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A Comparative Study Utilizing Carpet for Machine Noise Reduction in an Industrial Technology Woodworking Laboratory

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A COMPARATIVE STUDY UTILIZING CARPET FOR MACHINE NOISE REDUCTION IN AN INDUSTRIAL TECHNOLOGY WOODWORKING LABORATORY

by
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A Thesis

Submitted to the Graduate Faculty

of the

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in partial fulfillment of the requirements

for the degree of

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1973

This Thesis submitted by Eugene A. Schlomer in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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Title A COMPARATIVE STUDY UTILIZING CARPET FOR MACHINE NOISE REDUCTION IN AN INDUSTRIAL TECHNOLOGY WOODWORKING LABORATORY

Department Industrial Technology

Degree Master of Science

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Date July 27, 1973

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ABSTRACT

The nature and scope of this study was an experimental research project designed to determine what effect the installation of carpet would have on the reduction of potentially harmful airborne and structure-borne noise levels emitted from standard industrial woodworking machines commonly used in school instructional programs.

The specific objectives formulated for the study were to (1) determine the feasibility of using carpet as a sound absorbent floor covering material to control the airborne and structure-borne noise emissions from selected woodworking machines, (2) determine the potentially harmful noise levels produced by various woodworking machines, (3) determine what effect the carpet installed on the floor would have on noise emissions produced when processing cherry, as a typical hardwood, (4) determine what effect the carpet installed on the floor would have on noise emissions produced when processing clear white pine, as a typical softwood, and (5) determine what frequency range readings would be affected through the installation of carpet.

The seven woodworking machines tested for the purpose of this study were considered to be most widely utilized within present-day woodworking laboratories.

The experimental study was conducted using a sound level meter to measure the amount of noise emitted by the machines. The initial

readings were taken before the carpet was installed to provide a basis for comparing the experimental results. After installing the carpet, the noise emitted by each machine was measured in seven frequency bands and an overall dB(A) scale under the three test conditions.

The conclusions drawn from this research project were (1) carpet utilized as a sound absorbent floor covering material significantly reduced the noise emissions in a majority of the test conditions, (2) the addition of carpet caused a significant decrease in all upper frequency ranges, and in some cases, shifted the higher noise levels to a lower range, and (3) the installation of carpet further indicated in a number of cases that the noise level was stabilized resulting in less fluctuation between frequency bands causing steady increases or decreases in the noise level.

CHAPTER I

INTRODUCTION

Need for the Study

The sounds of our environment, have excelled in magnitude with each passing year from innovative technological advancements. These creations have fostered great achievements that have stimulated not only the technical and economic development, but progressively impend incidences resulting in a lack of auditory discrimination and other related hazards to exposed individuals. Environmental noise, however, was not a new disturbance causing discomfort to society. It undoubtedly fades back several centuries when coppersmiths experienced, through continual hammering, a markable hearing loss and, if established as a life long job, total deafness. Within that time period, negligible concern was substantiated in reference to noise exposures.

Finally in 1760, as an occurrence from the change in social and economic organization which resulted in the replacement of primitive tools by steam powered machines and tools and the development of large-scale industrial production, the Industrial Revolution was credited with the advent of noise as an occupational hazard. It was reported that workers who fabricated steam boilers were found to develop hearing loss in such numbers that the problem was regarded as (1, p. II-1) "boiler-makers disease." This was probably the first indication of human concern for the noise problem. Indeed, industrialism has since seriously multiplied the problem of noise pollution.

Finally, the onslaught of the railway systems, the invention of the internal combustion engine and the innovative uses of steel produced an expanded concern for the increased noise levels plaguing the society. With few exceptions, these advancements in technological and engineering excellence have only led to the manufacture of turbo-jet engines and large power generating plants together with more complicated and advanced electronically controlled machines which created a more urgent need for noise control.

This dilemma has reached the point where a majority of the people have been affected. The Wilson Report of 1963 (2, p. 17), presented by a committee studying the problem of noise, compared the results of surveys taken in 1948 and 1961 in which 1400 people were questioned on "whether they had ever been disturbed in their homes by external noise." It was reported that in 1948, 23 per cent of those questioned responded affirmatively, and by 1961 those affected by undesirable sound had risen to 50 per cent.

Among many individuals concerned with the noise problem, Dr. Vern Knudsen, a pioneer in acoustics, supported the fact that the sound level of society in general has been increasing at the rate of one decibel per year. Dr. Knudsen (3, p. 3) recently concluded that "the loudest noises to which we are exposed have increased some 20 decibels in the past 20 years, and if this rate of increase continues for another 20 years, they will become lethal."

In today's technological society, various groups of citizens throughout this country have formed to protest the noise problem, as well as those established by governmental agencies, in an attempt to control the environmental noise hazard. The U.S. Environmental Protection Agency (EPA) was delegated the job of protecting the community from harmful sound levels. In accordance with federal regulations, many states, cities, and municipalities have designated zoning codes to assist in regulating the potential noise problems. One of the first community action groups to take a defensive action against the noise problem was New York's "Citizens for a Quieter City."

Recently, the importance of present laws and regulations regarding the occupational safety and health of all persons involved, regardless of whether they are employed in industry or involved in school laboratories, has prevailed in the concerns of special protective agencies, as well as the educators of industrial education. Through recent legislation, factories, special work areas, and school laboratories are required to operate under specified noise tolerance levels as stated in the Occupational Safety and Health Act of 1970 (OSHA).

The Problem

The purpose of this study was to determine what effect the installation of carpet would have on the reduction of the potentially harmful noise levels produced by various woodworking machines. It has since become essential for woodworking laboratories to comply with the maximum tolerance level of 90 decibels within an eight hour period for machine noise emissions as established by OSHA.

The specific objectives formulated for the study were as follows:

1. To determine the feasibility of using carpet as a sound absorbent floor covering material to control the airborne and structure-borne noise emissions from selected woodworking machines.
2. To determine the potentially harmful noise levels produced by various woodworking machines.
3. To determine what effect the carpet installed on the floor would have on noise emissions produced when processing cherry, as a typical hardwood.
4. To determine what effect the carpet installed on the floor would have on noise emissions produced when processing clear white pine, as a typical softwood.
5. To determine what frequency range readings would be affected through the installation of carpet.

Definition of Terms

For the purpose and convenience of this study, selected terms were operationally defined as indicated:

Noise--defined by the American National Standards Institute (4, p. 10) as (1) "any undesirable sound" (2) "an erratic, intermittent or statistically random oscillation."

<u>Sound</u>--refers to a vibration of any elastic medium causing a wave motion within the frequency range capable of producing the sensation of hearing. In order for sound to have existed there must be a threefold phenomenon: the <u>source</u>--that material or object that is vibrating; the <u>transmission</u> of the vibration sound waves; and the <u>receiver</u>--the sensory perception designated by a hearing sensation, resulting in a complex of physiological and psychological reactions.

<u>Sound Isolation</u>--refers to methods of construction designed to resist the transmitted airborne and structure-borne sound waves through the utilization of wall, floor, and ceiling materials.

<u>Sound Attenuation</u>--refers to the reduction of the energy or intensity of sound through the use of absorbent materials.

<u>Ambient Sound</u>--defines the continuous, all-encompassing sound level (background noise) in a room or space, which is composed of sounds from both exterior and interior sources, none which, generally, the receiver can individually identify.

<u>Masking</u>--refers to the process by which the threshold of audibility of a transmitted sound appears to diminish by a greater loudness of background noise.

Resonance--defines the sympathetic vibration, resounding, or ringing of enclosures, room surfaces, panels, etc., when a simple harmonic excitation is induced by the natural frequency.

Absorption Coefficient "(A)"--refers to a number system assigned to materials and measures the percentage of noise reducing efficienty of acoustical materials. The coefficients vary from 0 to 1 -- a perfectly reflective material having an "a"=0, and a perfectly absorptive material having an "a"=1. The percentage of efficiency is called the Noise Reduction Coefficient (NCR). It is determined by averaging the sound absorption coefficients at 250, 500, 1000, and 2000 cycles per second (cps).

