordinances, etc.).
- *Cost Consideration* – Decisions as to the silencing equipment required should be analyzed using the principles of economic analysis. Usually several different silencing schemes exist, but all may not be economically attractive.

- *Schedules* – Delays in engineering and construction schedules can be very costly. It may not be easy to add silencing equipment on some items after the equipment is installed. It is therefore important that the noise control engineers establish the noise objectives early in the design phase.

Schedules should take into account noise control input early in plant design. A typical schedule showing the relationship of the noise control activities is shown in Figure 1.1.

ESTIMATING THE SCOPE OF THE PROJECT

The scope of the noise control activities for a new plant design may be divided into the following:

1. A survey of the site of the new plant and assessment of the impact of the new plant on the environment.
2. Noise control engineering to develop and design an acceptable noise environment.
3. Coordination with architects, heating and ventilation designers, and other specialty groups who use the input of the noise control engineer in specifying the materials, equipment, etc.

Table 1.2 presents estimated time requirements for the noise control phases in the design of an industrial facility.

REFERENCES

[1] "Report to the President and Congress on Noise," Administrator to the Environmental Protection Agency, 92nd Congress Document No. 92-63, February 1982.

[2] Ginnold, Richard E., "Occupational Hearing Loss–Workers Compensation Under State and Federal Programs," U.S. Environmental Protection Agency, Report No. 550/9-79-101, August 1979.

Table 1.1

Activities of the Noise Control Consultant (New Plant Design)

1. Establish noise criteria: a) perform noise survey of community b) specify outdoor noise criteria c) specify indoor noise criteria based on occupational exposure d) specify accoustical requirements for offices, conference rooms, auditoriums, etc.
2. Identify potential noise offenders.
3. Predict equipment noise levels, utilizing vendor information, if available.
4. Develop initial design considerations related to noise: a) location of plant b) orientation of plant and equipment c) location of transportation routes (trucking access and rail spurs) d) identification of indoor and outdoor equipment e) interior partitioning of plant f) location of substations and equipment rooms with respect to offices and control rooms
5. Establish noise reduction required for each piece of equipment.
6. Develop methods for noise control of each source.
7. Analyze bid tabs of equipment purchased. (Before equipment is purchased, a comparison of the competing equipment manufacturers' cost, quality, and delivery date should be summarized on a document known as a bid tab.)
8. Determine acoustical properties of walls, ceilings, glass, etc. for offices, conference rooms, control rooms, auditoriums, and building structures.
9. Write technical specifications for noise control equipment.
10. Perform sound measurements after construction completion to verify that noise objectives are met.
11. Determine remaining noise problem areas and implement corrective action.

