NOISE AND HEARING

RELATIONSHIP OF INDUSTRIAL NOISE TO HEARING ACUITY IN A CONTROLLED POPULATION

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

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Relationship of Industrial Noise to Hearing Acuity in a Controlled Population

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

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Foreword

Noise is an unwelcome byproduct of our present way of life. At home, in traffic, at play and at work, on the farm and in industry, everyone is being exposed to more and more noise from a multitude of sources. Although there have been many studies on the various physiologic and psychologic effects of noise, much more needs to be done to learn the full significance of such effects.

The number of workers subjected to potentially harmful noise levels probably exceeds the number exposed to any other significant hazard in the occupational environment. Increased mechanization and speeding up of industrial processes have often been accompanied by increased noise. In some cases, prolonged exposure to such noise can produce a permanent adverse effect on hearing ability. Because of the great diversity in noise environments, the differences in exposure time, and varying individual susceptibility to noise, the degree of hazard in many industrial situations has not yet been clarified. The problem is further complicated by the fact that hearing loss develops in a high percentage of the population as part of the aging process.

There is a pressing need for industrial noise standards. Despite the lack of sufficient reliable data for the correlation of noise exposure with hearing changes, it has been necessary to provide guidelines for the establishment of hearing conservation programs, for adjudication of compensation claims, for the development of regulations, and for the design of industrial processes. Several types of standards or criteria for such purposes have been proposed and are being applied in various ways.

The studies reported here present data which should help to verify the accuracy and reliability of different criteria which have been suggested.

HAROLD J. MAGNUSON, M.D.
Chief, Division of Occupational Health.

Acknowledgments

These studies would not have been possible without the cooperation and assistance of the Bureau of Prisons of the U.S. Department of Justice. We are greatly indebted to Mr. James V. Bennett, Director of the Bureau, for his complete support from the time the project was proposed until its completion. The audiometric and environmental phases of these studies have required essentially daily assistance, over a period of about 7 years, from many members of the Bureau of Prisons' staff. We regret that it is not practical to list all of them by name. The following individuals are listed, not only in appreciation for their own contributions but also as representatives of their staffs who likewise provided invaluable help:

In the *Bureau of Prisons headquarters in Washington, D.C.:* Captain A. H. Conner, Associate Commissioner, Federal Prison Industries, Inc.; Mr. T. Wade Markley, Deputy Associate Commissioner, Federal Prison Industries, Inc.; Mr. H. G. Moeller, Deputy Assistant Director, Bureau of Prisons; Dr. Stanley Krumbiegel, Chief Medical Officer, Bureau of Prisons, and his successor, Dr. Harold M. Janney. At the *U.S. Penitentiary, Lewisburg, Pa.:* Wardens George W. Humphrey, Fred T. Wilkinson, John C. Taylor, Charles R. Hagan, and Jay T. Willingham; Chief Medical Officers Carl I. Pirkle, Joseph Greco, and Leon A. Witkin; and Superintendent of Industries John R. Lazar. At the *U.S. Penitentiary, Leavenworth, Kans.:* Wardens Walter A. Hunter and Chesley H. Looney; Chief Medical Officers Russell O. Settle and James L. Baker; and Superintendents of Industries Oscar M. Shelton, Michael T. Santa, Orla E. Palmer, and Wade T. Springsted. At the *U.S. Penitentiary, Terre Haute, Ind.:* Wardens P. J. Madigan, J. Ellis Overlade, and Donald C. Byington; Chief Medical Officers Thomas H. Smith and Edward C. Rinck; and Superintendent of Industries Lester R. Parham. At the *U.S. Penitentiary, Atlanta, Ga.:* Wardens W. C. Hiatt, William Hardwick, and David M. Heritage; Chief Medical Officer Harold M. Janney; and Superintendent of Industries James D. Crowder.

We next wish to express our appreciation to Dr. Aram Glorig, director of research, American Academy of Ophthalmology and Otolaryngology, for invaluable assistance and guidance, particularly during the earlier phases of the study. Dr. Glorig specified the audiometric procedures, trained the personnel who began the hearing testing, guided us on equipment and test environments, and helped plan many features of the study. He was always available for consultation when special problems arose.

Many members of the staff of the Division of Occupational Health participated in the project in one way or another. Dr. W. Clark Cooper contributed a great deal in helping to plan the project and get it underway. Dr. W. M. Gafafer also provided substantial guidance in the development of the study. Mr. Edward S. Weiss helped substantially in developing the statistical methods and data-handling procedures used. Mr. Tetsuo Shimamoto and Dr. Hugh P. Brinton also provided assistance with statistics.