Octave Band--refers to the interval between any two sounds having frequency ratio of 2 to 1. The various frequency bands used in the study were 125, 250, 500, 1000, 2000, 4000, and 8000 cps bands.

Frequency--refers to the number of complete cycles of sound-induced air vibrations performed in one second, measured in cps and expressed in Hertz (Hz).

Hertz (Hz)--refers to the name for frequency, or cycles per second, and is equal to one cycle per second.

Sound Transmission--refers to the passage of sound through any material or structure. Airborne sound transmission--defines sound transmitted when a surface is set into vibrating by alternating air pressures of incident sound waves. Structure-borne sound transmission--refers to sound transmitted as a result of an impact or direct mechanical contact caused by a vibrating source, such as equipment, footsteps, objects dropped, etc.

Sound Pressure Level--refers to the ratio in decibels between any measured pressure (P) and the reference pressure (Pr) which is 0..0002 dynes/cm^2. It was found to be roughly equivalent to the smallest amount of pressure that will cause the ear drum to vibrate.

Noise Reduction--refers to the treatment of room surfaces, machine cabinets, guards, etc., with acoustical materials to alleviate the discomfort and distraction caused by the reflection of sound unwanted within the space.

Acoustical Material--refers to a product designed to absorb most of the sound striking it and reflecting less than 50 per cent back into the room or cabinet areas.. It's absorption depends on the thickness of porous material, the size and number of pores, and the frequency of the sound.

Decibel (dB)--refers to the smallest change in sound intensity that can be detected by the average human ear. The decibel scale extends from 0 dB (threshold of hearing), through 120 dB (threshold of feeling) to much higher sound pressures of 180 dB generated by some rocket engines resulting in total hearing loss or death. Decibels do not progress arithmatically, but logarithimically in such a system that 10 decibels of sound pressure equals 10 times the intensity at 0 dB, 20 dB=100 X intensity at 0 dB, etc. The reference pressure of 0.0002 is equivalent to the threshold of hearing.

"A" Weighted Scale--refers to the frequency range most analogous to the hearing sensations detected by the human ear.

Loudness--refers to the subjective response to a hearing sensation where the sound depends on the intensity, frequency and the characteristics of the individual's ear.

Pitch--defines the hearing sensation produced by the frequency of the sound waves. An increase in the number of vibrations per second will result in a higher pitch.

Hearing Loss or Damage--refers to a dulling of one's hearing sensation caused by loud or prolonged exposure to noise resulting in a deterioration of the auditory sense organ.

Noise Control--refers to the technology of obtaining an acceptable noise environment, consistent with administrative, engineering, and operational considerations.

Source of Experimental Material

The noise absorption material utilized within the study was donated under the assumption that a substantial reduction in noise would be experienced if proper placement was observed. Through a complimentary donation of carpeting, Mohasco Industries supplied 200 square yards for test purposes. It was determined that their commercial grade, Royal Pace line, with a rubber backing and a noise coefficient reduction of .35, would afford the best possible results. The carpet was manufactured with a low level loop design which resisted permanent damage when the pile was crushed.

Limitations

This study was limited to experimentation in the industrial technology woodworking laboratory. The material which covered the walls enclosing the test area consisted of low density fibrous sheeting. Three of the eight, 12 inch by 19 inch, twelve-lite, double hung windows were in the outside wall. All of the eight windows ran adjacent to the machine area. The height of the ceiling was measured to be 11 feet and covered with low density fibrous sheeting also. The floor consisted of a solid concrete slab, on which all machines, woodworking benches, tool cabinets and other laboratory equipment are positioned as shown in the floor plan, Figure 1. All of the equipment within the laboratory area remained in its designated position throughout the study.

The research material employed for possible noise control consisted of a commercial grade carpeting with a tight weave, backed with a rubber matting and providing a .35 NRC.

Of the machines tested, the study was limited to the processing of a biologically typical hardwood, cherry, and a typical softwood, pine.

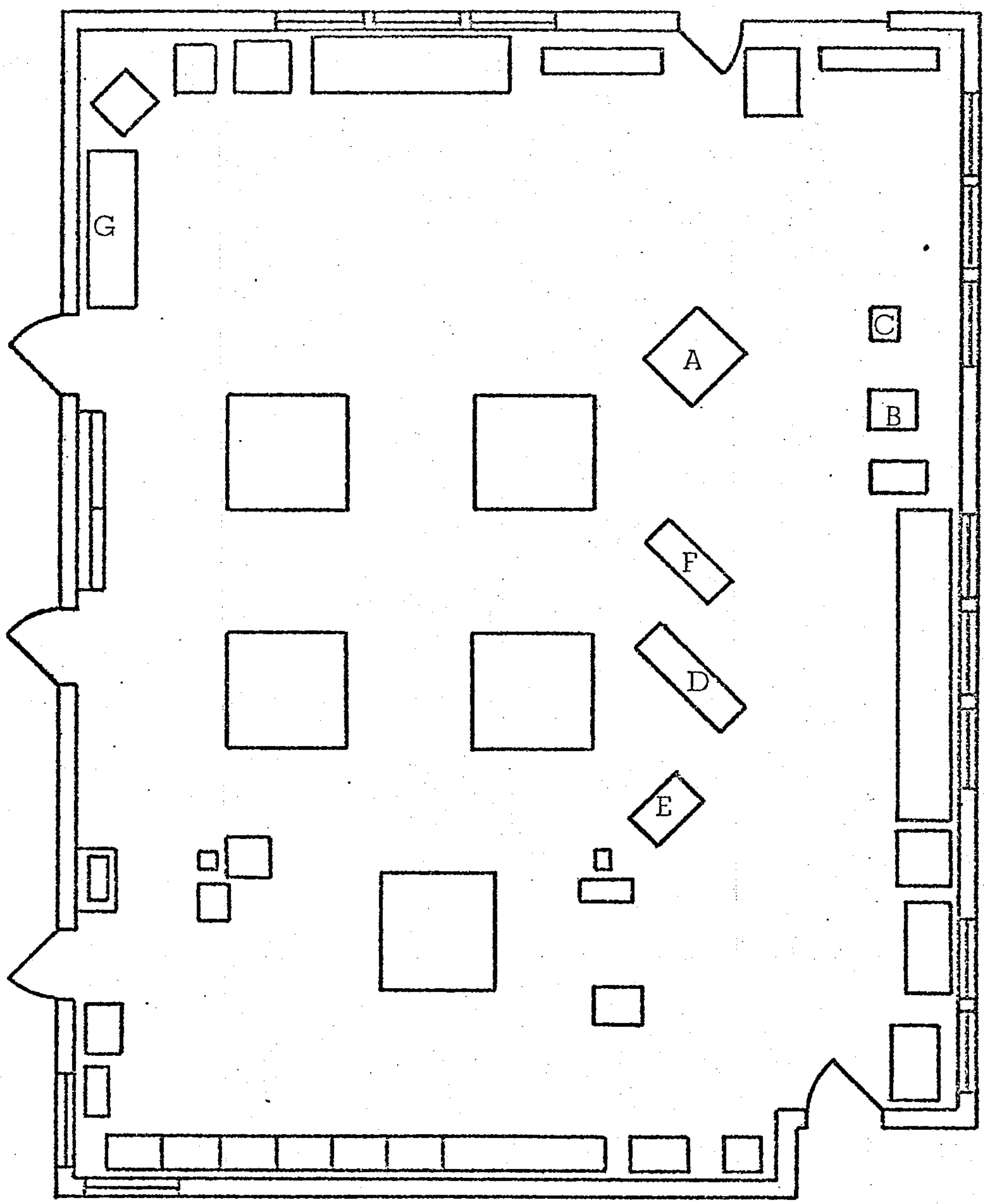

Fig. 1.--Woodworking Technology Laboratory Floor Plan

Unlettered block forms indicate other equipment typical to a woods laboratory. Machines tested, with their respective positions as indicated, were as follows:

A - Table Saw
B - Scroll Saw
C - Band Saw
D - Jointer
E - Planer
F - Uniplane
G - Radial Arm Saw

All tests were taken with the machines in proper maintenance and utilizing ideal cutting blades or knives.

