AN ABSTRACT OF THE THESIS OF

JOHN PATRICK HEALEY for the degree of MASTER OF SCIENCE

in HEALTH EDUCATION presented on March 7, 1979

Title: A COMPARISON OF NOISE ENVIRONMENTS BETWEEN OFFICES OF LANGTON HALL AND OTHER OFFICES ON THE OREGON STATE UNIVERSITY CAMPUS

Abstract approved: Redacted for Privacy

David C. Lawson

Purpose

The purpose of this investigation was twofold: 1) to determine if significant differences existed between noise measurements obtained from a sample of secretarial-type offices located throughout the Oregon State University campus and the group of secretarial-type offices located in Langton Hall; and 2) to determine if significant differences between subjective assessments of noise conditions existed between the group of secretaries employed in Langton Hall's offices and the group of secretaries employed in the sample of offices located throughout the O.S.U. campus.

Procedure

In this study, a previously tested questionnaire (5) was administered between the dates of May 23, 1978 and June 1, 1978 to S's in order to determine subjective assessments of noise conditons for both groups of offices. The control group, represented by employees in offices not exposed to noise sources originating from gymnasium

activity, were randomly selected from the population of offices located on the O.S.U. campus. Seven null hypotheses concerning subjective ratings of noise conditions and the effects of these conditions on work performance were tested for differences with the Fisher exact probability test.

Two additional null hypotheses concerning differences of measured sound levels were each tested by three different methods. These were:

1) Mean sound pressure ratios for offices of each group were analyzed for differences with the t test.
2) Equivalent A-weighted sound levels (L_{eq}s) for offices of each group were analyzed for differences with the Fisher exact probability test.
3) L_{10}'s, L_{50}'s, and L_{90}'s determined for each group were analyzed for differences with the Fisher exact probability test.

Conclusions

Subjects employed in offices of Langton Hall were found to rate significantly greater levels of noise "under the loudest conditions" than subjects employed in offices of the control group, while no significant differences were apparent from ratings of noise levels under "average" and "quietest" conditions. Also, no significant differences in "ability to use the telephone" under any conditions of noise were noted between the two groups. Langton employees reported that the "loudest noises" disturbed their work more frequently and identified the major source as intruding noise through the ceiling, a source virtually nonexistent in the other group of offices.

It was concluded from analysis of noise measurements, that during gymnasium activity periods, Langton Hall offices were subject to significantly greater levels of noise than were the offices of the control group.

A Comparison of Noise Environments Between Offices of Langton Hall and Other Offices on the Oregon State University Campus

by

John Patrick Healey

A THESIS

submitted to

Oregon State University

in partial fulfullment of
the requirements for the
degree of

MASTER OF SCIENCE

Completed March 7, 1979

Commencement June, 1979

APPROVED:

Redacted for Privacy

Professor of Health Education
in charge of major

Redacted for Privacy

Head of Department of Health Education

Redacted for Privacy

Dean of Education

Redacted for Privacy

Dean of Graduate School

Date thesis is presented March 7, 1979

Typed by CAMPUS PRINTING & COPY CENTER for

JOHN PATRICK HEALEY

TABLE OF CONTENTS

LIST OF TABLES

A COMPARISON OF NOISE ENVIRONMENTS BETWEEN OFFICES OF LANGTON HALL AND OTHER OFFICES ON THE OREGON STATE UNIVERSITY CAMPUS

I. INTRODUCTION

Langton Hall, a structure built in 1920 and located on the Oregon State University campus, houses classrooms, faculty and secretarial offices, a gymnasium, swimming pool, and various other athletic facilities for the School of Health and Physical Education. With the main gymnasium and two auxiliary gymnasiums situated above office and classroom spaces (see Appendix I), it was suspected that noise conditions generated from athletic activities may have adverse effects on the occupants of the rooms below these activities.

Statement of the Problem

The objective of this study was to investigate and determine possible differences of noise conditions between a group of offices in Langton Hall and a representative sample of offices located throughout the Oregon State University campus. To facilitate a comprehensive investigation of this problem, both subjective and objective measurements were obtained. Although the survey design employed here required numerous types of subjective ratings and physical measurements, the answers to only two questions were sought:

1) Are noise conditions, as measured by sound level instrumentation significantly greater in the

offices of Langton Hall than in other offices located throughout the O.S.U. campus?

2) Are office staff of Langton Hall's offices more annoyed by existing noise conditions than office staff employed in other offices located throughout the O.S.U. campus?

It is apparent from these questions that the study does not attempt to assess conditions nor the reactions to noise conditions in terms of preexisting standards. Rather, this type of comparative approach should provide results depicting a situation in which the severity of noise conditions in a designated environment exceeds those of other similar environments. The relationship, however, between previously published standards and the conditions determined from this investigation will be briefly discussed.

Need for the Study

A problem left virtually unattended in previous research and studies is the prioritization of noise condition severities within a related population of locations. These locations may be different job sites within an industrial plant, different classrooms within a school or school district, different sections of a library, etc. With noise receiving more recognition as a genuine element of environmental pollution, institutions of all types are starting to deal with the problem in a more affirmative manner. This phenomenon is realized in the increasing allocations of funds directed to noise abatement and control.

A frequent dilemma exists, however, when resources allocated for remedial action are insufficient to treat noise problems throughout the entire institution. Decisions must be made by administration or management that will insure optimum noise pollution relief without violating budget limitations.

It is hoped that this study can provide some insights for establishing allocation priorities relevant to noise abatement and control within institutions. While the investigative approach used here allows for assessment of noise conditions relative to recommended levels and established standards, a weakness of this approach is realized in the not infrequent situation in which most or all spaces in an institution exceed recommended levels. A particularly severe noise problem might then be dismissed as a necessary discomfort experienced by all occupants of the institution.

Several implications of this study may be of substantial value and deserve mentioning here.

1. Although inconclusive, a good indicator of prevailing conditions in O.S.U. offices should be provided by this study.
2. This study also offers a view of prevailing attitudes toward noise conditions throughout the campus.
3. Of particular interest, will be results concerning the identification of specific noise

sources. This aspect of the study alone may provide the means for establishing the appropriate direction of a noise abatement and control program.

Hypotheses

The null hypotheses to be tested are listed below. The relationship of the first seven hypotheses to the objectives of this study are discussed in the section titled "The Questionnaire" contained in this study. Hypotheses VIII and IX, concerning measured A-weighted sound levels, are discussed under the section titled "Acceptability Criteria for Office Noise" in the literature review.

I. Employees of Langton Hall's offices will not rate a significantly greater degree of noisiness under average noise conditions than employees from other campus offices.

II. Employees of Langton Hall's offices will not rate a significantly greater degree of noisiness under the loudest noise conditions than employees from other campus offices.

III. Noise ratings of quietest noise conditions will not differ significantly between employees of Langton Hall's offices and employees of other campus offices.

IV. Employees of Langton Hall's offices will not rate significantly greater difficulty using the telephone under average conditions of noise than employees of other campus offices.

V. Employees of Langton Hall's offices will not rate significantly greater difficulty using the telephone under loudest conditions of noise than employees of other campus offices.

VI. Employees of Langton Hall's offices will not attribute the cause of the loudest noises to "noises through the ceiling" more frequently than employees of other campus offices.

VII. Employees of Langton Hall's offices will not report a significantly greater frequency of work disturbance due to the loudest noises than employees of other campus offices.

VIII. During activity periods in Langton Hall's gymnasium, measured sound levels will not be significantly greater in Langton Hall's offices than in other campus offices.

IX. During non-activity periods in Langton Hall's gymnasium, measured sound levels will not differ significantly between Langton Hall's offices and other campus offices.

Limitations

Any generalizations and inferences made as a result of this study, took into consideration the following limitations:

1. This study included a sample of secretarial offices in operation during the period from May 24 to June 2, 1978. All data collection was carried out during this same period.
2. Noise conditions were measured in terms of A-weighted sound levels taken at ten-second intervals over a total period of five minutes for each office surveyed.
3. Subjects were specified as secretaries having been employed full-time in an Oregon State University campus office for not less than one month.
4. Attitudes toward office noise conditions were determined from a questionnaire originally constructed by Leo Beranek (5) and subsequently modified by this author to accomodate the specific objectives of the study at hand.

Assumptions

For the purpose of this study, the writer assumed the following:

1. The subjects responded honestly to the survey questionnaire and understood all questions included in it.
2. The times selected for testing of Langton Hall's offices were representative of typical

noise conditions during both activity and non-activity periods in the Langton Hall gymnasium.

3. The control group of offices was large enough to be representative of Oregon State University's campus offices.
4. The control group of subjects was large enough to be representative of Oregon State University's secretary population.

Definitions

For the purpose of clarity, the following definitions are provided for the present research study:

1. A-weighted sound level: "The ear does not respond equally to frequencies, but is less efficient at low and high frequencies than it is at medium or speech range frequencies. Thus, to obtain a single number representing the sound level of a noise containing a wide range of frequencies in a manner representative of the ear's response, it is necessary to reduce, or weight, the effects of the low and high frequencies. The resultant sound level is said to be A-weighted, and the units are dB." (38)
2. Athletic activities: In the context of this study, "athletic activities", also referred to as "activities", will refer to any scheduled or un-

unscheduled sports or games in progress on the Langton Hall gymnasium floor. These usually include; gymnastics, basketball, volleyball, badminton, rope jumping, and ballroom dancing.

3. dBA: A-weighted sound level.
4. Decibel: "One-tenth of a bel. Thus, the decibel is a unit of a level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power." (38)
5. Equivalent A-weighted sound level: Also referred to as L_{eq}, it "is the constant sound level that, in a given situation and time period, conveys the same sound energy as the actual time-varying A-weighted sound." (18)
6. L_{10} level: "The sound level exceeded 10 percent of the time period during which measurement was made." (38)
7. L_{50} level: "The sound level exceeded 50 percent of the time period during which measurement was made." (38)
8. L_{90} level: "The sound level exceeded 90 percent of the time period during which measurement was made." (38)
9. Masking: "The process by which the threshold of audibility for one sound is raised by the presence of another (masking) sound. The unit customarily used is the decibel." (38)

10. Objective measurements: Measurements of sound levels performed with a sound level meter.
11. Octave band: "The interval between two sounds having a basic frequency ratio of two. For example, there are 8 octaves on the keyboard of a standard piano." (38)
12. Sound level: "The A-weighted sound pressure level obtained by use of a sound level meter having a standard frequency-filter for attenuating part of the sound spectrum." (38)
13. Spectrum: "Of a sound wave, the description of its resolution into components, each of different frequency and (usually) different amplitude and phase." (38)
14. Speech intelligibility: "The ability to distinguish and understand speech signals." (38)
15. Subjective measurements: Sometimes referred to as "subjective assessments", are ratings of noise conditions in a designated environment that are based on a human observer's perceptions and attitudes.

CHAPTER II

REVIEW OF RELEVANT LITERATURE

Introduction

The purpose of this study was to determine whether the severity of noise conditions in offices of Langton Hall exceeded those of other offices located throughout the Oregon State University campus. A review of the literature related to this problem is contained in this chapter. Section one presents studies and literature concerned with the use of questionnaires in assessing relative noise conditions of different noise environments. The second section discusses various recommendations and suggestions for acceptable noise conditions. This discussion relates to objective measurements obtained for this study. The third portion is devoted to a review of literature related to room acoustics with special reference to the office environment. A subsequent section deals with the legal aspects of occupational noise with an emphasis on the noise sensitive occupations. The few statutes, regulations, and policies presently in existence that specifically concern noise in the office are also presented in this section. The last section discusses some of the findings concerning the relationships between noise and human performance that may be relevant to secretarial skills.

Subjective Noise Ratings

It has long been recognized that determination of noise acceptability based purely on physical measurements are often insufficient or inaccurate in reflecting the attitudes of those individuals who are actually exposed to the noise. While numerous studies have been carried out (56) in which subjective judgments are related to measurements of sound pressure levels and other physical parameters of sound, the state of the art has not progressed to the point in which noise surveys can rely exclusively on physical measurements. Aside from the intrinsic differences that exist from subject to subject, the complexities involved in obtaining a complete physical description of a given noise environment are often too cumbersome to determine and consequently, subjective responses are far from predictable. To illustrate this problem, a number of annoyance factors specific to the noise itself are presented here:

1. The intensity level and spectral characteristics of the noise.
2. The duration of the noise event.
3. The presence of discrete frequency components.
4. The presence of impulses.
5. The abruptness of onset or cessation of the noise. event.
6. Degree of harshness or roughness of the noise
7. Degree of intermittency in loudness, pitch, or rythm.