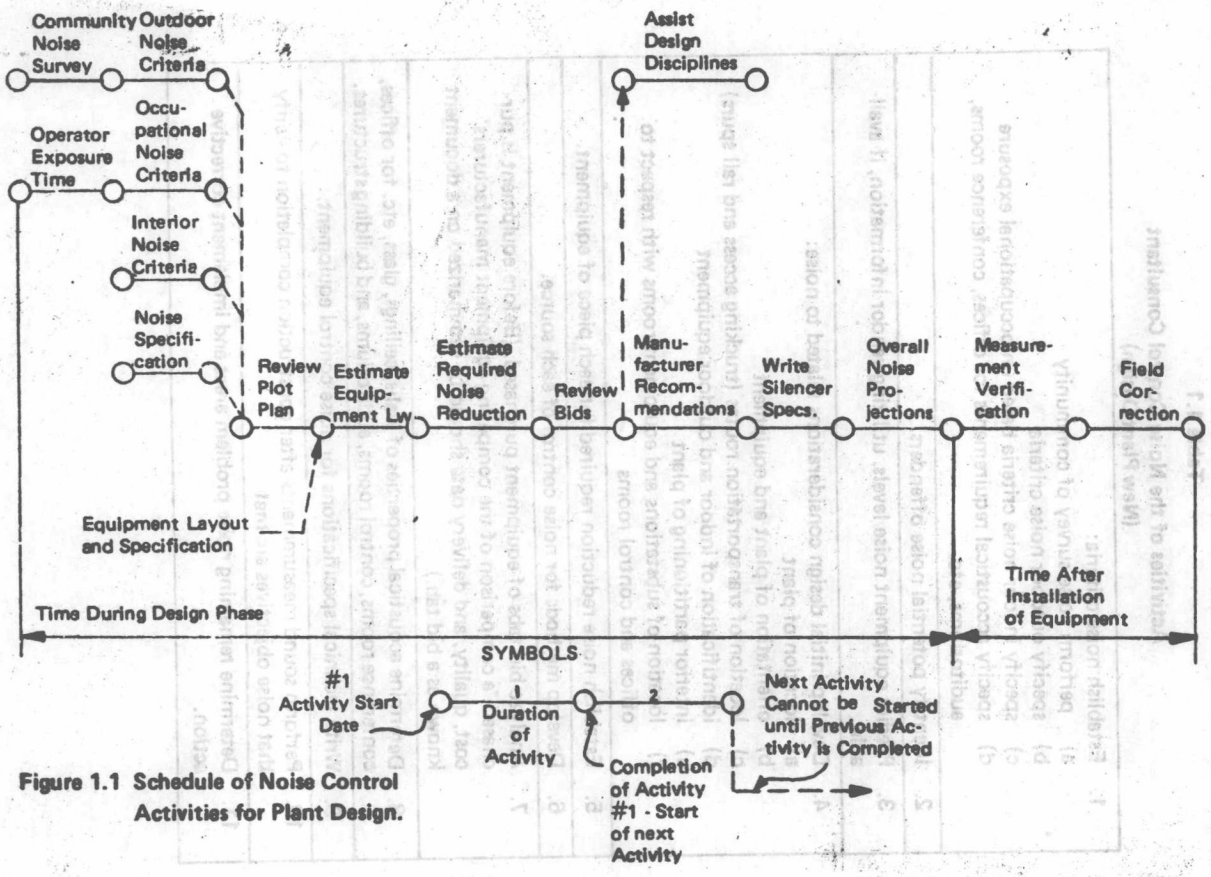

Figure 1.1 Schedule of Noise Control Activities for Plant Design.

Table 1.2
Estimating the Scope of Noise Control Activities

Establish Outdoor Noise Criteria (Excluding Noise Survey)	10-20 hrs
Estimate Operator Exposure Time at Each Area	10-20 hrs/area
Establish Occupational Noise Criteria	10-20 hrs
Establish Office, Auditorium, etc. Noise Criteria	10-20 hrs
Write Project Specification	10-20 hrs
Estimate Sound Levels of Equipment	1-2 hrs per noise source
Estimate Noise Reduction Required for Each Noise Offender	5-10 hrs per each type of noise offender
Review Bids	.5-1 hr per noise source
Compile Actual Noise Data	.5-1 hr per noise source
Write Silencing Specifications	10-20 hrs/specification
Analyze Bids & Purchase Silencing Equipment	10-20 hrs/specification
Prepare Overall Plant Summary	20-40 hrs
General Coordination Noise Control Group	10%-15% of Above Total
Field Measurements & Correction	40-80 hrs
Community Sound Survey by Noise Specialists	24-200 hrs

JOB SIMULATION EXPERIENCE

At the end of each chapter a Job Simulation Experience will be given. This experience will help you gain an overall view of the problems involved in noise control.

Job 1

The AJAX* Plant is comprised of several buildings, as illustrated in Figure 1.2. You are the noise consultant assigned to this

*The AJAX Plant is fictitious, but the principles that you will experience are not.

project. Based on the equipment specified, submit an estimate to the client of the direct engineering cost. Assume a unit rate of $30 per engineering hour, excluding the community sound survey. Use the low hour estimate of Table 1.2. The client will review your answers, and the expected analysis will follow each problem.

Potential Indoor Equipment Noise Offenders:

21 - 1800 RPM, 200 HP motors
1 - 3600 RPM, 125 HP motor
1 - compressor
1 - chiller
2 - control valves
100'- vacuum piping
2 - substations

Analysis

For each fan, pump, and cooling tower there is an associated motor. Both motor and driven equipment are potential noise offenders.