The sound level readings were limited to seven frequency bands, ranging from 125 to 8000 cps, and the "A" weighted sound level scale.

CHAPTER II

SURVEY OF RELATED LITERATURE

Need for Noise Control

An analysis of current literature indicated an ever increasing concern for the effective control of noise. The need to curb the noise crises that plagued our cities was realized early in the 20th century. Various methods, which ranged from listening with a telephone receiver at one ear to a standard buzzer-produced noise, while the other ear detected outside noise, to striking a tuning fork which vibrated at a specific frequency while the elapsed time was noted for the vibration to drop to the level of the background noise, were attempted in an anticipation to record noise levels. The facts were established that these methods were merely subjective ways of measuring noise and failed to produce accurate results.

Considering noise as with many other aspects of human life, it has been shown through history that nothing changes but time and technique. It was disclosed, for instance, that Germany is still confronted with a noise problem. A public opinion survey (5, p. 138) taken in 1968 pointed out that 50 per cent of those West Germans that were questioned felt they were being "harassed by noise." It argued that the main cause of the noise problem was still related to the streets, to transportation, and to occupation.

As a result of our technology and engineering achievements, the noise in our environment increased at an alarming rate. "In all probability, the noise level will grow not only in urban centers, but, with increasing populations and the proliferation of machines, noise will invade the few remaining havens of silence in the world," reported noise control expert Leo L. Beranek (6, p. 14), of Boston. It appeared apparent that in all probability, the future quiet spots of our nation that people often escape to, will exist only in memories.

How much noise has a person endured? It was questioned, whether we should sacrifice our contentment for a noise laden society bent on inventing more powerful machines. It was also debated, whether it is correct to equate an increase in noise pollution with related advancements in power output. Drs. Dougherty and Welsh (7, p. 760), pointed out that "in the community, the noise-pollution problem is just beginning, for noise in any machine is related to power output, a quantity that is growing as rapidly in the home as in industry or on the street corner." It further stated (7, p. 762) that "community noise exposure is often above maximum standards for industry." The underlying reason being that community noises have been associated with short-term exposures as compared to a regular eight-hour work period in industry.

The problem, pointed out Canadian noise researcher Tony Embleton (8, p. 2), chairman of the Noise Committee of the Acoustical Society of America, was that "noise pollution has crept up on us." Cases reported ten years ago established the fact that noise was climbing at the rate of one decibel a year. This fact was found to still be true."

Ironically speaking, experts agreed that this problem does not have to exist in a society with such advanced knowledge for creating technological phenomena or solving nuclear problems, but for man in this present stage of civilization noise has ceased to be a trivial problem. Berland (5, p. 140) quoted senior noise scientist Vern Knudsen of Los Angeles who was quite pessimistic when he stated, "Noise, like smog, is a slow agent to death."

Fortunately in some respects, the unprecedented noise exposure in combination with the increased scarcity of areas of escape, has disturbed millions of human beings. It not only has remained the talk of the popular stereotypes who have nothing better to do than complain about general problems, but also state officials, federal government officials, and responsible citizens were concerned.

It was found that even though such large cities as New York, Chicago, Los Angeles, Tokyo, and Madrid are in contention with each other for the title of noisiest, noise had ceased to be exclusively a large city problem. However, noise consultants agreed that it is not solely the problem of industrialized societies either. Many consultants across the nation document the assumption that the uncontrolled environmental noise problems and operations of industry go unheeded by those subjected to excessive noise exposure.

It was determined that if industry is unable to design for a quiet atmosphere, society may be forced to change its life style resulting in a degressive use of the conveniences and luxuries that are causing noise pollution. Barron (9, p. 255) asserted that "industry should take the initiative to design for quiet without waiting for legislation and proof of a market." The motivation would be regarded as the preservation of the human environment.

The concerned public have pointed out that effective legislation would be necessary for proper noise control. Those agencies that have been established to control noise pollution, at times, neglect to enforce the regulations. It is essential that a climate for noise abatement be established first. If this were successful, pressure for enforcement would be easy.

Barron (9, p. 256) further warned that "it was not enough for the noise victims and the enlightened to know the dangers of unregulated noise. Noise should be made visible"! He also contended "if people could see decibels, silence would be the order of the day." It was suggested that the first problem undoubtedly resides in conveying the image of noise to the public which would, hopefully, move them to demand abatement.

Effects of Unwanted Sound

The importance of controlling harmful noise levels was seen in the problems it created. Acousticians generally agreed that the prevailing concerns rest in the possible methods of abating noise problems causing physical and psychological disorders, undetected hearing loss or damage, interference with the reception of wanted sounds, and disruption causing inefficient production and job performance.

People have demonstrated that there tends to be no exact point on a scale when a sound becomes noise. It was observed that noise, as only a particular type of sound, does not carry the same connotation for everyone. Further evidence indicated that noise, as simply "unwanted sound," distinguishes between what is noise to the ears of one might be music to the ears of another. It was explained that the roar of a rock band on one side of a street signifies a wonderful time for those attending the dance, but on the opposite side of the street where people are trying to sleep, it can be extremely undesirable.

The damage associated with excessive noise depends on the length of time the receiver is exposed and the characteristics of the noise. Noise specialists have pointed out that a person who experiences prolonged exposure to excessive noise risks a measurable amount of hearing loss. The exact effect produced by such an exposure to the hearing sensation is referred to as nerve deafness. The Occupational Safety and Health Administration (10, p. 5) reported that "nerve deafness occurs when the cilia, the tiny hair-capped cells that act as sensors within the inner ear, become damaged." Noise consultants determined that the only consolation to this fact remains in a decrease of exposure time and only moderate levels of noise, in which case the fatigued hair-capped cells would recover within a few hours providing the noise was discontinued.

Medically proven, the ear is divided into three subdivisions, the outer, middle, and inner ear. The established function of the outer and middle ear are to receive and transmit sound pressure levels to the inner ear, which in turn, is composed of the hair cells and supporting cells comprising the auditory sense organ. In most recorded cases, hearing loss occurs within the inner ear resulting in a neural injury to the hair cells. It was proven through the study of animal ears that irrepairable damage was incurred due to high level noise exposure to the cell structure of the auditory sense organ.

Many proposed theories have tried to explain noise-induced injuries to the sense organ. Facts have been reported (10, p. 5) that "as the hair cells are repeatedly overstimulated, they begin to deteriorate . . . . a condition known as sociocusis sets in." It was further found that the result of such conditions are irrepairable hearing damage where even hearing aids were useless. Estimations show that there are between 10 and 17 million American laborers exposed to severe noise levels possibly attributing to permanent hearing damage. The question was raised that since the inner ear transmits bioelectrical signals to the brain where it is perceived, what effect if any, does excessive noise have on the brain?

Various specialists in the field of mental illness have reported that there are very few methods used that will significantly link excessive noise to mental health through psychiatric diagnosis. It must also be noted that this doesn't mean that the idea doesn't exist.

Berland (5, p. 81) quoted noise consultant Dr. Bogard who pointed out that "noise can be especially harmful to persons already under other kinds of stress by lowering their ability to cope with their emotional problems." The persistent noise in such cases could trigger a person into neurotic seizures or mental breakdown. Berland (5, p. 81) further quoted Bogard who stated that "when a person hears an unwanted sound, the person has a massive feeling of impotence and frustration." It was established, from such reporting statements, that an extensive number of cases of insanity were caused by highly anxious nervous systems that cannot cope with the repeated exposures to excessive noise.