8. The information content. (38)

Even if it was technically possible to obtain measurements of all these factors through a routine procedure, the problem encountered in correlating each factor to a given type of subjective assessment would be unreasonable. "One obvious way of including all relevant factors is to test buildings and to use the occupants as noise makers, noise receivers, and noise evaluators, relying on properly conducted sociopsychological studies to reveal gradations of acceptability." (27)

The most commonly employed statistical techniques for validating the predictability of judged perceived noisiness based on units of physical measurement have been:

"(a) product moment coefficients of correlation between the physical measures and judgments; and

(b) a rank ordering of the average differences and average or standard deviation of these differences between the physical measures of noises that were judged to be subjectively equal." (22:319)

The former technique has provided the standard basis upon which office noise surveys are generally conducted. (23:29)

A direct questioning approach to evaluating the general bothersomeness of office noise was first proposed by Beranek. (3) A subsequent revision (6) employed a set of equal loudness contours modified from those suggested by Rosenblith and Stevens. (44) Beranek's (1956) published study of office noise has served as an initial validation for the use of questionnaires in assessing noise conditions. (5) Among the questions his investigation sought to answer was, "Do people agree with each other when they assess a noisy environment on a rating scale, and how do their ratings depend on the physical parameters of the noises?" (5)

His questionnaire was composed of 15 rating scales, administered to 190 office employees at 17 different office locations. Subjects were asked to rate desirable noise conditions, general noisiness perceived, and their ability to use the telephone and to communicate with fellow workers. Interference with telephone conversation was rated as the most frequently disturbed aspect of the job. "More than 2/3 of those questioned stated that speech communication was an essential part of their activities and that the more intense noises of their offices interferred with it." (5:833) Also, "a high correlation was found between perceived noiseness and the measure called "speech interference level" (SIL), which is the average of the sound pressure levels measured in the three octave bands between 600 and 4800 cycles per second." (5:833) The study also indicated that "...when asked to rate noises, office personnel in widely separated locations in different types of organizations have in mind nearly the same noise levels when they make their noise ratings." (5:844)

Following Beranek's initial studies in subjective noise rating, most research was directed to the elucidation of more suitable measurement criteria, while the improvement of questionnaires tended to be deemphasized. Eventually, Keighly (1966) tested his suspicion that the terminology and scaling in questionnaires, and individual differences in noise tolerance may have played a significant role in subjective assessments of noise. (19) In a study similar in methodology to that of Beranek's, Keighly tested three variations of question scaling for intercorrelations. These included: a four-point scale of noisiness, a six-point scale covering both noisiness and proportion of time, and a six-point scale of acceptability. He found that the two noisiness scales were highly intercorrelated while the acceptability scale was not closely related to either of the other scales. These results substantiated his argument that "...scaling procedures must be reoriented towards the direct measurement of acceptability of the noise climate rather than aiming at ever finer discriminations of loudness." (19:73)

Keighley's questionnaire was also designed to reveal individual differences in noise tolerance. "The results indicate that there are consistent individual differences in noise tolerance and these also play some part in determining the individual ratings." (19:73)

While the advantages of conducting investigations in the field rather than the laboratory have been generally appreciated, in some cases an experimentally controlled setting or noise source can yield information not otherwise obtainable. Induced noises, for example, allow the experimenter to control specific noise characteristics or to introduce a novel noise into a selected environment.

The value of this approach can be demonstrated in a study by Ward and Süedfeld (1973) in which recorded highway noises were played on a university campus for the purpose of predicting the impact of a proposed highway near this site. Students were urged to respond to a questionnaire that "...concentrated on subjective reactions to the induced sound and on comparisons between cognitive and emotional responsivity to the experimental as compared to the normal sound levels." (50:311)

In a similar study, students were exposed to induced aircraft noise during a lecture. (37) While an annoyance rating scale provided results that were generally consistent with other surveys, additional information concerning short-term acclimatization was also obtained.

Mariner (1964) studied subjective responses to impact noise through ceilings in a laboratory setting. (27) Measurements of impact noises induced by both human feet and a standard tapping machine were found to have good agreement with subjective ratings of loudness. "However, because the psychology of the laboratory is different from that of the apartment house, this element of the test needs seriousness attention by psychoacousticians." (27:54)

The Federal Housing Administration has since determined that the ISO tapping machine used for impact sound simulation does not actually simulate footsteps. (33)

The disparity between laboratory and field results as has been evidenced through studies incorporating subjectivity, has been succinctly addressed in the statement by Mariner (1964):

> "Certainly no synthetic test which replaces people with devices and analytical procedures can have general validity just by happy coincidence." (27)

Acceptability Criteria for Office Noise

"The highest level of noise within a building that neither disturbs its occupants nor impairs its acoustics is called the acceptable noise level." (16) Although these recommended values are generally the result of judgments on the part of researchers, they are based to a great extent on such factors as speech intelligibility and subjective judgments by space occupants.

Before inspecting the criteria that have been proposed for acceptable noise conditions in the office environment, it would be appropriate to briefly review the history and development of various physical measures used in this area of research.

Early studies of annoyance-related noise relied primarily on theoretically derived measurement criteria. Researchers tended to emphasize the importance of spectral characteristics, and thus constructed types of physical measures that would specify sound pressures within different frequency bands. In this approach, equal loudness levels are specified for each octave band, thus determining a contour that reflects a relationship between frequency and a subjective assessment of sound intensity. A series of these equal loudness contours should signify level rank of general acceptability. (22)

These curves took on a number of revisions as information accumulated concerning the spectral determinants of acceptability. Beranek recommended (3) and later published (6) a set of "noise criteria" (NC) curves specifically designed to assess office noise. In his method, the highest loudness level determined from spectrum analysis that is tangent to or exceeds a contour, determines the NC rating for the combined frequencies. Some of the subsequent revisions and modifications of this closest tangent-octave-band method have included the Level Rank, SC, PNC, NCA, and NR methods which are frequently encountered throughout the literature. (22)

Young (1964) analyzed the results of Beranek's (1956) correlations (5) between subjective ratings and NC measurements. (57) While Beranek obtained reasonably good correlations using tedious spectral analysis techniques, Young found that, "since subjective ratings of office noise appear to be correlated with the A-sound level as well or better than with other commonly known noise ratings, and since the A-sound level can be measured readily with widely available meters, it is recommended as a replacement for the NC level in single-number specifications for office use." (57) Based on this finding, most current publications designate acceptability criteria in terms of dBA levels.

Published acceptability criteria find their most common application in accoustical design. Two design schemes are in popular use today; the "categorization scheme", and the "acceptable-level scheme". (20) The categorization scheme" designates recommended average transmission loss (TL) between two points in terms of decibels. Criteria designated through the acceptable level scheme are merely recommended average acceptable noise levels, usually indicated in dBA's.

In designing a private office in which "there is no apparent awareness of speech privacy as a problem", Cavanaugh, et. al. (1962) have recommended "a minimum TL of 35 db". (10)

When considering guidelines for acceptable noise levels, the types of activities generally occuring in the office should be taken into account. It was found, for example, that employees who operated office machines were less concerned about noise levels than clerical workers. (23) Authors have addressed this problem by making distinctions for various types of offices when publishing suggested acceptable noise levels.

A typical acceptable-level scheme is that offered by Beranek (1957):

private office large conference office	25-35 dBA
medium office	40-45 dBA
drafting rooms typing pools accounting areas	55-60 dBA

(6)

Thirteen recommended acceptable noise levels since 1950 are presented in Table 1. (18) Although fluctuations from author to author are evident, it should be noted that no directional shift has prevailed throughout the years.

Unfortunately, the architect or acoustical consultant may not have direct control over the noise generating characteristics of certain products and physical plant systems introduced into the office environment. While it has been difficult to legally mandate acceptable noise levels for many products, design goals for manufacturers are available throughout the literature. (32)

Recommended acceptable levels for air-conditioning systems, for example, have been specified for several types of offices. (52) Performance goals also exist for screens used in open-plan offices. (48)

From the reported studies, it is evident that specification of precise values within which noise levels are acceptable is a virtual impossiblity. Also, the fact that acoustical solutions exist, while a minimal percentage of offices presently meet recommended standards (20), suggests the need for improvement and enforcement of design codes and regulations.

Office Acoustics

It has been repeatedly suggested throughout the literature that one of the most annoying and distracting sounds in offices is the presence of intruding speech within the room or through the walls from adjacent rooms. (10) "When the occupants of an office or other space are reasonably well protected against intelligible speech originating from an adjacent or nearby area of the same room and has [sic] the assurance that he is not being overheard, he is said to have acoustical privacy or speech privacy." (14)

Table 1. Prior recommendations of acceptable noise levels for offices.*

		Private Office	General Office
Knudsen-Harris 1950	(20)	40-45 dB(A)	45-55 dB(A)
Beranek 1953	(4)	50 dB(A)	—
Beranek 1957	(6)	30-45 dB(A)	40-55 dB(A)
Lawrence 1962	(24)	35-45 dB(A)	40-60 dB(A)
Kosten-van Os 1962	(21)	30-45 dB(A)	60 dB(A)
ASHRAE 1967	(1)	25-45 dB(A)	35-65 dB(A)
Denisov 1970	(13)	40-45 dB(A)	50-60 dB(A)
Kryter 1970	(22)	35 dB(A)	35-40 dB(A)
USSR 1971	(45)	—	50 dB(A)
Beranek 1971	(7)	38-47 dB(A)	42-52 dB(A)
Doelle 1972	(14)	30-45 dB(A)	45-55 dB(A)
Wood 1972	(55)	40-45 dB(A)	45-55 dB(A)
Rettinger 1973	(41)	46 dB(A)	50 dB(A)

* Adapted from (18)

Spalding (1976) itemized seven major factors that he found to influence speech privacy in small offices. They are:

1. The intensity and quality of the speaker's voice.
2. Orientation of the speaker.
3. The airborne sound-transmission loss, or "attenuation factor" of ceilings.
5. The intensity and quality of masking sound.
6. The sound-absorbing qualities of room surfaces.
7. Size of the office. (48)

Methods usually employed in attaining acoustical privacy involve the installation of an integrated system of screens, carpeting, drapes, sound absorbing ceilings, and background masking noise equipment. (11)

One of the most important factors in interzone attenuation of noise is the use of screens or light partitions. Research has revealed that a critical feature of partition effectiveness is its distance from the floor. (48) Ideally, the partition should be brought as close to the floor as possible. Distances between partitions and ceilings are not nearly as important.

Concerning the ceiling plane, Spalding (1976) found that "the size and number of light lenses, and absorption characteristics of the ceiling board, and the configuration of the ceiling whether flat, vaulted, or baffled - all play a crucial role." (48) It has been suggested that the sound absorption efficiency of a ceiling is more dependent on the material used than its architectural form. (11) Successful treatments of existing ceilings, however, usually incorporate both architectural modifications and the introduction of sound absorbing materials. (17)

Acoustical research has yielded specifications for the design and construction of draperies that will successfully absorb noise while allowing for adequate translucency. (17)

"Walls, partitions and columns should be covered with sound absorptive materials such as fabricated or vinyl-covered perforated glass fiber panels." (17)

Floor carpeting has been generally accepted as a means of attenuating airborne noise (14,24), however, it is probable that the sound absorbing characteristics of the floor are less significant than those of other surfaces in the office. (48)

"Structureborne transmission is particularly important in the case of floors, since many impact sounds originate here." (24:81) Wood-joist constructions, such as the type found in Langton Hall, may be effective in controlling airborne sound, but they are poor for impact noise control. (25)

In reference to noise control in the office, the U.S. Department of Commerce has stated that "installing an acoustical ceiling, draperies, and thick carpeting will lower the noise level approximately 5 to 8 dB (or approximately 1/4 to 1/2 in loudness)." (30)

When adequate acoustical designs allow undesirable noises to interfere with desired sounds, a solution can often be found in masking techniques. "A masking sound - which can be anything from the noise produced by air-conditioning to piped-in, soft music - produces a moderate unobjectionable noise. It raises the overall "comfortable" noise level to the point of covering distracting sounds." (11)

Aside from speech intrusion, the most prevalent source of noise in an office environment is that generated by typing. Schirmer and Biehn (1969) studied the variations of typewriter noise relative to typing style, typing speed, and the type of machine used (portable or office machine). (17) They found that "the type of stroke and the speed play an important role in the measurement." (17) Several recommendations were offered for dealing with typewriter noise, but damping by means of a plastic and metal casing was found to provide the best solution.

Legal Aspects of Occupational Noise

Legal specifications for acceptable levels of noise in the office are virtually nonexistant in federal, state, or local statutes. Instead, legislative emphasis has been directed toward those occupations in which extremes of noise exposures pose a potential or immediate threat to physical health. (43) Noise levels commonly found in offices would seldom qualify as "physically damaging". Psychological effects, however, rarely constitute legal grounds for compensation or remedial action due to the difficulties involved in ascribing noise as the cause. "From a legal standpoint, annoyance per se is not a legal concept. Annoyance expresses the human response or results, not its cause." (18:7)

The first federal safety regulation on industrial noise exposure was introduced in 1967 as an amendment of the Walsh-Healey Public

Contracts Act of 1938. (12) This applied only to companies contracted with the federal government for at least $10,000. In 1970, the same occupational noise standards were included under the Occupational Safety and Health Administration for industries engaged in interstate commerce. (39) Table 2 presents OSHA's 1975 revision of permissible noise exposures.