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Abstract

The relationship of changes in hearing acuity to long-term exposure to industrial noise was studied in Federal penitentiaries during the period 1953–59 by the Division of Occupational Health of the U.S. Public Health Service.

The workers studied were employed in textile mills; wood products and sheet metal products manufacturing; brush, shoe, and clothing factories; and printing. Overall noise levels in these operations ranged from approximately 75 to 110 decibels.

Men employed in these plants had their hearing tested periodically. A group of approximately 600 men was maintained during the course of the study. Since replacements were made to take care of turnover, data were collected on 1,952 different individuals during the study. Of these, 1,070 had preemployment audiograms. Approximately 12,000 men had their hearing tested at the time of admission to the penitentiaries.

Findings are compared with four well-known proposed sets of criteria. For hearing conservation purposes the findings are in agreement with the recommendations of the Subcommittee on Noise of the American Academy of Ophthalmology and Otolaryngology and Air Force Regulation 160–3. In general, the damage risk criteria proposed by Rosenblith and Stevens for broad band noise are also confirmed. The theory that narrow band noise requires more stringent criteria is not substantiated by the findings of these studies, if the definition of Air Force Regulation 160–3 for such noise is employed. Approximately half of commonly encountered industrial noise would be classed as narrow band by this definition. The lower limit of 50 sones per octave band, as proposed by Hardy, does not always provide sufficient protection.

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Introduction

During 1953 and 1954 a series of studies was started by the U.S. Public Health Service at several Federal penitentiaries for the purpose of obtaining data on the relationship of changes in hearing acuity to long-term exposure to industrial noise. These studies involved periodic testing of the hearing of workers in a number of the industrial plants operated by the Federal Prison Industries, Inc., at the penitentiaries in Lewisburg, Pa., Leavenworth, Kans., Atlanta, Ga., and Terre Haute, Ind. The types of industries included were cotton and woolen textile mills; wooden and metal furniture manufacturing; shoe, clothing, and brush factories; and printing. The operations in these plants produce noise environments having total sound pressure levels in the approximate range of 75 to 110 decibels. Present evidence, as well as that available when the studies began, indicates that sustained exposure to noise exceeding the higher figure is likely to produce adverse effects on hearing, while, on the other hand, demonstrable harm seems improbable when noise levels are kept below the lower figure. Thus, standards designed to protect hearing from adverse effects by noise are likely to lie somewhere within the range encountered in the industries studied.

A brief description of these studies was published in 1954, and a report of some of the findings was published in 1958. That report is reprinted here as an appendix. The purpose of this report is to present in more detail the overall findings from the beginning of the studies up to July 1, 1959.

There have been numerous and widespread efforts, particularly during the past decade, to accumulate reliable data from which criteria for an acoustically safe environment can be developed. Much progress has been made during this period, but many critical questions are still unanswered. It is likely that many more years will pass before more reliable, precise standards for certain types of noise exposures can be developed. The reasons for these difficulties have been thoroughly discussed in the literature (*1*). Some of them are discussed elsewhere in this report. It is sufficient here merely to state that the problems involved in developing criteria are complex, among other reasons, because of (1) the wide variety of noise exposures with respect to duration, intensity, continuity, and frequency characteristics; (2) variation in individual susceptibility to noise; (3) difficulty in determining how much of any change in hearing level might be due to temporary shift in hearing threshold; (4) the extent to which changes are brought about due to aging; (5) the effects of nonoccupational noise exposures upon hearing; and (6) difficulties in conducting meaningful studies of large industrial populations without disrupting production or work schedules.

Various agencies, organizations, and individuals both in the United States and abroad have published suggested standards for noise, not only for damage risk and hearing conservation but also for speech communication and annoyance. This report, however, will be confined to the questions of damage risk and hearing conservation.

... and drum sanders. All of *Noise data*.—Sound pressure level measurements

General Description of Studies

Initially, approximately 600 workers in the industries under study were selected, and their hearing was tested periodically. The original procedure was to conduct hearing tests at 3-month intervals. This schedule was later modified, as described elsewhere in this report. As members of this group of workers, henceforth referred to as the "study group," were transferred out of the industries for any reason, they were replaced in the study group by other individuals having similar noise exposures.