It has been determined within reasonable accuracy that hearing damage is only the most obvious within the long line of noise-induced illnesses. New research has focused on an increasing concern that other disturbing physical difficulties may be caused or intensified by the increasing noise problem in the urban environment. It has been reported by various physicians (10, p. 5) that "a relationship between exposure to excessive noise over a period of time and the incidence of heart disease and cardiovascular dysfunction, gastrointestinal disorders, and allergies, as well as endocrine and metabolic effects exists." Further evidence indicated that even a "startle reaction" results in a constriction of the blood vessels inducing a decreased flow of blood to other parts of the body. At the same instant it was proven that adrenalin is released into the blood stream in anticipation for a quick response, which, in turn, increases the possibility of fatigue or migraine headaches. Other reported symptoms detectable because of excessive noise were speech interference, fear, nervousness, and psychosomatic illnesses, as well as disruption of relaxation and sleep.

In the past, our industrial societies have considered such conditions of noise pollution as no more than just occupational hazards. At the same time, noise induced hearing loss, described as a deafening by noise, has been so prevalent among factory workers that it has become very difficult to carry out surveys that would establish criteria for normal hearing. Taylor (11, p. 74) reported that "the most widespread and serious cause of noise-induced hearing loss is subjection to high noise levels in the subject's place of work." It was concluded that such occupations may entail being an operator on large earth-moving tractors, working in a steel factory, or any number of other industrial trades. It was surmised that this does not, however, necessarily mean that under only these types of circumstances will a worker suffer contributions to hearing loss.

When testing for possible hearing damage, certain audiometric procedures were followed to analyze a specific case to determine whether it was due to excessive noise rather than other inducing agents such as drugs or sharp blows on the head. Even though substantial audiometric evidence has indicated a noise-induced loss of hearing, it may still be questioned whether the damage was incurred at the workplace or under off-job conditions.

If a hearing loss exists, employers questioned to what extent would it affect the quality or even the quantity of work performed? It was determined that many factors can contribute to work output. The literature revealed that noise would tend to disrupt the quality of work rather than quantity since more errors would be evident when one was frustrated or under strain. It further supported the idea that it is also essential not to overlook the attitude of the worker when considering the factors affecting job performances.

A number of studies indicated that subjects who felt they had no control over random exposure to noise felt they perform poorer than those who could terminate such sounds. One study also indicated that those unable to cope with the noise but still must endure it, experience greater difficulty on the job. One fact was supported, in that it prevents meaningful and necessary communications which slows the work schedule and reduces productivity. The Department of Health, Education and Welfare (12, p. 25) concluded that, "Tense, anxious persons . . . . seemed less able to cope with certain laboratory tasks as compared with those who were more relaxed." It was made clearly evident that the cumulative impact of all occupational noise exposure established a significant challenge to the workers' health, productivity, and overall well-being.

Federal Regulations

The loss of hearing, as associated with excessive noise, was attributed to mainly industry. At least the main emphasis was placed on the industrial society when confronted with techniques of noise control. It has been proven that political action is the only possible recourse, and more effectively so, if noise were to be recognized as a general threat to the environment, as well as human health. In an attempt to control excessive noise resulting in hearing loss, the federal occupational noise standards established limits indicating the permissible noise exposures. These standards were established in an effort to control noise exposure for a particular duration. One fact was supported in that few legislative bodies would pass legislation to control noise without officially approved reference standards.

The first effective regulatory controls over occupational noise in the United States was enacted under federal law about 1955. The Walsh-Healey Public Contracts Act of 1936, which made reference to excessive noise exposure, neither prescribed limits nor referred to occupational hearing loss as a problem. The act was later amended in 1969 which defined the limits for occupational noise exposure. The intention was to promote effective hearing conservation programs. Yet the federal standards neglected to include all occupational or environmental noise hazards.

In 1970, the Department of Health, Education and Welfare was requested, after the enactment of the Occupational Safety and Health Act, to establish safe exposure limits for different lengths of on-the-job exposure by the use of previously accumulated data. Federal authorities reported (1, p. II-2) that "the recommended limits for safe exposure are primarily designed to conserve hearing since this is recognized as the most serious physical problem that noise may cause in humans." The facts also indicated that inclusive evidence would not pinpoint other such noise related illnesses or performance drops as being related to excessive noise exposures. But it should be noted (1, p. II-2), however, that "adherence to noise limits for hearing conservation will also reduce 'risks' of any other noise related problem."

The protection against excessive noise exposure was established by federal regulation as indicated under section 1910.95, Table G-16, of the Federal Register, which has been reproduced in Table 1. It was reported that the National Institute for Occupational Safety and Health (NIOSH) was rather skeptical in accepting the general standard of 90 dB(A) occupational exposure level for an 8 hour period which complied to federal regulation. NIOSH, along with many other authorities, felt that the maximum of 90 dB(A) was too high and should be lowered to 85 dB(A). Although it was established as being relevant to further advances in noise control, insufficient evidence could be gathered to support the reduction.

One problem was cited in opposition to the 90 decibel level, as warned by the Behavioral and Motivational Factors Branch of NIOSH (10, p. 6), was that it, "assumes quiet surroundings for auditory recovery during off-job hours . . . It is evident the non-occupational environment also contains high noise levels which, by themselves, may pose some hearing risk, or, at a minimum, aggravate workplace noise hazards to

TABLE 1

PERMISSIBLE NOISE EXPOSURES

Duration per day, hour:	Sound Level dB(A), slow
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4	115

Source: Department of Labor, Occupational Safety and Health Administration, Occupational Safety and Health Standards, Federal Register, Vol. 37, Number 202, Part II. "Occupational Noise Exposure," Table G-16 (Washington, D.C.: Government Printing Office, October, 1972), p. 22158.

hearing."

From the preceding facts it was shown that subjection to occupational noise definitely remains linked with environmental noise. It was determined that the fight against noise pollution will only be won with the combined effort of those on the local, state, and federal level, to combat the problem.

Noise-Control Measures

Various approaches to controlling excessive occupational and environmental noises have been outlined for the employer in the May 29, 1971, issue of the Federal Register. Within the contextual framework, the document established what action is expected of the employer if the permissible noise exposures exceed occupational and environmental standards. The document further provided a three-step program which was to be initiated if such sound levels were exceeded.

It was first determined that a program of noise control must begin with a noise reduction at the source through engineering control. It was established from the federal standard (13, p. 22157) that, "When employees are subjected to sounds exceeding those limits in Table G-16, feasible administrative or engineering controls shall be utilized." The action of 'Administrative' control was initiated to reduce the time the employee was exposed to the noise. It was found that employees could share a specific noisy job or leave such jobs to be performed during the night hours when fewer people were exposed.

Although the previous control was established as one protective method, it was determined that the program must focus on engineering control if sound at its source could be substantially lowered through proper engineering design of equipment. Reliable consultants (14, p. 24) dealing in the area of machine noise control, pointed out that "machinery manufacturers must aid in solving these problems by designing new machines to make less noise and by developing noise control alterations for existing machines." Prior to any acoustical treatment, it must be considered that proper machine maintenance and replacement of worn parts could substantially lower machine noise emissions. Cudworth (15, p. 26), reported that "in many cases the cause of noise is improper maintenance of the machine due to bearing play, shaft misalignment, etc., resulting in resonant vibration or siren noise."

Assuming the machine is in proper maintenance condition, facts indicated that isolating the vibration from hard stable surfaces would be effective in reducing noise. Crocker (16, p. 30) reported that typical sources of machine noises included the "magnetic driving forces, unbalance shaking forces, and machine working forces." In a reported case (16, p. 32) it was found that by placing four isolators under a machine, the noise within the room was reduced approximately 5 dB throughout the frequency range. It was agreed that an effective reduction in noise could be achieved in some cases, but on others it might become necessary to control the transmission path of the noise, a topic to be reviewed later.