Table 2. OSHA Permissible Noise Levels

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼	115 (39)

It is readily apparent that these levels exceed what would be considered acceptable in the office environment and other noise sensitive areas.

Congress responded to this inadequacy of OSHA's noise standards with the Noise Pollution and Abatement Act of 1970, and the Noise Pollution and Abatement Act of 1972. (40) The Noise Pollution and Abatement Act of 1970 required the Environmental Protection Agency to conduct comprehensive research into environmental noise pollution. Among the many provisions of the Noise Control Act of 1972 is the responsibility of the EPA to research and publish "information on the levels of environmental noise and the attainment and maintainance of which defined areas under various conditions are requisite to protect the public health and welfare with an adequate margin of safety." (40,18)

"Health and welfare" has been interpreted by the EPA to include "personal comfort and well-being and the absence of mental anguish and annoyance." (18:7) This act clearly states that adoption of ordinances is left to the states and localities. Thus, the primary purpose of EPA publications is to provide guidelines for state and local lawmakers. Furthermore, EPA's Model Community Noise Ordinance states that "any sound which...annoys or disturbs a reasonable person of normal sensitivities" constitutes a "noise disturbance". (43)

The International Labor Office has addressed the problem of establishing regulatory laws for noise sensitive occupations in their publication of suggested guidelines. (38) Of particular relevance to the office environment are their suggestions concerning oral communications, fatigue, and comfort:

"3.3.2. Consideration should be given to defining the maximum distance at which speech intelligibility is preserved at normal voice loudness." (38:18)

"3.4.2. Maximum noise levels should be established as necessary, with due regard to the work performed." (38:19)

"4.6.1. (2) The noise levels laid down should be such that work can proceed normally with a minimum of fatigue and discomfort." (38:23)

An indirect, yet often effective means of restricting noise levels for noise sensitive areas and occupations is to impose acoustical standards for certain types of buildings. The Department of Housing and Urban Development, for example, has established acceptable acoustical environments for construction and renovation of buildings under its funding. (12) Similiarly, the Federal Housing Administration released Bulletin No. 750, "Impact Noise in Multi-family Dwellings." (12)

Acoustical standards have been established by the General Services Administration for buildings purchased or constructed by the federal government and used for office space. (28) For this purpose they have introduced a single number rating, the Speech Privacy Potential (SPP), which measures the level of speech privacy between given distances. Test Methods PBS C.1 and PBS C.2 describe the SPP concept and the techniques for determining acceptable acoustical designs for office space. Test Method PBS C.1 calls for the subjective judgment of a jury of human observers. Verification of SPP levels is based on objective measures described in Test Method PBS C.2. Should objective measures fall within prescribed levels, there is no need to apply PBS C.1.

The Noise Control Act of 1972 has prescribed local autonomy in setting standards for ambient community noise. (40) To this date, however, only a few states have taken this initiative. (48) Oregon was one of the first states to enact a land use regulation specifying acceptable noise levels. (31) This regulation applies to all private property land usage and includes operation of all motor vehicles. Maximum continuous noise levels have been specified for day (L_d), and night (L_n), at 60 dBA and 55 dBA, respectively.

The Worker's Compensation Laws of Oregon, and the Oregon Safe Employment Act, contained in Oregon's Revised Statutes (1977) make no specific reference to noise in the occupational environment. (56) The Oregon Safe Employment Act does, however, "assure that Oregon assumes fullest responsibility, in accord with the federal Occupational Safety and Health Act of 1970 (Public Law 91-596), for the development, administration and enforcement of safety and health standards." (39) Enforcement of OSHA noise standards then, represents the minimum responsibility the state has with regard to occupational noise.

The Worker's Compensation Department of Oregon has specified rules concerning acceptable exposures and proper safety and health practices in a separate publication entitled "The Series 22 Health Compliance Regulations". (46) Although the state of Oregon is empowered to elaborate on federal standards, the state regulations concerning occupational noise exposures are identical to those of OSHA. This implies that an employee in the state of Oregon has no legal protection against noises that produce annoyance other than common law.

The Oregon State Legislature has recognized certain inadequacies of the OSHA standards as is evidenced in ORS 467.010 to ORS 467.990. While OSHA has restricted its regulations to protecting the worker from physical impairment and injury, Oregon's state statutes also cite the objective of providing "protection of the health, safety and welfare of Oregon citizens from the hazards and deteriorization of the quality of life imposed by excessive noise emissions...". (34) The Environmental Quality Commission of Oregon has been given the authority "to adopt reasonable state-wide standards for noise emissions permitted within (the) state and to implement and enforce compliance with such standards." (34) This commission has also been empowered to investigate and make rulings on citizen's complaints of excessive noise emissions. (35)

Publications that may answer questions concerning legal recources are obtainable through the EPA Office of Public Affairs (Washington, D.C. 20460).

Effects of Noise on Work Performance

Because of the difficulties encountered in controlling experimental investigations in the office work environment, most research concerned with the effects of noise on human performance has been conducted in laboratory-type settings. An early review of published articles in this area by Kryter indicated that "...noise per se does not appear to reduce nonauditory work productivity in the factory and office, it even improves some performance by apparently isolating the person from being interrupted by certain distracting auditory signals or speech." (22:578)

In view of the more recent contradictory studies, this may have been an oversimplification of the relationship. Broadbent and Little

(1960) studied the effects of noise reduction on the numbers of broken rolls of film and equipment shutdowns caused by workers in a film factory. (9) While worker performance improved, it was also noted that the performance of workers in the control group improved. This prevailing trend was attributed to a general improvement of morale, possibly caused by the Hawthorne effect.

In a similiar study by Almeida (1950), absenteeism among electric punch card operators was observed to decrease when noise levels were reduced. (2)

Conversely, an experimental design in which noise levels were increased, showed an increase of mail sorting errors caused by postal workers. (22:580)

Laboratory settings have assisted the researcher in controlling and observing specific dimensions of the noise and the task. Task complexity has received wide attention as a critical feature determining the extent to which performance may be effected.

Warner and Heimstra (1971) tested the effects of intermittent noise on visual search tasks of varying complexity and found that performance was more dependent on task complexity than on the noise schemes. (51) Inconsistent results for performance of low complexity tasks with varying noise schemes were attributed to unused perceptual capacities of the subjects.

Boggs and Simon (1968) addressed this contradictory evidence by pairing tasks of different complexity levels and determining which suffered more errors. (8) Their investigation supported the contention that a decrement in performance will be evident only if task complexity exceeds a certain minimum level.

Woodhead (1966) found that task preference played a substantial role in determining relative effects of noise on two simultaneously performed tasks. (54)

The effects of occupational impact noise on the precision and speed of unguided hand movement were studied by Pecenka (1976). General results of this study indicated that, "with rising intensity of noise there was a higher mean of errors in the unguided hand motions performed." (36) The particular task employed in this research resembled typing in many of its perceptual and motor skills demands.

Weinstein (1974) examined the effects of noise on the proofreading skills of 33 college students. (53) He found that increased noise intensity caused a decrease in recognition of both spelling and grammar errors. A decidedly greater effect on the recognition of grammar errors was explained in terms of its relatively greater complexity.

Of particular concern in this present research are the effects of low level noise on noise sensitive occupations The EPA has stated that, "Noise levels of less than 90 dBA can be disruptive, especially if they have predominantly high frequency components, are intermittent, unexpected, or uncontrollable." (38)

Considering the numerous task dimensions involved in the secretarial-type occupations, it would be exceedingly difficult to predict a general influence of noise on job performance. A more practical consideration might be the attitudes expressed by office employees.

III. RESEARCH PROCEDURES

Population and Sample

The procedure used for selection of subjects and offices in this study has both random and nonrandom components. Elements of the office population considered here must have met all of the following criteria:

1. Must be located on the Oregon State University campus proper.
2. Must serve as a regular workplace for secretarial staff.
3. Must have at least one full-time employee working in a secretarial capacity.
4. Must be a departmental, sub-departmental, school, or college office where secretarial duties are usually related to academic curriculum.
5. May not be located in the administration building.

Within Langton Hall there are seven offices that meet these criteria. All seven have been incorporated into this study and constituted the experimental group. Due to the small number of offices in this group, it was essential that all of these were investigated in order to minimize possibilities of sampling error. Twelve offices, composing the control group, were randomly selected from a pool of 92 offices that also met these criteria. The pool of offices was listed alphabetically according to name, and then numbered in this sequence. A sample was then drawn with the use of a table of random numbers. (26:513) Locations of these offices and Langton Hall are illustrated in Appendix II.

Subjects consisted of those individuals employed on a full-time basis as secretaries in the offices selected for study. A total of 24 secretaries served as subjects and they comprised two groups; Langton Hall secretaries, the experimental subjects (Sec. Gp. L), and secretaries from other campus offices, the control subjects (Sec. Gp. C). Each office provided either one or two subjects. Secretaries who had not been employed in their present location for at least one month were eliminated from the study due to an insufficient acclimatization period. The occupational title of "secretary" has been used here to include all office personnel involved at least part of their working day in functions such as typing, telephone answering, and operation of office equipment. This would, therefore, include questionnaire respondents who indicated job titles such as "clerical assistant" or "administrative assistant".

The date and time of each testing session was randomized within the limitations posed by the experimental design. Due to the two conditions under which dBA levels were to be measured in Langton Hall, two groups of one-hour time blocks were determined from the gymnasium activity schedule. One group consisted of control time blocks during which no activities were occuring in the gymnasium. The experimental group of time blocks represented activity periods. Within each group of time blocks, however, the date and time of testing each office was randomized by means of a table of random numbers. (26:513)

From Langton Hall's seven offices, eight subjects responded to the survey. The twelve offices of the other group produced a total of seventeen control subjects, one of which was eliminated from the study due to incompletion of the questionnaire. This was the only case of subject attrition.

In two instances, it was not possible to survey offices and their subjects at the times indicated by the randomized sampling schedule. It was suspected that postponement of the survey would allow for the possibility of an interaction between an initial and secondary meeting with the subjects. For this reason, alternate offices were randomly selected from the remaining pool. No attrition incidents of this nature were encountered for Langton Hall.

All subjects were female, and their ages ranked from 22 to 60 years. Length of employment ranged from one month to ten years. For each of the two groups, distribution of subjects by age and length of employment are given in Table 3.

In order to assure the anonymity and safety of subjects used in this study, a description of the research procedures has been reviewed by Oregon State University's Committee for Protection of Human Subjects. The note of approval is contained in Appendix VI.

Table 3. Distribution of subjects in Sec. Gp. L and Sec. Gp. C relative to ranked age and ranked length of employment.

Sec. Gp.	Ranked ages
C	60
L	60
L	54
C	52
C	52
L	51
C	50
C	46
C	44
C	41
C	37
C	36
C	36
L	29
C	28
C	27
C	25
L	23
L	23
L	23
C	23
C	22
C	22
L	22

Sec. Gp.	Ranked length of employment
L	120 months
C	72 "
L	72 "
C	72 "
C	72 "
C	60 "
C	48 "
L	36 "
C	36 "
L	30 "
C	30 "
C	24 "
L	24 "
C	24 "
L	20 "
C	18 "
C	12 "
L	11 "
C	9 "
C	9 "
C	8 "
C	2 "
C	1 "
C	1 "

The Questionnaire

The questionnaire used for this study is contained in its entirety in Appendix V. Of the 12 questions 11 are Likert-type scales, while the remaining question asks the subject to check the cause of the loudest noise source from a list of possibilities.

It was considered essential that a high correlation exist between subjective ratings and physical measurements of noise prior to administration of the questionnaire. Rather than constructing a questionnaire and testing it for validity and reliability before administration to S's, a questionniare designed specifically for subjective noise environment rating was selected from a study by Leo L. Beranek. (5)

Each question was statistically tested by Beranek for rank-order correlations between ratings of noise conditions and various physical measurement criteria. Of particular interest in this respect is question #4. This question asks for a rating of the noise at the time the subject is filling out the form. At this same time, the researcher is recording physical measurements of sound levels used for determining correlation coefficients with questionnaire responses to Item #4. Beranek obtained a rank-order correlation coefficient of about 0.85 using speech interference levels as measurement criteria. This correlation coefficient was increased to 0.95 when he used loudness levels in phons instead of speech interference levels. Interpretation of the answers to Item #4, however, are based on the corresponding answers to questions #1,

#2, and #3. If, for example, the subject rates "noise at this instant" midway between "average" and "loudest", then the answer assigned to #4 would be halfway between the answers to questions #1 and #2.

It must be borne in mind that a critical element in implementing a previously tested or standardized survey is the continuity and general order of questions. Question interaction, may to a large extent, be dependent on the order in which they are presented. Hence, the order found in Beranek's questionnaire was maintained in this study in spite of the necessary inclusion of some questions not relevant to the specific objectives of this study.

Beranek suggests several revisions for his questionnaire, most of which involve scale length and adjectival cues. These were all employed in the construction of the questionnaire used in this study.