Number of Sources Outdoors (From Figure 1.2):

26 H & V fans and motors
1 forced draft fan and motor
2 pumps and motors
1 cooling tower and motor
4 vents
2 intake louvers
1 outdoor substation

Total outdoor potential noise sources:

$$(30 \times 2) + 4 + 2 + 1 = 67$$

Note: Each piece of driven equipment has an associated motor. Thus, the number of driven sources (fans, pumps, and cooling towers) is multiplied by 2.

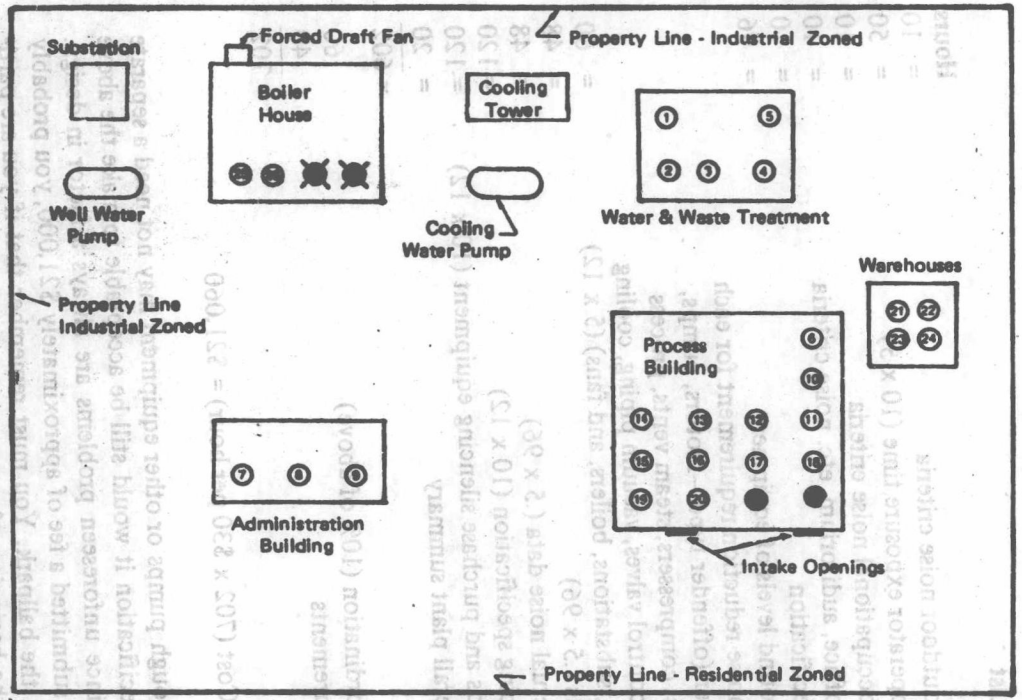

Figure 1.2 Plot Plan of AJAX Plant.

Since the number of indoor sources is given as 29, the total number of potential noise sources is 96.

Activity List

	Hours
Establish outdoor noise criteria	= 10
Estimate operator exposure time (10 x 5)	= 50
Establish occupational noise criteria	= 10
Establish office, auditorium, etc. noise criteria	= 10
Project specification	= 10
Estimate sound levels of equipment	= 96
Establish noise reduction requirement for each offender (offender types—motors, pumps, chillers, compressers, steam vents, process vents, control valves, vacuum piping, cooling towers, substations, boilers, and fans) (5 x 12)	= 60
Review bids (.5 x 96)	= 48
Compile actual noise data (.5 x 96)	= 48
Write silencing specification (10 x 12)	= 120
Analyze bids and purchase silencing equipment (10 x 12)	= 120
Prepare overall plant summary	= 20
	= 602
General coordination (10% of above)	60
Field measurements	40
	702

Consulting Cost (702 x $30 per hour) = $21,060

Even though pumps or other equipment may not need a separate silencing specification it would still be acceptable to make the above allowance since unforeseen problems are always a factor in design. Thus if you submitted a fee of approximately $21,000, you probably would be in the ballpark. You must remember that if you are participating at the beginning of a project, equipment is likely to change. The above allocation should account for normal design changes.