Attention was directed to the control of noise at its source. It was believed that by cutting down or dampening the resonant sound product within machine cabinets, that significant results would occur. Materials manufactured for such treatment consisted of sheet lead, leaded plastic sheets, damping tile, lead/foam sheets, or casting compounds. Noise control experts overwhelmingly agreed that the one material most common to reducing noise was the use of lead. Agne (17, p. 30) found that due to its "dense, limp, and impermeable structure," it was quite suitable for impregnating various materials to produce acoustical sound barriers and sound absorption materials. Noise consultants have frequently reported (18, p. 20) that sound absorption materials were used primarily when a reduction in "reflected sound from boundary surfaces" and where a "build-up in sound level" was evident due to reverberation in a confined space, such as machine cabinets. Reference was further made to the use of sound barrier material as being effective for acoustical enclosures around noisy machines. A study conducted by Nickerson (19, p. 35) reported that styrofoam and rubber provided an effective acoustical barrier.

Yerges (20, p. 31) further supported the use of acoustical absorbents when he stated that, "absorbents in practical quantities, applied to acceptable surfaces, will reduce overall plant noise by about 3 to 7 dB(A)." Acoustical engineers cautioned that only a specified quantity of absorbent should be used for a desired noise reduction. If, on the other hand, only a small quantity of material can be placed near the noisy area, insufficient results would be experienced.

Since it is not feasible in every occupation to rely on engineering control to effectively reduce noise within a short duration of time, the Federal Register (13, p. 22158) further states, "If such controls fail to reduce sound levels within the levels of Table G-16, personal protective equipment shall be provided and used . . . ." In analyzing the law, it indicated that all protection be provided and used by the employee, but the ultimate responsibility for their effectiveness resided with the employer. OSHA (21, p. 10) recommended that, "each employer conduct an educational training program on the importance of using the protective hearing equipment." It was agreed that such a program should be continued until 100 per cent acceptance was noted, unless such laxed atmosphere be considered a strict violation of the Act.

The two basic types of protective hearing devices used include ear muffs and ear plugs. Through audiometric measuring these devices were found to be quite effective, but workers objected because they were (21, p. 11) "uncomfortable when worn several hours a day." Further complaints listed that such devices caused headaches, irritation and could even cause poor production through a hinderance in communication.

A counteraction against the objectionable use of protective hearing devices was reportedly developed which incorporated the use of radio receivers. The reported advantage to this method allows for effective noise control while the employee is tuned in to communication systems. Also reported were new developments in ear plugs that eliminate high frequency noises but enabled the employee to engage in normal conversation. It was generally agreed that such an improvement would lead to better production with less physical distresses encountered by the workers.

While employees were required to wear ear protection and engineering controls to battle the noise problem at the source, the Federal Register (13, p. 22158) further established that, "In all cases where the sound levels exceed the values shown here [Table 1], a continuing, effective hearing conservation program shall be administered." Federal consultants determined that the law should remain in effect as long as the noise exceeded the permissible limits, however, subsequent periodic checks would be made of individual employees in order to eliminate or stop deterioration resulting in the hazards of hearing loss. It was also determined that such a program would save a considerable amount of previously compensated insurance premiums. The Federal Council for Science and Technology (9, p. 87) reported that "if only 10 per cent of workers eligible were to file claims, and the average were $1000, the total could reach $450 million."

Sound Measuring Systems

In order to design a work area for quiet operation, it was determined that certain noise criteria be established prior to construction. There have been two methods accepted that have survived over the years which use various rating schemes, each contingent on a time-lapse factor. The techniques consisted of the A-weighted sound level, and the more specific octave band noise levels.

Due to the versatility of the various sound-level meters manufactured, it was pointed out that an operator could obtain three distinct descriptions of a noise when such meters were stabilized. The three series of readings were determined by switching to weighting networks, which included scales A, B, and C. These scales were designed, according to the American Standard Association standard on measurement meters. The particular use of each scale was established under specific noise levels composed of varying frequencies.

The A scale most closely detected the sensations heard by the human ear. The frequency of this scale (5, p. 9) remained more sensitive to the higher than the lower frequencies. The B scale, which is rarely used, was reportedly characterized by a frequency ranging between 124 to 12,000 Hz, but it was indicated (5, p. 9) that it was somewhat more sensitive to the higher frequencies. It was pointed out that the C scale functions between a frequency range of 25 to 10,000 Hz, and has very few particular sensitivities. An example where a higher noise reading on the C scale than on the A scale would mean that the noise was heavily weighted toward the low frequency which the human ear would not detect.

The measurement of sound intensity has been designated by a unit called the decibel (22, p. 47), which implies "a given ratio between two powers.." Audiologists have pointed out that the decibel scale ranges from 0 dB(A), which is the weakest audible sound that can be detected by a very perceptive human ear within quiet surroundings, to 140 dB(A), which is the threshold of pain, and beyond to 190 dB(A) noise emissions reportedly detected from rocket engines. It was determined that the range of the decibel scale for sound pressures that was used mostly in acoustic measurement, started at 0.0002 microbar, which was considered the threshold of hearing, to approximately 10,000 to 100,000 microbars for rocket propulsion associated noises. As a result of an extensive range of sound intensity it was established that the level would progress logarithmically, instead of arithmetically. Therefore, by using the logarithmic system, audiologists formulated a small range of numbers that could be used to measure a wide range of sound. It was shown that a decibel progression from 0 dB to 10 dB is equal to 10 x the intensity at 0 dB; 20 dB would be equal to 100 x the intensity at 0 dB; etc. In column 1 of Table 2, a list of linear effective sound pressures were given as referred to above. Column 2 represented the same sound pressures only in scientific notation. Column 3 indicated the pressure level as a decibel--dB(A)--rating in reference to .0002 microbar. It was established that all sound level meters would be calibrated in decibels relative to a reference pressure of 0.0002 microbar.

A slight change in decibel value reportedly gave a large change in the intensity of the noise. On the other hand, engineers (10, p. 4) have determined that an improvement in the noise environment of even a "small decline in the decibel level is significant." Rupert Taylor (11, p. 54), acoustical engineer and consultant, proved that a drop of

TABLE 2.

LINEAR, EXPONENTIAL, AND DECIBEL (LOGARITHMIC) SCALE FOR EFFECTIVE SOUND PRESSURE

Effective Sound Pressure		Sound-Pressure Level dB
Descriptive Term microbar (1)	Equivalent Notation microbar (2)	Relative to 0.0002 microbar (3)
1,000,000	10^6	194
100,000	10^5	174
10,000	10^4	154
1,000	10^3	134
100	10^2	114
10	10	94
1	1	74
0.1	10^{-1}	54
0.01	10^{-2}	34
0.001	10^{-3}	14
0.0002	2×10^{-4}	0
0.0001	10^{-4}	-6
0.00001	10^{-5}	-26

Source: Leo L. Beranek, Noise Reduction, (New York: McGraw-Hill Book Company, Inc., 1960), Table 3.3, p. 51.

three decibels indicates "the noise level has diminished to one-half of its previous level."

As one of the methods mentioned earlier for determining noise criteria, the octave-band analyzer reportedly functions similar to the sound-level meter. The literature pointed out that it determines a frequency analysis of a particular output signal from the sound-level meter. The analyzer incorporated the use of an amplification factor and a series of filters, which indicated on each filtered passband, a given signal strength. Therefore, the measuring indicated an accurate analysis of various frequency levels in regard to sound intensity. The frequency passbands generally tested were the 125, 250, 500, 1000, 2000, 4000, and 8000 cycles per second bands. When analyzing noise criteria, it was reported (23, p. 43) that "physical characteristics of noise to man's reaction or response are based on the level of the noise in various frequency bands which provide important information for noise control."