Questions #1 and #2 relate to hypotheses I and II, respectively. Question #3 asks the subject to rate noise levels under the quietest conditions. It had been anticipated that under the quietest conditions in Langton Hall, the noise source of major concern, gymnasium activity, would not be present. With this source eliminated, it could be further speculated that the remaining sources of noise in Langton Hall offices would be reasonably similiar to those found in other office environments throughout the campus. For this reason, it had been anticipated that no significant differences of noise ratings for quietest conditions would result. Retention of this null hypothesis would support the contention that noise generated from gymnasium activity is a significant addition to ambient office noises. Identification of this source as a problem not generally found in other office environments could be further substantiated by answers to question #11. This item will be statistically treated to determine any significant differences in the frequency of identifying "noise through the ceiling" as the loudest source of noise.

Questions #5, #8, #9, and #10 were included to maintain the continuity of Beranek's original survey and to indicate a given subject's qualifications for answering certain questions validly. A subject, for example, who indicated extreme infrequent use of the telephone would be eliminated from the results of her answers concerning ability to use the telephone under different noise conditions. Similiarly, questions #9 and #10, concerning hearing ability and sensitivity to noise, were used to screen subjects who were either extremely hard of hearing or insensitive to noise.

Information concerning disturbance of work was obtained from questions #6, #7, and #12. Each of these questions relates to specific hypotheses.

The continuous scales employed in this study were arbitrarily subdivided into 170 increments of 1mm each. Ratings were recorded as the distance between the marked point on the scale and the furthest point on the left. This distance has been expressed in centimeters.

Instrumentation

The instrument selected for sound level measurement was the General Radio 1982 Precision Sound-Level Meter. While certain treatments of sound level measurements require the use of recording instrumentation, the approach used here, as well as the nature or the noise sources, made this unnecessary. Also, because the methodology of this study has been modeled after previously published studies that implement portable precision sound level meters, (5,57) the selection of instrumentation here was deemed appropriate by virtue of reproducability.

Consistent with the advantages of reproducability, the Environmental Protection Agency's Office of Noise Abatement and Control (18) has stated that the equipment should be commercially available as is the GR 1982.

Concerning functional characteristics and qualitative standards of the sound level meter, the GR 1982 meets or exceeds all those specified by the Occupational Safety and Health Act. (39) Some of the more pertinent instrument specifications are listed here:

1. Microphone: 1/2-inch Electret-Condenser Microphone with flat random incidence response, mounted with detachable preamplifier (GR 1981-4000) that plugs

into nose of instrument. Input impedance; approximately $2G\Omega // < 3pF$'

2. Calibration: Field calibration performed with the GR 1562-A Sound-Level Calibrator according to specifications provided in calibrator manual.
3. Frequency response: A, B, and C weighting; 10 octave band filters ranging in center frequency from 31.5 Hz to 16 kHz.
4. Display: Meter with three inch scale marked in 1-dB increments, four ranges: 30-80 dB, 50-100 dB, 70-120 dB, 90-140 dB. Also, 4-digit LED display with 0.1-dB resolution. Direct reading on all ranges. Present digital reading can be "captured" by pushbutton.

Data Collection

The time and date of data collection for individual offices were determined through randomization techniques. An attempt was made to commence survey procedures for each office on the hour in order to minimize variations of noise caused by hourly cycles of student foot-traffic.

Upon entering the office, the researcher identified himself and briefly explained the purpose of the survey. Details concerning comparisons to be made with other offices were not revealed. Although it is considered good practice in conducting these types of surveys to consult the office supervisor before approaching

S's, this was not done in this study. It was suspected that consulting a supervisor might increase the possibility of office staff interaction prior to administration of the questionnaire. In the event that a secretary or office supervisor requested further details or evidence of authorization, they were presented with a note signed by the Director of Safety for O.S.U. that sanctioned and briefly explained the purpose of the survey. This note is contained in Appendix VII.

Each of the personnel of all offices was administered the three-page questionnaire. The total time necessary to complete the form ranged from about 4 to 6 minutes. While S's were completing these questionnaires, A-weighted sound levels were recorded every ten seconds for a total period of 5 minutes.

All measurements of A-weighted sound levels were performed with the same sound level meter. The meter was calibrated according to catalogue specifications prior to each measurement session and also checked for calibration drift following each session.

Analysis of the Data

The Questionnaire:

Rating scales of the type used in this study are "ordinal" scales. Unlike "equidistant-interval" scales, equal intervals along an ordinal scale do not necessarily indicate equal differences in magnitude. It is, however possible to derive relative magnitudes for the responses to the questionnaire. Consistent with these observations is the fact that an arithmetic average will not legitimately reflect the central tendency for subjective scaling of this type. Rather, it is necessary to use the median which has the additional advantage of minimizing the statistical significance of unreasonably extreme deviations.

The Fisher exact probability test was selected as the most appropriate instrument for determining significant differences between the two independent samples. This test is based on exact probabilities and unlike the chi-square test, it may be used with very small samples. (47:114) Two-by-two bivariate frequency tables were used with median values determining the dichotomies. In effect, responses were regarded as being in a group either above or below the median.

In the case of question #11 which calls for identification of the loudest noise source, responses of "d" and all responses other than "d" constituted the dichotomy.

Rejection or retention of null hypotheses I, II, III, IV, V, VI, and VII was determined from analysis of questions #1, #2, #3, #6, #7, #11, and #12, respectively.

A-Weighted Sound Level Measurements:

Raw data obtained from noise measurements were in the form of A-weighted sound levels (dBA's). It must be recalled that "the decibel is a unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power". (38) From this relationship between sound level and power, a relationship between sound level and pressure of intensity can be derived.

dB (sound level) = 10 $\log_{10}X^2$, where X^2 is a ratio of the observed sound power to a reference sound power.

This can be further simplified to;

dB (sound level) = 20 $\log_{10}X$, where X is a ratio of the observed sound pressure to a reference sound pressure.

As these equations illustrate, sound levels are of an ordinal nature, while sound pressure ratios may be scaled in equidistant intervals. Also, of prime importance to this study, is the fact that sound pressure is analogous to loudness which in turn is a descriptor of how sound is perceived as a sensory experience.

All dBA readings were converted to pressure ratios to accomodate parametric treatment. For each room tested, an arithmetic average (the mean) of the pressure ratios was determined. The t test was then used to determine differences between mean pressure-ratios for the two groups of offices.

It was also decided to confirm the t test results by treatment the data with the non-parametric Fisher exact probability test. This allowed for the conversion of all mean pressure ratios to A-weighted sound levels which, by definition, are the equivalent A-weighted sound levels (L_{eq}'s). (18) Because the

EPA, as well as other authors have "considered (the equivalent A-weighted sound level) the best measure of the magnitude of environmental noise..", (18) it was deemed appropriate to incorporate this measure into the data analysis.

While the EPA has itemized a number of advantages for adopting the L_{eq} as a standard measure, it still fails to explicitly reflect the temporal aspects of noise. For this purpose, the noise levels were also specified in terms of sound pressure levels exceeded 10 percent of the time, 50 percent of the time, and 90 percent of the time. These measures are expressed as L_{10}'s, L_{50}'s, and L_{90}'s, respectively. Differences between the two samples for each of these measures was determined through the Fisher exact probability test.

In summary, hypotheses VIII and IX were tested for differences in averages by both parametric and non-parametric techniques. Also, differences in the temporal characteristics of measured noises were determined by non-parametric methods.

IV. ANALYSIS OF THE DATA

Introduction

The objective of this study was to compare noise conditions in the offices of Langton Hall to noise conditions in a random sample of offices located on the Oregon State University campus. These comparisons were based on both subjective and objective measurements. The first seven null hypotheses presented in this chapter are based exclusively on subjective measurements and were each analyzed with the Fisher exact probability test. Exact probability values, rather than tabular values, have been determined for each hypothesis tested with this non-parametric instrument. Distributions of subjective ratings relative to medians are presented here in the form of two-by-two bivariate frequency tables.

Hypotheses VIII and IX, relating to objective measurements, are each tested for differences of; 1) mean sound pressure ratios, 2) equivalent A-weighted sound levels, 3) L_{10}'s, 4) L_{50}'s, and 5) L_{90}'s. The t test for two independent samples is used to compare mean sound-pressure ratios. The remaining measurements are all treated with the Fisher exact probability test.

A 0.05 level of significance has been selected as a basis for retaining or rejecting the null hypotheses.

A summary of subjective and objective data is contained in Appendices III and IV, respectively.

Symbols and terms used in the presentation of this data are:

Sec. Gp. L = The group of subjects employed as secretaries in Langton Hall.

Sec. Gp. C = The group of subjects employed as secretaries in a randomly selected group of offices on the Oregon State University campus.

Off. Gp. L = The group of secretarial offices located in Langton Hall.

Off. Gp. C = The randomly selected sample of secretarial offices located on the Oregon State University campus.

Null Hypothesis I

Employees of Langton Hall's offices will not rate a significantly greater degree of noisiness under average noise conditions than employees from other campus offices.

Null hypothesis I was retained. No significantly greater degree of noisiness under average conditions was reported by employees of Langton Hall's offices. Analysis of distribution data is presented in Table 4.

Table 4. Bivariate frequency distribution for subjective ratings of noise under average conditions.

	below median	above median	
Sec. Gp. L	3	5	8
Sec. Gp. C	9	7	16
	12	12	24

p = 0.33

Null Hypothesis II

Employees of Langton Hall's offices will not rate a significantly greater degree of noisiness under the loudest noise conditions than employees from other campus offices.

Null Hypothesis II was rejected. The Fisher exact probability test indicated that significant differences existed for rating distributions of noisiness under the loudest conditions between the two groups of subjects.

Table 5. Bivariate frequency distribution for subjective ratings of noise under loudest conditions.

	below median	above median	
Sec. Gp. L	1	7	7
Sec. Gp. C	11	6	17
	12	12	24

p = 0.03

Null Hypothesis III

Noise ratings of quietest noise conditions will not differ significantly between employees of Langton Hall's offices and employees of other campus offices.

Null hypothesis III was retained. The Fisher exact probability test was used in determining a two-tailed probability level. No significant difference was indicated for ratings of noisiness under the quietest conditions.

Table 6. Bivariate frequency distribution for subjective ratings of noise under quietest conditions.

	below median	above median	
Sec. Gp. L	3	5	8
Sec. Gp. C	9	7	16
	12	12	24

$p = 0.66$

Null Hypothesis IV

Employees of Langton Hall's offices will not rate significantly greater difficulty in using the telephone under average conditions of noise than employees of other campus offices.

Null hypothesis IV was retained. As is apparent from Table 7, rating distributions relative to the median were identical between the two groups of subjects.

Table 7. Bivariate frequency distribution for subjective ratings of ability to use the telephone under average noise conditions.

	below median	above median	
Sec. Gp. L	4	4	8
Sec. Gp. C	8	8	16
	12	12	24

p = 0.66

Null Hypothesis V

Employees of Langton Hall's offices will not rate significantly greater difficulty in using the telephone under loudest conditions of noise than employees of other campus offices.

Null hypothesis V was retained. No significant differences, or even directional tendencies, are indicated by analysis of rating distributions. Table 8 shows the same distribution pattern as was found for hypothesis IV.

Table 8. Bivariate frequency distribution for subjective ratings of ability to use the telephone under the loudest noise conditions.

	below median	above median	
Sec. Gp. L	4	4	8
Sec. Gp. C	8	8	16
	12	12	24

p = 0.66

Null Hypothesis VI

Employees of Langton Hall's offices will not attribute the cause of the loudest noises to "noise through the ceiling" more frequently than employees of other campus offices.

Null hypothesis VI was rejected. As is indicated by inspection of Table 9, and the results of the Fisher exact probability test, Langton Hall's secretaries identified "noise through the ceiling" as the major cause of the loudest noises significantly more frequently than the other group of subjects.

Table 9. Bivariate frequency distribution for identification of cause of loudest noises.

	not ceiling	ceiling	
Sec. Gp. L	0	8	8
Sec. Gp. C	15	1	16
	15	9	24

$p = 0.000012$

Null Hypothesis VII

Employees of Langton Hall's offices will not report a significantly greater frequency of work disturbance due to the loudest noises than employees of other campus offices.

Null hypothesis VII was retained. No significantly greater frequency of work disturbance under the loudest conditions was reported by secretaries of Langton Hall. With a probability level of less than 0.10, however, a trend is identifiable and this will be discussed in the next chapter.

Table 10. Bivariate frequency distribution for ratings of frequency of work disturbance caused by the loudest noises.

	below median	above median	
Sec. Gp. L	2	6	8
Sec. Gp. C	10	6	16
	12	12	24

p = 0.096

Null Hypothesis VIII

During activity periods in Langton Hall's gymnasium, measured sound levels will not be significantly higher in Langton Hall's offices than in other campus offices.

Null hypothesis VIII has been rejected for each of the five measurement criteria tested. Analysis of the data indicates significantly greater noise levels in Langton Hall's offices during gymnasium activity periods. Statistical results for the five criteria tested are presented individually.