After the studies were started, routine audiometric testing became a part of the physical examination given each inmate when he entered the institution. Since there had previously been no audiometric testing, no data were available on the hearing of those in the original study group prior to their assignment to the industry. The entrance examination audiograms, however, provided such baseline information for most of the men replacing those in the original study group.

With the turnover in employment, a total of 1,952 men were included in the study group at some time or other during the period covered by this report. Preemployment audiograms were available for 1,070 of these men.

Work histories prior to admission to the penitentiaries were not obtained. Consequently, no information is on hand to indicate previous noise exposures of significance. While such data would be desirable, particularly in considering the hearing of specific individuals, the general hearing level of men admitted to the institutions indicates that the men in the study group were generally not subjected to significantly unusual amounts of noise prior to entering the institutions.

At the time the studies were begun, groups of workers not exposed to excessive noise on their jobs were included for control purposes. However, with the subsequent availability of audiometric data on large numbers of men at the time of admission, it was decided that these supplemental control data would not be required.

Hearing testing was performed by personnel at the institutions, and the data were sent to the Division of Occupational Health of the Public Health Service for filing and analysis. Originally, the data were placed on marginal-punched hand-sorted cards. Because of the volume of data involved, a change was made during the course of the study to IBM cards.

Noise measurements and analyses in the industries under study were made periodically by engineers of the Division of Occupational Health. The data obtained were recorded on marginal-punched cards.

All hearing testing was performed in acoustically treated testrooms in the institution hospitals. These hospitals are under the direction of Public Health Service physicians on assignment to the Bureau of Prisons. The personnel performing the hearing tests were under the general supervision of these Public Health Service officers. Dr. Aram Glorig, consultant on these studies, visited each of the institutions at the time the study was to begin and personally instructed hospital personnel in the audiometric test procedures to use. Although it was first thought that civil service personnel in the hospitals would do most of the audiometry, much of this work was later taken over by inmates who were on work assignment to the hospitals.

Since this project continued over a number of years, there was some unavoidable turnover in personnel engaged in the audiometric testing. Each man taking on such duties received instructions from his predecessor. It is recognized that this was not an entirely satisfactory procedure and that it would have been better for each individual performing hearing tests to have been personally instructed by Dr. Glorig. Unfortunately, this was not practicable. The senior author of this report, however, had accompanied Dr. Glorig for the original instructions, and each time he revisited an institution, he checked on the audiometric techniques employed to insure that they continued to be consistent. In addition, written instructions on audiometric test procedures were given to each of the institutions.

Only pure-tone, air-conduction audiometry was performed with testing at 500, 1,000, 2,000, 3,000, 4,000, and 6,000 cycles per second (cps). All audiometers used met the standards of the American Standards Association and the American Medical Association. The audiometers were occasionally returned to the factory for calibration, but frequent testing of control personnel was primarily relied upon for assurance that the instruments did not get out of calibration. The individuals performing the audiometry also were instructed to test their own hearing each day prior to beginning testing of inmates. In addition, the authors and other Public Health Service engineers who participated in the noise studies usually had their hearing tested during each of their visits to the institution. This provided a check both on the audiometric techniques and the accuracy of the instruments. Consistent results were obtained by this procedure. This was true not only for the data obtained at each institution but also with regard to the agreement of results between the various institutions.

Hearing of both left and right ears was tested each time. Originally, as a standard procedure, the left ear was tested first. After about a year, this procedure was changed so that the right ear would be tested first in approximately half of the cases. This change was made to eliminate any possible effect on the data from any learning process associated with the first ear tested. No particular difference in the results was observable from this change in procedure.

As stated previously, men in the study group were originally tested every 3 months. Our findings during the first year or so of testing indicated that changes after the first 3 months were generally at such a slow rate as to make testing at such frequent intervals unnecessary. The test schedule was therefore modified so that testing was done 3 months, 6 months, and 12 months after assignment to a job and then annually thereafter. With the exception of the men in the original study group, each man usually had a baseline audiogram obtained at the time of his entrance into the institution. If a period of more than a few months transpired from his entrance into the institution until his assignment to an industry, an additional audiogram was sometimes obtained to serve as a baseline.

The procedure employed after the adoption of the revised test schedule consisted of sending to each institution each month individual IBM cards showing the names of the men to be tested during that month. The audiometric results were written directly on these cards, which were then returned to the Division of Occupational Health for coding and punching. Audiometric data obtained in connection with entrance examinations were also recorded on similar cards.