The importance of significant sound-level reading, as shown in the literature, required a specific procedure for proper operation. A properly calibrated instrument was considered essential for accurate sound pressure level readings. Failure to calibrate a meter of different design, upon subsequent use, revealed (23, p. 41) that results may "differ by as much as 10 dB for the same noise and yet still be within ASA standards."

Along with proper calibration, it was determined that the best microphone for general use, adaptable for significant sound-level readings is the condenser type microphone. It was reportedly used most often because of its (23, p. 42) "long-term stability, predictable behavior in all types of environment and smooth, fixed frequency response." It was found that the high frequencies could be more accurately measured.

Further review indicated that all measurements should be taken at the operator's position when measuring noise emissions from machines. It was also determined that all readings be taken at the operator's ear level for maximum accuracy. Conclusive evidence indicated that the validity of any sound-level readings must begin with a working knowledge of the instrument and proper calibration for accurate results. Yerges (24, p. 13) stated that "only careful, systematic gathering of data will give us the information necessary for evaluation, judgment, and specification."

CHAPTER III

METHOD AND PROCEDURES

Type of Research

The investigation performed by the author was an experimental research project designed to ascertain the various methods of reducing noise emissions from standard industrial woodworking machines commonly used in school instructional programs, by utilizing sound absorbent materials. The experimental design allowed for the control of specific variables which were believed to be contributing factors in the emission of harmful noises.

Description of Test Area

The industrial technology woodworking laboratory consisted of a floor area 36 feet by 48 feet and was constructed with 11 foot walls resting on a concrete slab floor. An investigation of the material covering the walls and ceiling revealed that they consisted of low density fibrous sheathing.

Within the walls adjacent to the machine area, there were eight, 12 inch by 18 inch, twelve-lite, double hung windows, of which three were positioned in the outside wall. The bottoms of all the windows were 40 inches up from the floor. There were also two 41 inch by 47 inch observation windows located in one corner of the laboratory.

The position of all laboratory equipment and test machines remained in their specific positions, as illustrated in Figure 1, throughout the experimentation.

Measurement Instrument Choice

The researcher determined that the criteria concerning the selection of a precision sound level meter, basically entailed a means by which overall dB(A) readings, as well as a series of frequency readings, could be accurately measured. The instrument chosen by the author for the purpose of the study was a Type 2203, manufactured by Bruel and Kjaer of Naeram, Denmark.

The battery operated sound-level meter incorporated a 0.95 inch diameter, Type 4132 condenser microphone. It was found that the cartridge type condenser microphone satisfied the specifications for laboratory standard pressure microphone Type L of the American Standard Z.24.8. Through an investigation of the specifications on the meter, it was found that the shell of the meter was shaped specifically to minimize acoustic diffraction to insure an accuracy level of a ± 1 dB between 20 and 15,000 cycles per second (cps).

The meter was acoustically calibrated with a Type 4420, 250 cps pistonphone. The acoustic calibrater, as determined by audiologist, can be utilized with a number of other microphones.

The researcher also used an Octave Filter Set, Type 1613, manufactured by Bruel and Kjaer, which was used in combination with the sound level meter. The investigator determined that the frequencies measured for the purpose of the study would include the 125, 250, 500, 1000, 2000, 4000, and 8000 cps octave bands.

The instrument was calibrated by setting the attenuator dial on 120 dB, linking the Octave Filter Set at 250 cps through the external frequency setting to the sound level meter, and then positioning the pistonphone on the microphone.

Further adjustments provided on the meter included a "Fast" and "Slow" response speed as indicated by a switch. Through the review of previous federal research, the author determined that the "Slow" response speed would be utilized in the study to more closely correspond to the results accumulated and presented in the federal standards table on permissible noise exposures (Table 1).

Selection of Test Machines

The woodworking machines tested for the purpose of this study were considered to be most widely utilized within present-day woodworking laboratories. The researcher had determined through observation and use of the machines that of the seven machines measured, five appeared to emit more noise than the others. This revealed the necessity to formulate methods that would be effective in reducing the potentially harmful noises emitted from these machines.

For the purpose of this study, the selected machines and characteristics of their cutting mechanisms were described as follows:

Delta Model 96, 10 inch circular saw equipped with a 40 tooth, 10 inch carbide tipped, combination blade.

Powermatic Model 95, 24 inch scroll saw equipped with a standard 10 tooth-per-inch, 1/4 inch by 5 inch blade.

Delta Model 141, 14 inch band saw equipped with a standard 1/2 inch blade.

Powermatic Model 60, 8 inch jointer equipped with a set of standard knives.

Boise Crane Model 1002, 4 inch by 12 inch thickness planer equipped with a set of standard knives.

Rockwell Model 22-300, uniplane equipped with eight carbide tipped cutters.

Dewalt Model 1030, 10 inch radial arm saw equipped with 40 tooth, 10 inch carbide tipped, combination blade.

All of the machines tested were equipped with new or reconditioned cutting blades or knives. It was observed that nearly all of the machines tested were manufactured with metal bases, except for the radial arm saw which had been placed on a wooden cabinet. Further information on machine specifications may be reviewed by consulting the operator's manual.

Research Design

The experimental study was conducted using a sound level meter to measure the amount of noise emitted by the machines. The initial readings were taken before the carpeting was installed which provided a basis for comparing the test results. Throughout the collection of the data, it was established that a difference of 3 dB would be considered significant. This was based on the review of literature, which further supported this reference level when it stated (11, p. 54) that a lowering of 3 dB would reduce the noise by one-half of the previous level.

A pilot study was conducted prior to the major research project which determined the length and width of the stock which would be processed. It was found that a piece of stock 24 inches long would allow adequate time to take a reading. It was also determined that 1/2 inch would be removed from the stock when performing all sawing operations when the noise readings were made. One-sixteenth inch of stock was removed per cut on the planer. The jointer and uniplane were adjusted to remove 1/8 inch of stock on each operation. The pilot study revealed that this amount of stock removed for the respective machines was the most appropriate to minimize the possibility of excessive vibration.

The two species of wood chosen for the study included a hardwood, which was cherry, with the softwood being clear white pine. All of the material processed consisted of 1 inch, nominal thickness stock, surfaced on four sides. The machines tested were equipped with new or reconditioned cutting blades or knives and were in adjustment as described in the machine's specification manual. The safety guards on the machines, as supplied by the manufacturers, were operational to insure optimum safety for the operator.

To provide greater durability and more efficient use of the carpet, it was determined that the carpeting should be permanently adherred to the concrete floor. After installing the carpet, the noise emitted by each machine was measured individually in seven frequency bands and an overall dB(A) reading for both species of wood and under no load.

The data were recorded and analyzed. The results were then compared with the reference level of 3 dB noise reduction for significance. All readings which were 3 dB less when the sound level readings were compared with and without carpet were regarded as significant for the purpose of this study.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

Findings

The purpose of this study was an attempt to (1) determine the feasibility of using carpet as a sound absorbent floor covering material, to control the airborne and structure-borne noise emissions from selected woodworking machines, (2) determine the potentially harmful noise levels produced by various woodworking machines, (3) determine what effect the carpet installed on the floor would have on noise emissions produced when processing cherry, as a typical hardwood, (4) determine what effect the carpet installed on the floor would have on noise emissions produced when processing clear white pine, as a typical softwood, and (5) determine what frequency range readings would be affected through the installation of carpet.

While conducting the experimental research program, neither the test machines nor any other equipment were moved from their original positions, as shown in Figure 1. It should also be noted that the measurements were taken during the time when the building was not in use to insure that the ambient noise levels were consistent.

The report of the findings was arranged into seven tables, consisting of three conditions each, based on the operation of the machines under no load and load through the processing of both a hardwood and a softwood. For each specific dBA reading and frequency band reading, the findings were compared with the non-carpeted facility. It was further determined that the frequency bands would be divided into three categories to facilitate discussion, which were: lower ranges [125 and 250 cps bands] middle ranges [500, 1000, and 2000 cps bands], and upper ranges [4000 and 8000 cps bands].