Mean Pressure-Ratios:

The t test was used to determine if significantly greater noise levels existed in Langton Hall's offices as evidenced by mean sound-pressure ratios. As can be seen from Table 11, an exceptionally high degree of significance was obtained.

Table 11. Analysis of mean sound-pressure ratios for Langton Hall's offices and other campus offices.

Office Group	Mean	SS	S	df	t
L	790	507584	291	6	4.067*
C	312	228997	144	11	

*Significant at the .001 level.

Equivalent A-Weighted Sound Levels (L_{eq}'s):

Mean sound-pressure ratios for each office were converted to A-Weighted sound levels and analyzed with the Fisher exact probability test for distribution frequencies relative to a median value.

Table 12. Bivariate frequency distribution of equivalent A-weighted sound levels determined for Langton Hall's offices and other campus offices. Measurements taken in Langton Hall during gymnasium activity periods.

	below median	above median	
Off. Gp. L	0	6	6
Off. Gp. C	9	3	12
	9	9	18

$p = 0.0045$

L_{10}'s, L_{50}'s, and L_{90}'s:

The two groups of offices were compared for frequency distributions of A-weighted sound levels that were exceeded 10, 50, and 90 percent of the time. During gymnasium activity periods, Langton Hall's offices show significantly greater noise levels for all three measures as is indicated by Tables 13, 14, and 15.

Table 13. Bivariate frequency distributions of L_{10}'s determined for Langton Hall's offices and other campus offices. Measurements taken in Langton Hall during gymnasium activity periods.

	below median	above median	
Off. Gp. L	0	7	7
Off. Gp. C	9	2	11
	9	9	18

$p = 0.0011$

Table 14. Bivariate frequency distribution of L_{50}'s determined for Langton Hall's offices and other campus offices. Measurements taken in Langton Hall during gymnasium activity periods.

	below median	above median	
Off. Gp. L	1	6	7
Off. Gp. C	8	3	11
	9	9	18

$p = 0.0249$

Table 15. Bivariate frequency distribution of L_{90}'s determined for Langton Hall's offices and other campus offices. Measurements taken in Langton Hall during gymnasium activity periods.

	below median	above median	
Off. Gp. L	1	6	7
Off. Gp. C	8	3	11
	9	9	18

$p = 0.0249$

Null Hypothesis IX

During nonactivity periods in Langton Hall's gymnasium, measured sound levels will not differ significantly between Langton Hall's offices and other campus offices.

Null hypothesis IX was retained for each of the five measurement criteria tested. For those time periods during which no activities were occuring in Langton Hall's gymnasiums, no significant differences of measured noise levels were apparent between Langton Hall's offices and other campus offices. Statistical results for the five criteria are presented individually.

Mean Pressure-Ratios:

The t test was used again for determining if significant differences existed for mean sound-pressure ratios between the two groups of offices. Based on the t value obtained from this parametric approach, null hypothesis IX was retained.

Table 16. Analysis of mean sound pressure ratios for Langton Hall's offices and other campus offices during non-activity periods in Langton Hall's gymnasium.

Office Group	Mean	SS	S	df	t
L	267	31782	73	6	0.8933*
C	312	228997	144	11	

*Not significant

Equivalent A-Weighted Sound Levels (L_{eq}'s):

As in the treatment of hypothesis VIII, mean sound-pressure ratios for each office were converted to A-weighted sound levels and analyzed with the Fisher exact probability test for distribution frequencies relative to a median value.

Table 17. Bivariate frequency distribution of equivalent A-weighted sound levels determined for Langton Hall's offices and other campus offices. Langton Hall measurements taken while no gymnasium activities were occuring.

	below median	above median	
Sec. Gp. L	3	4	7
Sec. Gp. C	6	5	11
	9	9	18

p = 1.00

L_{10}'a, L_{50}'s, and L_{90}'s:

Tables 17, 18, and 19 present frequency distributions for A-weighted sound levels as a function of percentage of time. Measurements were taken in Langton Hall's offices during the gymnasium's nonactivity periods. No significant differences were apparent between the two groups of offices for any of these measures.

Table 18. Bivariate frequency distribution of L_{10}'s determined for Langton Hall's offices and other campus offices. Measurements taken in Langton Hall during gymnasium's nonactivity periods.

	below median	above median	
Off. Gp. L	3	3	6
Off. Gp. C	6	6	12
	9	9	18

$p = 1.00$

Table 19. Bivariate frequency distribution of L_{50}'s determined for Langton Hall's offices and other campus offices. Measurements taken in Langton Hall during gymnasium's nonactivity periods.

	below median	above median	
Off. Gp. L	4	3	7
Off. Gp. C	5	7	12
	9	10	19

$p = 0.8599$

Table 20. Bivariate frequency distribution of L_{90}'s determined for Langton Hall's offices and other campus offices. Measurements taken in Langton Hall during gymnasium's nonactivity periods.

	below median	above median	
Off. Gp. L	3	4	7
Off. Gp. C	6	5	11
	9	9	18

$p = 1.00$

V. DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Discussion

To assist in the discussion of results, four main areas of concern have been delineated from the survey. They are: 1) subjective identification of loudest sources of noise, 2) subjective assessments of noisiness, 3) subjective assessments of work disturbance, and 4) objective measurements of noise. Conclusions relevant to each area are included in the context of this discussion. These conclusions are also itemized in a section following the discussion.

Subjective Identification of Loudest Sources of Noise:

The strongest evidence implicating gymnasium activity as the loudest source of noise in Langton Hall comes from responses to question #11. Without exception, Langton Hall's secretaries stated that "noise through the ceiling" caused the loudest noises. This particular source of noise was identified by only one secretary of Sec. Gp. C. Although instructions for question #11 specified that only one cause was to be identified, four secretaries from Sec. Gp. C identified more than one cause. Their responses, however, were incorporated into the data analysis because none of these subjects included "noise through the ceiling" in their multiple responses. The most frequently cited cause of noise in Off. Gp. C was "typewriters and other office equipment" (answer "c"). This was followed by "talking in hallways and offices" (answer "e").

Interpretation of these results may provide some profound implications. It can be reasonably assumed that levels of noise produced by typewriters, office machines, and talking are similar in most offices to the extent that the sources are similar themselves. In not a single case, however, did a Langton Hall secretary identify these as major causes. It could be inferred then, that not only is "noise through the ceiling" the major cause of noise in Langton Hall, but that it is peculiar to Langton Hall and excessive in level to what is normally found in other offices of the O.S.U. campus.

The significance of these results is further enhanced by the question design. With seven possible answers itemized, plus provisions for an open-ended response, the consistency found in responses from Langton Hall's secretaries is a convincing indictment of gymnasium activity as the major source of excessive noise.

Subjective Assessments of Noisiness:

Analysis of responses to questions #1, #2, and #3 provide information concerning the subjective assessments of noise. Only under the loudest conditions did Langton Hall's secretaries report a significantly greater degree of noisiness. Interestingly, the frequency distributions for noisiness during average and quietest conditions were identical.

It was anticipated that S's from Langton Hall would interpret "quietest conditions" as those occuring during periods when no gymnasium activities were in progress, while "loudest conditions" were contingent upon the presence of these activities. Considering the overwhelming evidence implicating "noise through the ceiling" as the cause of the loudest noises, this would seem a reasonable assumption. Subjective interpretation of what constitutes "average conditions" is understandably subject to a greater degree of variation for it implies neither the presence nor absence of a particular noise source as might the terms "loudest conditions" and "quietest conditions". Because the statistical results show no significant difference of distributions between the two groups of S's for noisiness during average conditions, Langton Hall secretaries may have associated "average conditions" with the absence of the loudest noise source. In the absence of noise through the ceiling in Langton Hall, the remaining types of sources are those found to be ubiquitous to all office environments on the campus with variations only in their intensity, duration, and frequency of occurence. Statistical analyses of hypotheses I and III would indicate then, that the noisiness ratings for the noises common to all offices does not differ significantly between the two groups of secretaries. Although retention of hypotheses I and III allow for speculation consistent with results concerning identification of the loudest noise sources, rejection of hypothesis II has provided the only conclusive evidence of a relationship existing between ratings of the two groups. It has thus been concluded, that under the loudest conditions, secretaries of Langton

Hall perceive greater levels of noise than secretaries from other campus offices.

Subjective Assessment of Work Disturbance:

As the review of the literature illustrates (see p. 29), it has been very difficult to characterize the effects of noise on work performance. Considering the inconsistent results found throughout the literature, and the diffuse attention given to this area in the survey, any results would have been of questionable validity. Analysis of question #6 and #7, dealing with ability to use the telephone under average and loudest conditions of noise, served to indicate frequency of work disturbance. Question #12 was of a more obtrusive nature and directly asked for a rating of work disturbance frequency as a result of the loudest noises. Null hypotheses IV, V, and VII, relating to survey questions #6, #7, and #12, respectively, were all retained.

Analysis of the one-tailed hypotheses IV and V demonstrated no significantly greater difficulty for telephone use in Langton Hall's offices under either average or loudest noise conditions. Furthermore, the frequency distributions for the two conditions were identical ($p = 0.66$). Accepting that the subjective assessments for noisiness under loudest conditions were valid, these results imply that either telephone use is relatively insensitive to noise levels or that questions #6 and #7 are poor indicators of ability to use the telephone. The possibility that ability to use the telephone is relatively insensitive to noise seems to be the most tenable explanation. Telephone use, under most circumstances, would not quality as a complex task. This would mean that a reserve capacity to attend the operation of a telephone would probably exist in the event of distracting noises. Also, the non-verbal nature of Langton Hall's loudest noises would be less likely to decrease speech intelligibility as would loud, intrusive speech.

No significantly greater frequency of work disturbance caused by the loudest noises could be established for Langton Hall. Null hypothesis VII was retained on the basis of a 0.05 acceptable significance level, however, a trend may be present due to a noticeably low probability for the frequency distribution (p = 0.096). If the loudest noises are actually louder than in Langton Hall's offices, as was concluded from the rejection of null hypothesis II, then three possible explanations exist for these results. They are:

1) The frequency of occurence of the loudest noises is not significantly greater in Langton Hall's offices than in other campus offices.
2) The frequency of work disturbance is not related to frequency of the loudest noise.
3) Question #12 does not establish a valid relationship between frequency of work disturbance and the frequency of the loudest noises.

Objective Measurements of Noise:

Basically, two types of information were sought from objective measurements of noise levels; average sound levels, and sound levels as functions of time. These two areas of inquiry will be discussed separately. This study interpreted "average" sound levels in two ways; the mean sound-pressure ratio, and the equivalent A-weighted sound level (L_{eq}). Sound levels as functions of time were presented as A-weighted sound levels that were exceeded 10, 50, and 90 percent of the time (L_{10}, L_{50}, and L_{90}, respectively).

A t test was employed to compare mean sound-pressure ratios for Off. Gp. L and Off. Gp. C. It was concluded that during gymnasium activity periods, mean sound-pressure ratios were significantly greater in Off. Gp. L than in Off. Gp. C. Analysis of equivalent A-weighted sound levels with the Fisher exact probability test confirmed these results.

Identical statistical treatments were employed for comparisons of average noise levels between Off. Gp. C and Off. Gp. L during the absence of gymnasium activities in Langton Hall. Results indicated that neither the mean sound-pressure ratios nor the equivalent A-weighted sound levels were significantly greater for Off. Gp. L than Off. Gp. C.

These results appear to be consistent with those observed for subjective noisiness ratings. Noise levels as indicated by objective measurements of central tendency are apparently similar in Off. Gp. L and Off. Gp. C in the absence of the gymnasium noise source. This similarity is evidenced in S's responses to questions #1 and #3. Similarly, the higher ratings of "noisiness during loudest conditions" observed from Sec. Gp. L are consistent with the measurements of noise levels in Langton Hall, presumably taken during these conditions.

Several points should be made here concerning the qualitative nature of noises generated from gymnasium activities in Langton Hall. The gymnasium floor in Langton Hall is composed of wood and is supported by a wood-joist type of construction. No resilient material has been interposed between the activity floor and the supporting structure, nor have any architectural techniques been implemented to interrupt floor-structure continuity. (14) This is to be expected considering the age of the building. Dropped acoustical ceilings, however, have been installed in offices situated below the gymnasium. Because the transmission-loss effectiveness of wood construction and acoustically treated ceilings has been shown to be very good for airborne sound (see p. 23), the noises originating from gymnasium activities must be of a structureborne nature.

The noises reaching offices from the gymnasium are easily identified as foot-fall and ball bouncing. These two types of noise sources are generally regarded as impact noises which, under usual circumstances, would present additional technical difficulties for their measurement. (33) Considering the brief duration of individual noises generated on the gymnasium floor, these noises would qualify as impact or impulse noises. Since the repetition of this impulse noise source is high enough to prohibit resolution of individual bursts with a sound level meter, it falls into a special category of impulse-type noises sometimes referred to as "quasi-steady noise". (30:36) While it is recognized that discrete noises caused by infrequent foot-fall requires special measurement techniques (33), quasi-steady noise may be considered similar to steady noise in regard to the measurement techniques employed.