The scheduling of the individual tests during the month was left to the convenience of each institution, since there were sometimes special problems of work schedules not only in the industries but also in the hospital. The usual procedure, however, was for the hospital to send the industry a list of the men to be tested on a given date. These men were then sent, under escort, from the plant to the hospital in small groups in order to minimize interference with plant operations.

As is usually the case in industrial studies of this type, it was practicable to do audiometric testing only during the regular day shift. This meant that men employed on that shift would report for hearing tests directly from the workplace and after one or more hours of noise exposure. Experience has shown that, where the noise exposure is considerable, some temporary shift in the hearing threshold develops, the amount of this shift increasing during the workday. As stated above, several men were usually sent from the industry to the hospital in a group. This procedure was followed for security reasons as well as convenience. Since the men were tested one at a time with approximately 5 minutes required for each test, the period of time away from the noise in which to recover from temporary threshold shift was also variable. Because of these variables, the data obtained were undoubtedly somewhat different from those which would be obtained under an ideal schedule where each man is tested after exactly the same period of time away from noise exposure, preferably after a sufficient interval to have eliminated any temporary threshold shift effects. Where the primary interest is in the effects of noise upon the hearing of a specific individual, these variables would be of particular importance. However, in these studies the interest was in the effects upon groups and, with all groups being handled in approximately the same manner, it is felt that the effects of these variables tend to cancel out and are of less consequence.

Every effort was made to select the best possible locations for the audiometer rooms used in the four hospitals. Convenience and availability were factors which had to be considered in addition to the quality of the noise background. Dr. Glorig assisted in the selection of rooms to be used for audiometric purposes and in the design of the acoustical treatment employed. Octave band analyses of the test environments in the four institutions are shown in table 1, along with the minimum requirements for audiometric test rooms recommended by the American Standards Association. It will be observed that these requirements were met.

TABLE 1. *Octave band analyses showing sound pressure levels in decibels of background noise in audiometric test rooms used in study*

Institution location	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
Atlanta	52	43	43	33	26	20	16	10	53
Terre Haute	51	37	35	29	22	17	13	12	54
Leavenworth	53	44	42	33	29	24	19	16	55
Lewisburg	49	42	34	28	26	22	20	16	51

	500 (300–600)	1,000 (600–1,200)	2,000 (1,200–2,400)	3,000 (2,400–4,800)	4,000 (2,400–4,800)	6,000 (4,800–10,000)
American Standard Criteria [1]	40	40	47	52	57	62

[1] American Standard Criteria for Background Noise in Audiometer Rooms, S3.1–1960.

Environmental Studies

Federal Prison Industries

The Federal Prison Industries, Inc., is a Government-owned corporation which was established by the U.S. Congress in 1934. The law requires that goods produced in these factories meet Federal specifications and that they may be sold only to other governmental agencies. Also, the articles manufactured must be diversified as to kind to minimize competition with private industry and free labor.

As the plans for the study were developed, it was decided to include factories located at Lewisburg, Pa., Atlanta, Ga., Terre Haute, Ind., and Leavenworth, Kans. The operations included in the study were those involved in printing and in the manufacture of steel shelving, wooden and steel furniture, shoes, brushes, clothing, and cotton and woolen textiles. The equipment used and manufacturing methods employed correspond to those in private industry, and the men work the usual 40-hour week. Sound pressure levels found are similar to those we have encountered for comparable operations elsewhere and agree with data reported in the literature by other investigators.

The following table gives the approximate number of employees at each factory:

Atlanta: Cotton textiles	400
Terre Haute: Woolen textiles	175
Leavenworth:	
Clothing	80
Shoe	450
Brush	180
Wooden furniture	90
Printing	40
Lewisburg:	
Metal furniture	360
Clothing	60

Noise Measurement

Procedures

The environmental studies included the determination of general overall sound pressure levels throughout the various factories, octave band analyses of those operations and areas which appeared to be representative of exposures in the various departments, and special studies of the noises of certain operations.

A total of 552 octave band analyses were made throughout the factories for the purpose of defining the environmental sound pressure levels. Approximately 3,000 measurements were made with a sound survey meter to check the general environmental sound levels prior to the octave band analyses. Peak sound pressure levels were measured with a peak meter where they were thought necessary. A number of magnetic tape recordings were made and later analyzed in the laboratory by means of the oscilloscope and graphic level recorder.