Report of Data

A review of the data listed in Table 3 indicated that a greater amount of noise was produced by the jointer in the upper frequency bands when operating under the three test conditions on the concrete floor. When comparing the carpeted no load condition, it was found that the noise was stabilized or lowered within all frequency ranges. The data further indicated that the carpeting significantly lowered the frequency levels in the 1000, 2000, and 4000 cps bands when operating under no load.

The findings also showed that there was a significant reduction of noise in the dBA level under all three conditions. While processing hardwood, it was found that only in the 4000 cps band was the noise significantly reduced. Table 3 further revealed that the most noise was produced in the middle and upper frequency ranges in which only two levels were significantly decreased when processing both species of wood.

TABLE 3

NOISE LEVELS OF THE TABLE SAW IN EIGHT FREQUENCY BANDS AND A dBA TAKEN IN THE OPERATORS POSITION AT A DISTANCE OF TWO FEET FROM THE CENTER OF THE CUTTING BLADE UNDER THE THREE TEST CONDITIONS

Frequency Ranges cps	No Load			Hardwood			Softwood		
	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference
125	64	63	1	68	67	1	64	61	3
250	64	63	1	67	66	1	65	64	1
500	64	62	2	72	71	1	68	66	2
1000	64	61	3	76	73	3	75	73	2
2000	67	62	5	75	76	-1	78	75	3
4000	68	62	6	84	81	3	82	81	1
8000	60	58	2	82	80	2	82	80	2
dBA	72	68	4	93	90	3	86	82	4

According to the data in Table 4, there were significant decreases in the dBA level for the band saw under all three conditions. It further reported that in almost all frequency ranges the noise level was significantly decreased when operating under the three conditions.

Table 4 also indicated, under no load conditions, that the band saw produced a higher sound pressure level in the lower frequency range. Further analysis of Table 4 revealed that when processing both species of wood, the noise levels were stabilized within each set of frequency ranges. Within the non-carpeted setting, however, the greater emissions of noise were indicated in the upper frequency bands, during the processing of the material.

The data cited in Table 5 revealed that the carpeting significantly reduced the noise level of the dBA readings for the scroll saw under all three conditions. An inspection of the data also indicated a general increase in the sound intensity in the middle frequency ranges when measured without carpeting and under all three conditions. However, the data collected after installing the carpet revealed, under the no load condition, that the loudest frequency ranges had shifted to the lower bands.

A further study of Table 5 indicated that when processing both species of wood, a significant reduction of noise occurred in five frequency bands; excluded were the 250 and 1000 cps bands. It also indicated that the higher sound levels produced in the middle frequency bands had decreased resulting in significant reductions of sound in the

TABLE 4

NOISE LEVELS OF THE BAND SAW IN EIGHT FREQUENCY BANDS AND A dBA TAKEN IN THE OPERATORS POSITION AT A DISTANCE OF TWO FEET FROM THE CENTER OF THE CUTTING BLADE UNDER THE THREE TEST CONDITIONS

Frequency Ranges cps	No Load			Hardwood			Softwood		
	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference
125	75	67	8	72	68	4	72	68	4
250	80	75	5	78	74	4	78	76	2
500	80	76	4	76	74	2	78	75	3
1000	72	67	5	74	69	5	78	70	8
2000	70	63	7	75	73	2	79	73	6
4000	69	61	8	82	71	11	80	71	9
8000	66	60	6	83	73	10	82	77	5
dBA	80	75	5	84	81	3	84	81	3

TABLE 5

NOISE LEVELS OF THE SCROLL SAW IN EIGHT FREQUENCY BANDS AND A dBA TAKEN IN THE OPERATORS POSITION AT A DISTANCE OF TWO FEET FROM THE CENTER OF THE CUTTING BLADE UNDER THE THREE TEST CONDITIONS

Frequency Ranges cps	No Load			Hardwood			Softwood		
	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference
125	74	69	5	77	71	6	75	70	5
250	77	71	6	74	77	-3	77	78	-1
500	84	71	13	82	79	3	82	79	3
1000	78	65	13	76	78	-2	75	74	1
2000	75	64	11	79	76	3	78	73	5
4000	71	61	10	79	74	5	74	70	4
8000	64	61	3	74	68	6	73	65	8
dBA	84	72	12	84	80	4	85	80	5

500 and 2000 bands. A shift of the higher sound levels from the middle to lower frequency bands occurred under all conditions.

A review of the data listed in Table 6 indicated that there was no significant reduction in the dBA level when testing the radial arm saw under a no load condition. A further review of the data showed a significant reduction in the dBA level when processing hardwood, but failed to show significance for the softwood.

The data in Table 6 also indicated that a small reduction under the no load condition was achieved in two frequency bands while the other levels revealed an increase or remained at the same level. The data collected during the processing of the hardwood indicated a significant decrease in the noise level in all frequency ranges, except for the 4000 cps band. It was further shown that a significant reduction occurred in the lower and middle frequency ranges when processing the softwood. The data also showed that the highest noise levels occurred in the upper frequency range under all three conditions.

According to the findings in Table 7, the jointer showed a significant decrease in the dBA frequency range when the materials were processed. Further review of the data indicated no significant decrease in the dBA level under the no load condition. It was also recorded that a significant increase occurred in the lowest frequency level under all three conditions.

The data also indicated in Table 7 that a significant decrease occurred in the upper frequency levels under all three conditions. It

TABLE 6

NOISE LEVELS OF THE RADIAL ARM SAW IN EIGHT FREQUENCY BANDS AND A dBA TAKEN IN THE OPERATORS POSITION AT A DISTANCE OF TWO FEET FROM THE CENTER OF THE CUTTING BLADE UNDER THE THREE TEST CONDITIONS

Frequency Ranges cps	No Load			Hardwood			Softwood		
	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference
125	60	60	0	75	64	11	70	63	7
250	56	58	-2	78	69	9	73	68	5
500	61	62	-1	82	76	6	78	75	3
1000	66	65	1	91	83	8	88	78	10
2000	71	72	-1	92	88	4	90	86	4
4000	83	81	2	98	97	1	91	91	0
8000	71	71	0	102	94	8	92	90	2
dBA	85	85	0	101	96	5	96	94	2

TABLE 7

NOISE LEVELS OF THE JOINTER IN EIGHT FREQUENCY BANDS AND A dBA TAKEN IN THE OPERATORS POSITION AT A DISTANCE OF TWO FEET FROM THE CENTER OF THE CUTTING BLADE UNDER THE THREE TEST CONDITIONS

Frequency Range cps	No Load			Hardwood			Softwood		
	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference
125	68	83	-15	67	84	-17	66	83	-17
250	71	73	- 2	74	75	- 1	74	74	0
500	77	75	2	85	83	2	83	77	6
1000	72	69	3	81	78	3	74	72	2
2000	69	64	5	84	78	6	76	75	1
4000	67	63	4	82	80	2	79	71	8
8000	63	59	4	84	75	9	85	79	6
dBA	78	76	2	89	86	3	87	83	4

further indicated a shift of the higher noise levels from the middle frequencies to the lower frequencies under the no load condition, but showed another shift to the higher frequency bands when the material was processed.

On the basis of the data in Table 8, the datarevealed a significant decrease in the dBA level of the uniplane under the no load condition. A significant decrease in the dBA level was achieved when the hardwood was processed, but a similar decrease failed to occur when the softwood was processed. It was also revealed that a significant decrease occurred in all frequency ranges, except for the 8000 cps band, when operating under no load conditions.

A study of Table 8 further indicated significant decreases in the middle and upper frequency ranges when the materials were processed. It was also noted that an increase in the noise level occurred in the lower frequency ranges when both materials were processed. The data further revealed that in nearly all middle frequency ranges the noise levels were significantly reduced. It was also recorded that a significant shift occurred from the middle and upper frequency ranges to the middle frequency ranges after the carpeting was installed.