Another distinguishing feature of the noise intruding through ceilings in Langton Hall is its fluctuation. Fluctuating noise is a type of nonsteady noise characterized by a minimal sound level variance of six decibels at "slow" meter speed. (30:36) Sound level measurements of all offices in Langton Hall met and exceeded this criteria. This characteristic of the measured noise can be accounted for by the nature of activities occuring on the gymnasium floor. Most measurements were taken while basketball games were taking place. The shift of activity from one end of the court to the other would explain the wide range of decibel levels.

Thus, as discrete functions of time, it was possible that sound levels in Langton Hall may have been similar to those encountered in other campus offices if fluctuations of sound levels in Langton Hall produced extremes in adequate excess to those observed in other campus offices. This possibility was dismissed through comparisons of L_{10}'s, L_{50}'s, and L_{90}'s. In effect, it was found that for any of the percentages of time tested, sound levels in Langton Hall's offices exceeded those of other campus offices when gymnasium activities were occuring. As anticipated, no differences of these measures were apparent during periods of non-activity in the gymnasium.

Difficulties arise in assessing the relative weights that should be assigned to the various forms of evidence presented in this study. As the review of the literature indicated (see p. 16), certain types of subjective ratings are superior to others in providing valid and reliable information. It has been well documented that ratings of annoyance, disturbance, and acceptability do not correlate with physical measures as well as noisiness ratings. (19)

By virtue of discrete responses, the identification of particular noise sources is less subject to violations of reliability than are ratings on a continuous scale. (15)

In summary, regardless of the relative weights assigned to each type of evidence, it has been demonstrated that a noise pollution problem does exist in Langton Hall's offices, and that this problem is in excess to what is normally found in other campus offices. Also, if a hierarchy could be formulated to rank evidence as to importance, it would only serve to confirm and reinforce these findings.

Conclusions

The following conclusions are derived from the results of this study:

1. For quietest conditions of noise, secretaries employed in Langton Hall did not report significantly greater levels of noisiness than secretaries employed in other campus offices.

2. For average conditions of noise, secretaries employed in Langton Hall did not report significantly greater levels of noisiness than secretaries employed in other campus offices.

3. For loudest conditions of noise, secretaries employed in Langton Hall reported significantly greater levels of noisiness than secretaries from other campus offices.

4. For average conditions of noise, secretaries employed in Langton Hall did not report significantly greater difficulty using the telephone than secretaries employed in other campus offices.

5. For loudest conditions of noise, secretaries employed in Langton Hall did not report significantly greater difficulty using the telephone than secretaries employed in other campus offices.

6. Secretaries employed in Langton Hall attributed "noise through the ceiling" as the cause of the loudest noise more frequently than did secretaries employed in other campus offices.

7. Secretaries employed in Langton Hall did not report a significantly greater frequency of work disturbance caused by the loudest noises than did secretaries employed in other campus offices.

8. A-weighted sound levels measured in Langton Hall's offices during periods of non-activity in the gymnasium were not significantly greater than A-weighted sound levels measured in other campus offices.

9. A-weighted sound levels measured in Langton Hall's offices during activity periods in the gymnasium, were significantly greater than A-weighted sound levels measured in other campus offices.

10. A-weighted sound levels exceeded 10, 50, and 90 percent of the time in Langton Hall's offices during periods of non-activity in the gymnasium, were not significantly greater than A-weighted sound levels exceeded 10, 50, and 90 percent of the time in other campus offices.

11. A-weighted sound levels exceeded 10, 50, and 90 percent of the time in Langton Hall's offices during activity periods in the gymnasium were significantly greater than A-weighted sound levels exceeded 10, 50 and 90 percent of the time in other campus offices.

Recommendations

Recommendations for further research and suggestions for improving this study are offered here. Also provided, are suggested methods of remedial action for problems disclosed in this investigation.

1. Development of a questionnaire with increased sensitivity to the effects of noise on work performance would allow for more reliable application of subjective methods.

2. Further research is necessary to develop a questionnaire that would provide valid correlations between subjective ratings of noisiness and identifiable physical parameters of impact and other types of non-steady noise.

3. Research investigating the influence of noise on work performance in the office would disclose information pertinent to the cost effectiveness of noise control.

4. In view of the structureborne nature of noises generated by gymnasium activity in Langton Hall, it would be desirable to conduct a similar study employing vibration testing equipment.

5. An unobstrusive behavioral study relating noise to work performance in the office could provide information not obtainable through the subjective methods employed in this study.

6. Spectral analysis of the noises generated by gymnasium activity in Langton Hall could provide information necessary to implement technical solutions.

7. As a standard operational procedure, the Oregon State University Administration should institute a program for regular noise monitoring of all occupational and academic environments on the campus.

8. As an extension to the random spot testing used for obtaining sound level measurements in this study, it would be appropriate to obtain sound level measurements that would reflect the 8-hour work day. This approach, however, would necessitate the introduction of additional sound monitoring equipment and would require analysis of a significantly greater volume of data.

BIBLIOGRAPHY

1. ASHRAE, Guide and Data Book, Systems and Equipment. N.Y., New York: American Society of Heating, Refrigerating, and Air Conditioning Engineers, 1967.

2. Almeida, H. R., "Influence of Electric Punch Card Machines on the Human Ear". Arch. Otolaryngol. 51, 215-222, 1950.

3. Beranek, Leo L., "Noise Control in Office and Factory Spaces". 15th Annual Mgt. Chem. Engr. Conf., Trans. Bull. 18, 26-33, 1950.

4. Beranek, Leo L., Reynolds, J. L., and Wilson, K. E., "Apparatus and Procedures for Predicting Ventilation System Noise". Journal of the Acoustical Society of America. 25:313, 1953.

5. Beranek, Leo L., "Criteria for Office Quieting Based on Questionnaire Rating Studies". The Journal of the Acoustical Society of America. Vol. 28, No. 5. Sept., 1956. pg. 833-852.

6. Beranek, Leo L., "Revised Criteria for Noise in Buildings". Noise Control. Vol. 3, No. 1. 1957.

7. Beranek, Leo L., Noise and Vibration Control. N.Y., New York: McGraw-Hill, 1971. pg. 585.

8. Boggs, D. H., and Simon, J. R., "Differential Effects of Noise on Tasks of Varying Complexity". Journal of Applied Psychology. Vol. 52, No. 2. 1968. pg. 148-153.

9. Broadbent, D. E., and Little, E. A., "Effect of Noise Reduction in a Work Situation". Occupational Psychology. Vol. 34. 1960. pg. 133-140.

10. Cavanaugh, W. J., Farrel, W. R., Hirtle, P. W., and Walters, B. G., "Speech Privacy in Buildings". Journal of the Acoustical Society of America. Vol. 34. 1960. pg. 475-481.

11. Cumpston, C., "Acoustical Privacy: Key to Successful Open Office Planning". Administration Management. Vol. 34. No. 7. 1973. pg. 17-18.

12. Cunnif, P. F., Environmental Noise Pollution. N.Y., New York: John Wiley and Sons, 1977.

13. Denisov, E. I., "New Health Norms on Noise". Institut Gigujeny Truda: Profzabolenvaniy, AMN SSSR, Moscow, Vol. 14, No. 5. 1970. pg. 47.

14. Doelle, L., Environmental Acoustics. N.Y., New York: McGraw-Hill, 1972.

15. Guilford, J. P., Psychometric Methods. N.Y., New York: McGraw-Hill, 1954. pg. 263-299.

16. Harris, C. M., Handbook of Noise Control. N.Y., New York: McGraw-Hill, 1957.

17. Informatics, Inc., Noise Facts Digest. Wash., D.C.: U.S. E.P.A., 1972.

18. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. Wash, D.C.: U.S. E.P.A., March 1974.

19. Keighley, E. C., "The Determination of Acceptability Criteria for Office Noise". Journal of Sound and Vibration. Vol. 4. No. 1. 1966. pg. 73-87.

20. Knudsen, E. O., and Harris, C. M., Acoustical Designing in Architecture. N.Y., New York: John Wiley and Sons, 1950.

21. Kosten, C. W., and van Os, G. J., "Community Reaction Criteria for External Noises". National Physical Laboratory Symposium No. 12, London: H.M.S.O. 1962.

22. Kryter, K., The Effects of Noise on Man. N.Y., New York: Academic Press, 1970.

23. Langdon, F. J., "A Study of Annoyance by Noise in Automatic Data Processing Offices". Journal of Building Sciences. Vol. 1. 1965. pg. 69-78.

24. Lawrence, A., Acoustics in Buildings. Australian Science Series. Vol. 1. 1962. pg. 70.

25. Lindahl, R., "The Consultant and Impact Noise". Building Research. Jan.-Feb. 1964. pg. 61-62.

26. Marascuito, L. A., and McSweeney, M., Nonparametric and Distribution-Free Methods for the Social Sciences. Belmont, Calif.: Wadsworth Pub. Co., 1977.

27. Mariner, T., "Technical Problems in Impact Noise Testing". Building Research. Jan.-Feb. 1964, pg. 52-60.

28. Meisen, W. A., "Experience with Test Methods PBS C.1 and PBS C.2". Noise-Con 77, National Conference on Noise Control Engineering, Hampton, Virginia. N.Y., New York: Noise Control Foundation, 1977. pg. 471-474.

29. Mills, T. H. G., and Robinson, D. W., "The Subjective Rating of Motor Vehicle Noise". Engineer. Vol. 211. 1961. pg. 1070.

30. Noise Emission Measurements for Regulatory Purposes, N.B.S. Handbook 122. Wash., D.C.: Nat. Bureau of Standards. March 1977.

31. Noise Source Regulations in State and Local Noise Ordinances. Wash., D.C.: U.S. E.P.A., Feb. 1970.

32. Olishifski, P. E., and Harford, E. R., Industrial Noise and Hearing Conservation. Chicago: National Safety Council, 1975.

33. Olynyk, D., and Northwood, T. D., "Subjective Judgments of Footstep-Noise Transmission through Floors". Journal of the Acoustical Society of America. Vol. 38. No. 6. Dec. 1965. pg. 1035-1039.

34. Oregon Revised Statute 467.010. 1977.

35. Oregon Revised Statute 467.040. 1977.

36. Pecenka, F., "The Effect of Occupational Impact Noise on the Precision and Speed of Unguided Hand Movement". Dissertation Abstracts, 1976/77, Science & Engr. pg. 4381-B.

37. Perret, E., and Grandjean, E., and Lauber, A., "Subjective Ratings of Aircraft Noises by Students During a Lecture". Ergonomics Research Society. Vol. 6. 1963. pg. 307.

38. Public Health and Welfare Criteria for Noise. Wash., D.C.: U.S. E.P.A., July 27, 1973.

39. Public Law 91-596, 84 Stat. 1590, U.S.C.A., 651-678, as amended.

40. Public Law 92-574, 86 Stat. 1234, U.S.C.A., 1234-1246, as amended.

41. Rettinger, M., Acoustic Design and Noise Control. N.Y., New York: Chemical Publishing Co., Inc., 1973.

42. Robinson, D. W., "The Subjective Rating of Motor Vehicle Noise". Engineer. Vol. 211. 1961. pg. 1070.

43. Rodgers, W. H., Handbook on Environmental Law. St. Paul, Minn.: West Pub. Co., 1977.

44. Rosenblith, W. A., and Stevens, K. N., Handbook of Acoustic Noise Control. II. Noise and Man. Rept. WADC TR 52-204. U.S. Air Force Aerospace Medical Laboratory. Wright-Patterson A.F.B., Ohio, 1953.

45. "Sanitary Norms for Permissable Noise in Living Quarters and Public Buildings and in Residential Construction Areas". Main Sanitary - Epidemiological Adm., U.S.S.R., 1971.

46. Series 22 Health Compliance Regulations. Available through Worker's Compensation Department, Labor and Industries Building, Salem, Ore. 97310.

47. Siegel, S., Non-Parametric Statistics for the Behaviorial Sciences. N.Y., New York: McGraw-Hill, 1956. pg. 114.

48. Spalding, G. R., "Understanding Office Acoustics". Administration Management. July 1976. pg. 21.

49. Sulewsky, J. E., "Acoustical Design Guidelines for Office Landscaping". Sound and Vibration. Vol. 5. No. 6. 1971. pg. 17-18.

50. Ward, L. M., and Suedfeld, P., "Human Responses to Highway Noise". Environmental Research. Vol. 6. 1973. pg. 306-326.

51. Warner, H. D., and Heimstra, N. W., "Effects of Intermittent Noise on Visual Search Tasks of Varying Complexity". Perceptual and Motor Skills. Vol. 32. 1971. pg. 219-226.

52. Webb, J. D., Noise Control in Industry. London: Sound Research Laboratories, 1976.

53. Weinstein, N. D., "Effect of Noise on Intellectual Performance". Journal of Applied Psychology. Vol. 59. No. 5. 1974. pg. 548-554.