An inspection of the data in Table 9 indicated that a significant decrease in the dBA level occurred under no load and when the softwood was processed. It further indicated that no significant decrease was observed when processing hardwood. The findings also revealed that in nearly all frequency levels a significant decrease in the noise level was

TABLE 8

NOISE LEVELS OF THE UNIPLANE IN EIGHT FREQUENCY BANDS AND A dBA TAKEN IN THE OPERATORS POSITION AT A DISTANCE OF TWO FEET FROM THE CENTER OF THE CUTTER WHEEL UNDER THE THREE TEST CONDITIONS

Frequency Range cps	No Load			Hardwood			Softwood		
	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference
125	85	77	8	77	78	-1	76	78	-2
250	82	78	4	80	81	-1	79	83	-4
500	102	97	5	95	90	5	94	91	3
1000	91	82	9	92	85	7	91	88	3
2000	85	79	6	89	84	5	84	86	-2
4000	77	74	3	92	85	7	87	84	3
8000	73	71	2	90	88	2	91	86	5
dBA	99	96	3	96	92	4	96	94	2

TABLE 9

NOISE LEVELS OF THE THICKNESS PLANER IN EIGHT FREQUENCY BANDS AND A dBA TAKEN IN THE OPERATORS POSITION AT A DISTANCE OF TWO FEET FROM THE CENTER OF THE CUTTER HEAD UNDER THE THREE TEST CONDITIONS

Frequency Ranges cps	No Load			Hardwood			Softwood		
	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference	Without Carpeting	With Carpeting	Difference
125	67	63	4	72	67	5	68	65	3
250	76	72	4	75	71	4	73	69	4
500	81	76	5	86	83	3	84	79	5
1000	77	73	4	94	88	6	87	84	3
2000	77	74	3	90	89	1	88	85	3
4000	76	73	3	87	86	1	87	86	1
8000	75	73	2	86	83	3	86	84	2
dBA	83	79	4	96	94	2	95	92	3

established by installing the carpet.

The findings reported in Table 9 indicated that the high noise levels from the middle and lower frequency ranges were significantly reduced under the no load condition and when processing softwood. They also revealed similar significant decreases in the middle and lower frequency levels when the hardwood was processed. The data also revealed a shift of the highest noise levels, which were produced in the middle frequency ranges in all three conditions, to more stable overall levels occurring within the middle and upper frequency ranges.

Summary of Data

An analysis of the data revealed that the noise emissions occurring in the upper frequency ranges were altered by installing carpet. This was indicated by a reduction of noise in all upper frequency ranges within each condition for all test machines.

A summary of the data showed that a significant reduction occurred in the dBA level for six of the machines tested under the no load condition. It also showed that only the radial arm saw indicated no change in the amount of noise produced under no load. The data further indicated significant decreases in the middle frequency ranges for six machines, excluding the radial arm saw.

A general review of the data indicated that approximately one-half of those machines tested showed significant reductions in noise produced in the lower frequency ranges under no load conditions.

A further inspection of the data revealed a significant reduction in the dBA level for all machines when processing hardwood, except the thickness planer which narrowly failed to produce significant results. The data indicated that the lower frequency ranges produced by the test machines when processing hardwoods, were less affected in almost every instance when utilizing carpet. The two exceptions were the thickness planer and the radial arm saw. The data also showed that significant decreases occurred in all middle and upper frequency ranges for all machines when processing hardwood.

The data collected when processing softwood revealed that a significant decrease in the dBA level occurred for all test machines excluding the radial arm saw and uniplane which failed to produce a significant reduction by one sound level. An analysis of the data revealed that the majority of the test machines produced significant decreases in the noise level in the lower frequency ranges.

The analysis further indicated that significant decreases occurred in all middle frequency ranges when processing the softwood. During the operation of four machines, the largest decrease occurred in the upper frequency ranges, while the other machines indicated their largest reductions in the middle frequency range.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was concerned with (1) determining the feasibility of using carpet as a sound absorbent floor covering material to control the airborne and structure-borne noise emissions from selected woodworking machines, (2) determining the potentially harmful noise levels produced by various woodworking machines, (3) determining what effect the carpet installed on the floor would have on noise emissions produced when processing cherry as a typical hardwood, (4) determining what effect the carpet installed on the floor would have on the noise emissions produced when processing white pine as a typical softwood, and (5) determining what frequency range readings would be affected through the installation of carpet.

The conclusions formed through conducting this study are based on decibel readings acquired through testing woodworking machines in the Industrial Technology Department at the University of North Dakota. Any generalizations made from the results should take into account the limitations of this study.

Conclusions

The following conclusions have been ascertained from the results of the data in this study:

1. There were significant decreases in all upper frequency ranges under the three test conditions performed on each machine through the addition of carpet.

2. The carpeting significantly reduced the sound transmission of structure-borne and resonant sound waves produced within metal cabinets against the concrete floor in 93 comparative results of the frequency ranges of all test conditions.

3. A significant decrease in the sound pressure level occurred in 16 comparative results when the dB(A) level was tested under the twenty-one conditions after installing carpet.

4. In seven of eight conditions where the dBA noise level exceeded OSHA standards, there was no substantial degree of sound absorption to allow compliance with the standard; however, five of seven still indicated a significant reduction by adding carpet.

5. All machines, except the thickness planer, revealed a significant reduction in the dB(A) level while processing hardwood in the carpeted facility.

6. A significant reduction occurred in the dB(A) level for six machines tested under the no load condition, excluding the radial arm saw which did not show a significant decrease.

7. Significant decreases occurred in the middle frequency ranges for all machines operating under a no load condition, again excluded was the radial arm saw which did not show a significant decrease.

8. The radial arm saw was the only machine positioned on a wooden base that showed no reduction in the dB(A) level or any significant change in the frequency ranges while operating under a no load condition.

9. Significant decreases occurred in all middle and upper frequency ranges during the processing of hardwood by all machines when compared to the carpeted facility.

10. A majority of the test machines revealed significant decreases in the sound pressure levels of the lower frequency ranges when processing softwood.

11. Excluding the radial arm saw and the uniplane, five test machines indicated a significant decrease in the dB(A) level when processing softwood.

12. As a result of adding carpet, all machines produced significant decreases in the middle frequency ranges when processing softwood.

13. The largest decrease in the upper frequency ranges was revealed when processing softwood with the band saw, scroll saw, jointer, and uniplane, while the other machines produced greater reductions in the middle frequency ranges by adding carpet.

Recommendations

The results of this study should provide a basis for extended research through which other sound absorbent materials could be utilized to further reduce the harmful noise levels being produced in various frequency ranges and dBA levels. The writer feels that further significant reductions could occur by using acoustical material within the machine cabinets and around guard areas which would appear to provide adequate reductions for complying with the Occupational Safety and Health Act.

For statistically significant results, a study could incorporate only one machine, enclosed in a small room, and utilize sound absorbent materials on the walls and ceiling to absorb significant amounts of incident sound waves resulting in a reduction of the reverberant noise. This method would also facilitate the collection of more data under a single variable, thus reducing the probability of human error.

Similar reductions in sound pressure levels could be accomplished by placing a module around the test machine and then proceed with the experiment of various acoustical materials.

It is apparent that research is necessary to determine the feasibility of using carpet from the standpoint of maintenance and depreciation. Consideration should also be given to the affect stains, paints, varnishes, and other solutions will have on the carpet.

It is also recommended that subsequent research be carried out to substantiate the results of this study.

The writer further recommends that extensive research be implemented to form a rationale for the importance of effective sound control in the industrial arts laboratories. Even though the noise exposure time for the student may be within federal standards, the instructor who has worked in the laboratory for a majority of the school day is highly subjected to possible hearing damage.

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