54. Woodhead, M. M., "The Effect of Noise on Distribution of Attention". Journal of Applied Psychology. Vol. 50. No. 4. 1966. pg. 296-299.

55. Woods, R. I., Noise Control in Mechanical Services. London: Sound Attenuators, Ltd., and Sound Research Laboratories, Ltd., 1972.

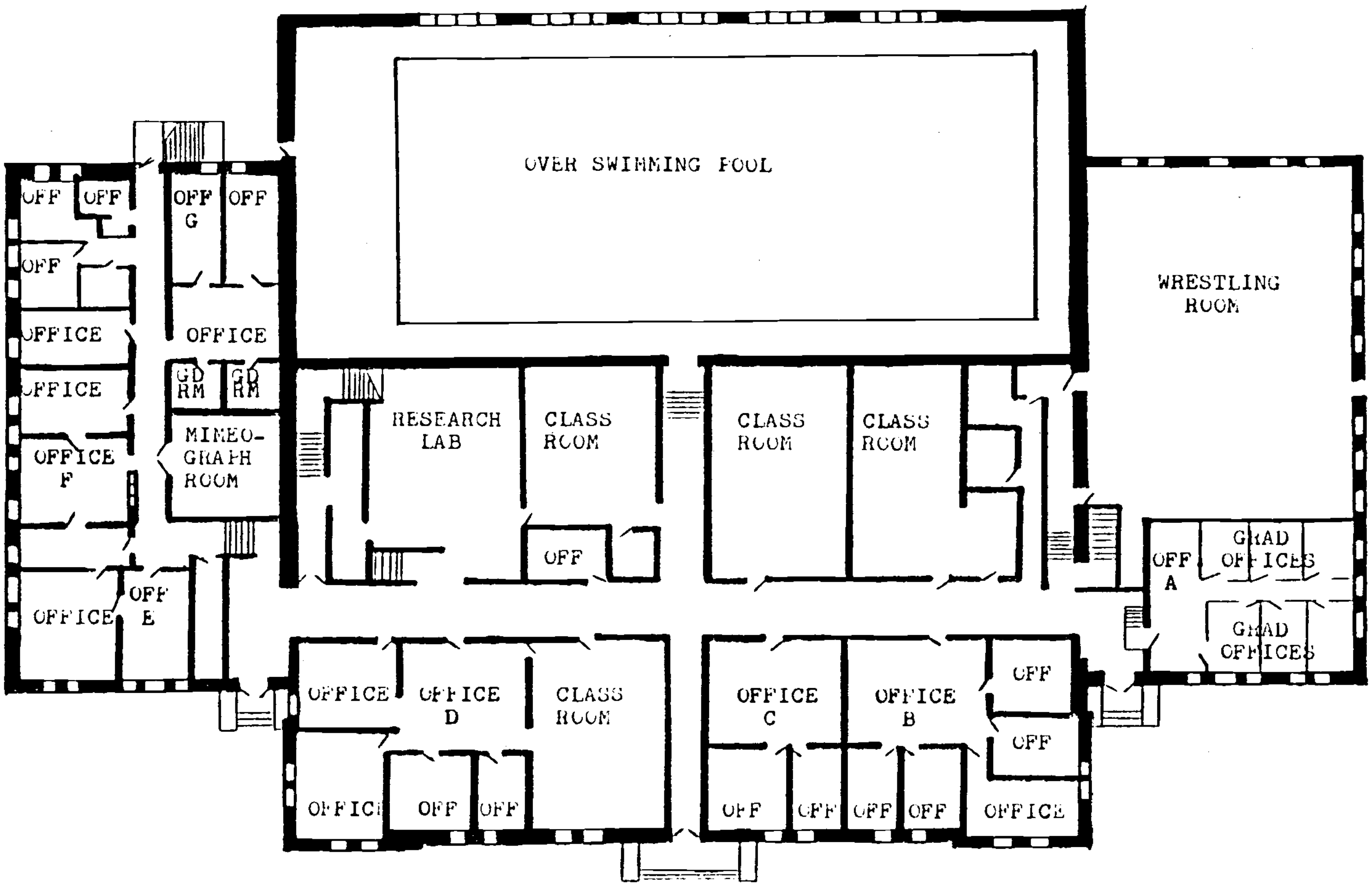
56. Worker's Compensation Laws of Oregon. Salem, Ore.: Worker's Compensation Department of Oregon, 1977.

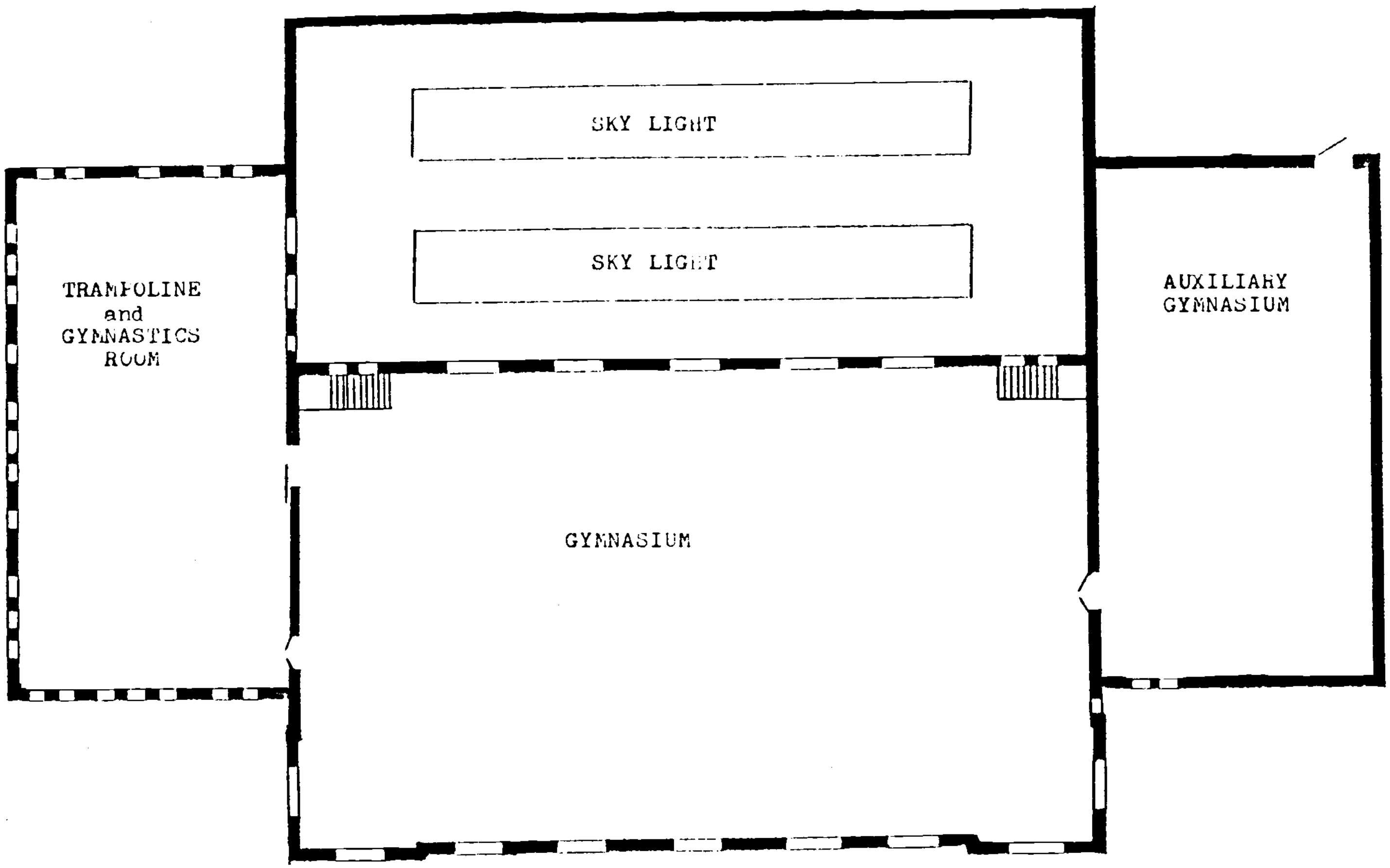
57. Young, R. W., "Single Number Criteria for Room Noise". Journal of the Acoustical Society of America. Vol. 36. No. 2. Feb. 1964.

APPENDICES

APPENDIX I

FLOOR PLANS OF LANGTON HALL


OVER SWIMMING POOL
WRESTLING ROOM
OFF
OFF
OFF
OFF G
OFF
OFFICE
OFFICE
OFFICE
GD RM
GD RM
OFFICE F
MIMEO-GRAPH ROOM
OFFICE
OFF E
RESEARCH LAB
CLASS ROOM
OFF
CLASS ROOM
CLASS ROOM
OFF A
GRAD OFFICES
GRAD OFFICES
OFFICE
OFFICE D
CLASS ROOM
OFFICE C
OFFICE B
OFF
OFF
OFFICE
OFF
OFF
OFF
OFF
OFF
OFF
OFFICE

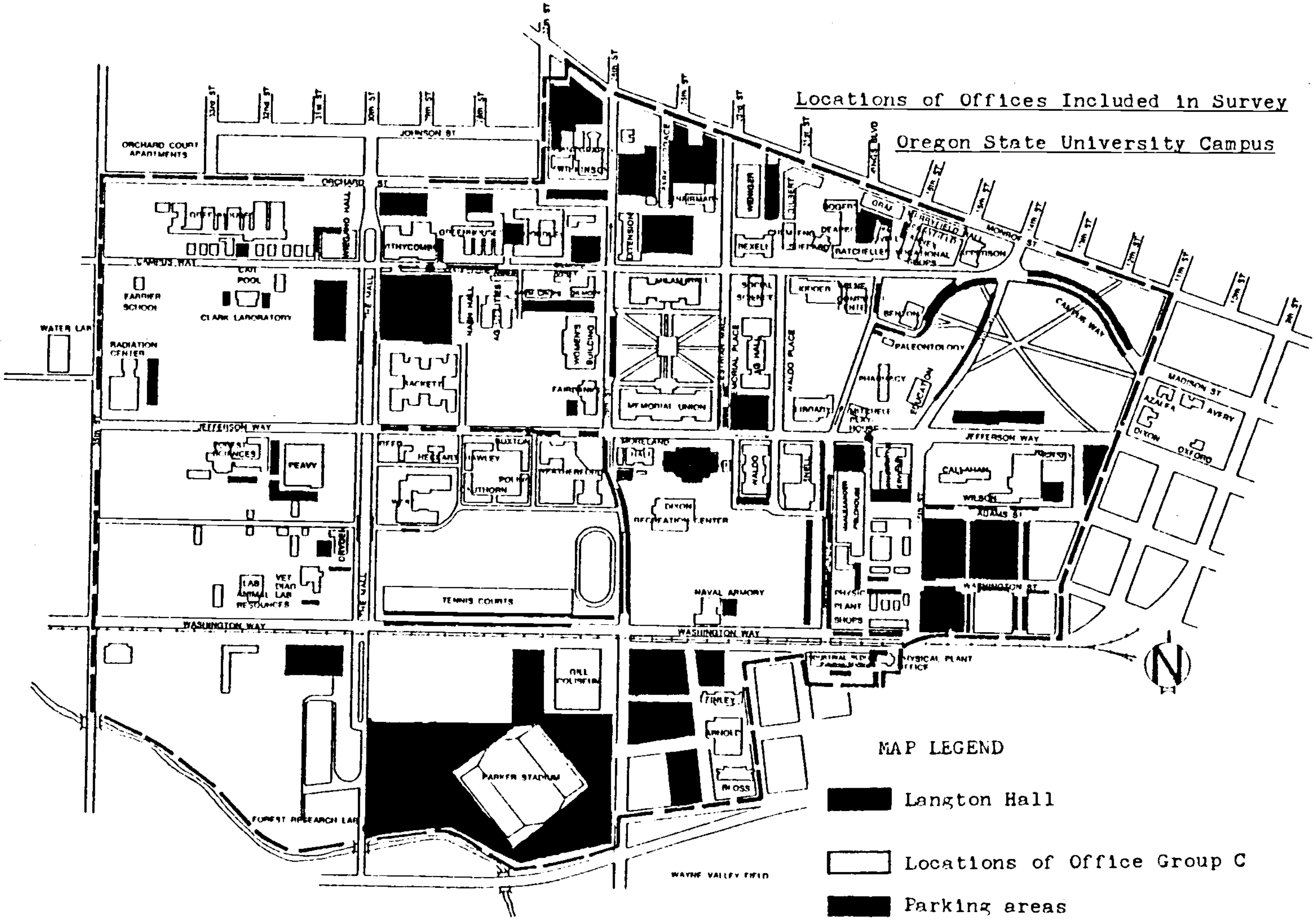

SKY LIGHT
SKY LIGHT
TRAMPOLINE
and
GYMNASTICS
ROOM
AUXILIARY
GYMNASIUM
GYMNASIUM

APPENDIX II

LOCATIONS OF OFFICES INCLUDED IN SURVEY

Locations of Offices Included in Survey

Oregon State University Campus



APPENDIX III

SUMMARY OF DATA FROM QUESTIONNAIRE

Ranked responses to Question #1: "How noisy is this room under average conditions?"

Subject's Office no.	Sec. Gp.	Rating (Range = 0.0 to 17.0)
14	L	14.4
1	C	14.0
15	L	12.0
18	L	10.8
16	L	10.4
6	C	10.3
1	C	9.5
3	C	9.1
4	C	9.1
5	C	8.7
9	C	8.0
13	L	7.3
2	C	7.2
17	L	7.1
17	L	7.0
10	C	6.8
12	C	6.8
8	C	6.6
4	C	5.4
19	L	5.0
8	C	3.5
11	C	3.5
7	C	3.4
2	C	2.8
Median = 7.25		

Ranked responses to Question #2: "How noisy is this room under the loudest conditions?"

Subject's Office No.	Sec. Gp.	Rating (Range = 0.0 to 17.0)
19	L	17.4
18	L	17.1
14	L	17.0
1	C	15.0
17	L	14.2
15	L	14.1
5	C	14.1
17	L	14.0
6	C	14.0
9	C	13.9
16	L	13.8
4	C	13.8
10	C	13.8
1	C	13.7
3	C	13.1
2	C	12.2
13	L	10.5
2	C	10.2
7	C	10.1
8	C	10.1
12	C	7.4
4	C	7.2
8	C	7.0
11	C	6.9
Median = 13.78		

Ranked responses to Question #3: "How noisy is this room under the quietest conditions?"

Subject's Office No.	Sec. Gp.	Rating (Range = 0.0 to 17.0)
17	L	7.3
1	C	5.0
3	C	4.1
13	L	3.9
18	L	3.9
1	C	3.6
6	C	3.5
7	C	3.5
4	L	3.5
5	C	3.5
8	C	3.4
16	L	3.4
4	C	3.2
3	C	3.2
15	L	2.4
10	C	1.9
12	C	1.8
4	C	0.7
9	C	0.5
2	C	0.3
14	L	0.3
2	C	0.0
19	L	0.0
11	C	0.0
Median = 3.3		

Ranked responses to Question #6: "Rate your ability to use the telephone in this room under average conditions of noise."

Subject's Office No.	Sec. Gp.	Rating (Range = 0.0 to 17.0)
14	L	12.2
1	C	11.0
16	L	10.5
6	C	9.2
2	C	8.6
17	L	7.7
4	C	7.2
12	C	7.2
3	C	7.1
1	C	6.1
13	L	5.9
5	C	5.8
9	C	5.6
18	L	5.3
15	L	2.8
10	C	2.6
17	L	0.8
7	C	0.5
3	C	0.3
4	C	0.2
8	C	0.2
19	L	0.2
2	C	0.0
11	C	0.0
Median = 5.7		

Ranked responses to Question #7: "Rate your ability to use the telephone in this room under average conditions of noise."

Subject's Office No.	Sec. Gp.	Rating (Range = 0.0 to 17.0)
1	C	17.4
19	L	17.2
5	C	14.7
2	C	14.2
2	C	14.2
10	C	14.1
16	L	13.5
14	L	13.1
17	L	11.8
6	C	11.7
9	C	11.6
1	C	11.4
18	L	9.8
4	C	9.1
13	L	8.1
17	L	6.3
3	C	5.8
8	C	5.4
12	C	5.3
7	C	5.2
4	C	2.9
15	L	2.8
8	C	0.4
11	C	0.0
Median = 10.6		

Ranked responses to Question #12: "How often does the loudest noise disturb your work?"

Subject's Office No.	Sec. Gp.	Rating (Range = 0.0 to 17.0)
1	C	14.1
6	C	11.8
1	C	10.1
3	C	10.1
16	L	9.9
4	C	9.6
18	L	7.6
9	C	7.5
19	L	7.4
13	L	6.3
17	L	6.3
14	L	6.2
8	C	6.1
5	C	6.0
7	C	5.8
17	L	5.8
10	C	5.7
8	C	5.4
2	C	5.3
15	L	3.7
4	C	3.4
2	C	1.4
12	C	1.3
11	C	0.0
Median = 6.15		

APPENDIX IV

SUMMARY OF DATA FROM SOUND LEVEL MEASUREMENTS

Ranked equivalent A-weighted sound levels (Leq's) for Office Group L and Office Group C.

No activities occuring in Langton Hall gymnasium.			Activities occuring in Langton Hall gymnasium.		
Office No.	Office Gp.	Leq (dBA)	Office No.	Office Gp.	Leq (dBA)
1	C	54.94	16	L	61.65
5	C	54.07	14	L	60.70
7	C	54.02	17	L	57.38
13	L	50.22	13	L	56.90
15	L	50.22	15	L	56.76
11	C	50.10	19	L	56.64
2	C	49.89	1	C	54.94
14	L	49.87	5	C	54.07
10	C	49.74	7	C	54.02
9	C	49.54	18	L	51.37
4	C	49.33	11	C	50.10
19	L	48.96	2	C	49.89
17	L	48.62	10	C	49.74
3	C	45.83	9	C	49.54
18	L	45.35	4	C	49.33
6	C	43.70	3	C	45.83
8	C	43.47	6	C	43.70
16	L	43.47	8	C	43.47
12	C	43.08	12	C	43.08
Median = 49.54			Median = 51.37		

Ranked sound levels exceeded 10 percent of the time (L_{10}'s) for Office Group L and Office Group C.

No activities occuring in Langton Hall gymnasium.		
Office No.	Office Gp.	L_{10} (dBA)
1	C	62.5
5	C	59.2
7	C	57.7
2	C	55.7
11	C	54.8
13	L	54.0
17	L	53.9
19	L	53.3
10	C	53.2
14	L	52.2
4	C	52.0
15	L	51.8
9	C	51.4
3	C	51.2
6	C	51.1
18	L	48.0
8	C	47.7
12	C	47.5
16	L	46.5
Median = 52.2		

Activities occuring in Langton Hall gymnasium.		
Office No.	Office Gp.	L_{10} (dBA)
16	L	68.3
14	L	66.7
19	L	65.7
15	L	63.6
17	L	62.7
1	C	62.5
13	L	61.0
5	C	59.2
18	L	58.6
7	C	57.7
2	C	55.7
11	C	54.8
10	C	53.2
4	C	52.0
9	C	51.4
3	C	51.2
6	C	51.1
8	C	47.7
12	C	47.5
Median = 57.7		

Ranked sound levels exceeded 50 percent of the time (L_{50}'s) for Office Group L and Office Group C.

No activities occuring in Langton Hall Gymnasium.		
Office No.	Office Gp.	L_{50} (dBA)
7	C	53.8
5	C	53.1
1	C	51.7
11	C	50.0
15	L	50.0
10	C	49.9
13	L	49.5
4	C	49.3
9	C	49.1
14	L	49.1
19	L	48.6
17	L	47.6
18	L	45.8
3	C	44.0
16	L	43.2
2	C	43.0
8	C	42.4
12	C	41.3
6	C	40.2
Median = 49.075		

Activities occuring in Langton Hall Gymnasium.		
Office No.	Office Gp.	L_{50} (dBA)
14	L	60.3
16	L	59.7
17	L	56.4
13	L	55.5
15	L	54.7
19	L	53.9
7	C	53.8
5	C	53.1
1	C	51.7
11	C	50.0
10	C	49.9
4	C	49.3
9	C	49.1
18	L	49.1
3	C	44.0
2	C	43.0
8	C	42.4
12	C	41.3
6	C	40.2
Median = 50.0		

Ranked sound levels exceeded 90 percent of the time (L_{90}'s) for Office Group L and Office Group C.

No activities occuring in Langton Hall gymnasium.		
Office No.	Office Gp.	L_{90} (dBA)
7	C	50.0
15	L	48.2
13	L	47.6
14	L	47.4
5	C	47.3
1	C	46.9
9	C	45.5
19	L	45.3
11	C	44.8
10	C	44.6
4	C	44.4
17	L	44.2
18	L	41.3
8	C	39.6
12	L	39.1
16	C	39.1
3	C	39.1
2	C	38.8
6	C	37.4
Median = 44.6		

Activities occuring in Langton Hall gymnasium.		
Office No.	Office Gp.	L_{90} (dBA)
13	L	52.5
14	L	52.2
16	L	51.0
7	C	50.0
15	L	48.7
17	L	48.3
19	L	48.0
5	C	47.3
1	C	46.9
9	C	45.5
11	C	44.8
10	C	44.6
4	C	44.4
18	L	42.8
8	C	39.6
12	C	39.1
3	C	38.9
2	C	38.8
6	C	37.4
Median = 45.5		

APPENDIX V

THE QUESTIONNAIRE

Sheet 1

SUBJECTIVE RATING OF NOISE CONDITIONS IN THIS ROOM

This questionnaire is part of a survey of noise conditions at Oregon State University. You are asked to answer the questions below and to make ratings without consultation with your fellow employees. We want this to represent your own opinion. Your answers should apply to noise conditions that have existed during the past few months. But first,

Your age____________Sex________________

Your job title____

Building and room number____________________________________

Please mark your location in this room on a simple sketch below. All subsequent questions will refer to this location.

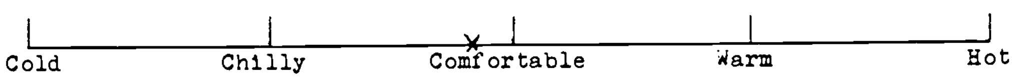
How long have you worked in this room?____________________________

____

NOTE: In the questions that follow you are asked to rate the noisiness of this room on rating scales. An example of how to use a rating scale is given here:

EXAMPLE

Suppose you are asked to rate the warmth of this room under average conditions on a scale drawn below. Assume you feel that on the average the room is slightly cooler than comfortable. Your rating would be an "X" located as follows:



Note that you may put the mark anywhere along the scale, not just at the indicated names.

Sheet 2

REMEMBER -- YOUR ANSWERS ARE TO BE FOR CONDITIONS OF THE PAST FEW MONTHS.

1. How noisy is this room under average conditions?

Very Quiet	Quiet	Moderately Noisy	Noisy	Very Noisy	Intolerably Noisy

2. How noisy is this room under the loudest conditions?

Very Quiet	Quiet	Moderately Noisy	Noisy	Very Noisy	Intolerably Noisy

3. How noisy is this room under the quietest conditions?

Very Quiet	Quiet	Moderately Noisy	Noisy	Very Noisy	Intolerably

4. Is the noise at this instant

Quietest	Average	Loudest

5. How often do you use the telephone here?

Never	Sometimes	Moderately Often	Often	Very Often	Continually

6. Rate your ability to use the telephone in this room under average conditions of noise.

Satisfactory	Slightly Difficult	Difficult	Impossible

7. Rate your ability to use the telephone in this room under the loudest conditions.

Satisfactory	Slightly Difficult	Difficult	Impossible

Sheet 3

8. What noise rating do you feel should <u>not be exceeded</u> in this room if you are to accomplish <u>your</u> duties without loss of performance?

Very Quiet	Quiet	Moderately Noisy	Noisy	Very Noisy	Intolerably Noisy

9. Is your hearing

Good	Average	Hard of Hearing

10. How sensitive are you to noise?

Insensitive	Average	Sensitive

11. What causes the loudest noises? (Check one)

___a. Walking in hallway - footsteps
___b. Noise from adjacent rooms
___c. Typewriters and other office equipment
___d. Noise through the ceiling
___e. Talking in hallways and office
___f. Bells
___g. Automobile traffic
___h. ______________________________

12. How often does the loudest noise disturb your work?

Never	Sometimes	Often	Very Often

APPENDIX VI

RESEARCH APPROVAL FORM FROM COMMITTEE FOR PROTECTION OF HUMAN SUBJECTS

OREGON STATE UNIVERSITY

Committee for Protection of Human Subjects

Summary of Review

Title: Assessment of Employee's Attitudes toward Noise Conditions in OSU Offices

Project Director: David C. Lawson (John P. Healey)

Recommendation:

XX Approval

_____ Provisional Approval

_____ Disapproval

_____ No Action

Remarks:

Redacted for Privacy

Date: November 15, 1978

Signature:

D. Ralph Shay
Assistant Dean of Research
Phone: 754-3437

mep
cc: Don MacDonald

APPENDIX VII

LETTER OF ENDORSEMENT FROM DIRECTOR OF SAFETY

Office of the President Oregon State University Corvallis, Oregon 97331 (503) 754-4133

May 11, 1978

TO WHOM IT MAY CONCERN

FROM: John Campbell, Director of Safety

SUBJECT: Office Noise Survey

Mr. John Healey is a graduate student with the Department of Health, Oregon State University. He is conducting an office noise survey in connection with his graduate program. Mr. Healey has authorization for such a survey as long as employees are not inconvenienced and work operations are not generally interrupted. The information obtained by the survey should be useful to this office.

JC:dca