In preparation for the environmental surveys, floor plans of all the factories were obtained and the location of each machine was shown. Then survey meter readings were taken throughout all areas. From these data it was determined where octave band analyses should be made.

Sound level measurements were made approximately annually at each selected location over a 7-year period. Measurements were made of the operations as they were being done on the specific day of the visit. It was assumed that this would give a random sample of working conditions. Except for the metal furniture plant, there was little variation from day to day or year to year.

The sound-measuring equipment was calibrated with an acoustical calibrator each morning before starting, at noon, and again at the end of the day's work. Whenever there was any indication that the equipment was not functioning properly, the calibration was repeated.

The equipment was moved about in the factory on a rubber-tired cart equipped with a microphone boom. With the use of the boom it was possible to move the microphone close to a factory machine operator while the instrument operator remained at some distance and thus did not disturb the sound field.

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Before each octave band analysis, a quick screening survey was made in the immediate vicinity to determine the best location for the microphone for obtaining a set of measurements which would be representative of the worker's exposure.

Equipment

Survey meter readings were obtained with a General Radio Co. sound survey meter, Type 1555–A.

During the first part of the study, a General Radio Co. sound level meter, Type 759–B, was used, and during the latter part of the study an H. H. Scott, Inc., sound level meter, Type 410–C, was used.

The octave band measurements were made with an H. H. Scott, Inc., octave band analyzer, Type 420–A.

Both a Rochelle salt crystal and an Altec 633 dynamic microphone were used at various times. The acoustical calibrator was used to determine the temperature correction for the Rochelle salt crystal microphone.

The General Radio Co.'s Type 1552–A sound-level calibrator, and the Type 410–X15 acoustic calibrator and Type 811–A random noise generator of H. H. Scott, Inc., were used to calibrate the respective company's equipment.

The magnetic tape recordings were made with an Ampex 400 tape recorder operated from the output of the sound level meter.

Laboratory analyses of the magnetic tape recordings were made with the use of either a Tektronix Type 535 oscilloscope or a Bruel & Kjaer Type 2304 level recorder.

A General Radio Co.'s Type 1556–A impact noise analyzer was used to measure impact type noises.

Atlanta

Cotton Mill

Description of operations.—At Atlanta the cotton textile mill was selected for the study group. The cotton for the mill is received at a building located outside the institution's walls. Here the bales of cotton are broken open and the preliminary processing is done. The material is then transferred to the picker room where the final processing begins. Our study includes those operations beginning at the picker room and ending with the weaving of the fabrics.

The mill is engaged in the manufacture of cotton duck of two predominant weights. The light weight is used in the manufacture of mattress covers, and the heavier weight is used for mail-pouches and mail sorting baskets manufactured at the institution.

The mill occupies the larger part of two brick buildings. One is a three-story building 134 feet by 382 feet in size. The first floor of this building is used for the manufacture of mattresses, mail-pouches, and mail sorting baskets; the second, for picking, carding, drawing, and slubbing operations; and the third, for spinning and winding operations. The second building is a one-story saw-tooth-roof building 172 feet by 470 feet. In this building the twisting and weaving operations are done. This structure also has a partial basement in which the beaming department is located.

The sound pressure levels data are grouped by departments rather than by machines. Usually the levels are fairly uniform throughout the departments due to the large numbers of similar machines. In most cases a man operates several machines and works in an area rather than at a single machine.

In the *Spinning Department* the following operations are carried out: picking, carding, drawing, slubbing, winding, and spinning.

The picker room is about 60 feet by 100 feet in size and has an 18-foot ceiling. This room has brick walls, concrete ceiling, wooden floors, and windows on two sides. A masonry wall separates this room from the carding area.

The six pickers in the room normally operate simultaneously. The sound pressure levels are fairly uniform throughout the room, tending to be the lowest at the feed end of the pickers, intermediate at the discharge end, and highest between two machines. The men in this room spend a large portion of their time at the discharge end of the pickers removing the rolls of cotton from the machines and weighing them.

The carding, drawing, and slubbing are done in a room 300 feet by 135 feet by 18 feet high. This room has brick walls, wooden floors and ceiling, and windows on two sides.

The spinning and winding are done on the third floor of the same building in a room 135 feet by 290 feet with an 18-foot ceiling. It has brick walls, wooden floors and ceiling, and windows on two sides.

FIGURE 1. *Spinning machines—Atlanta cotton mill.*

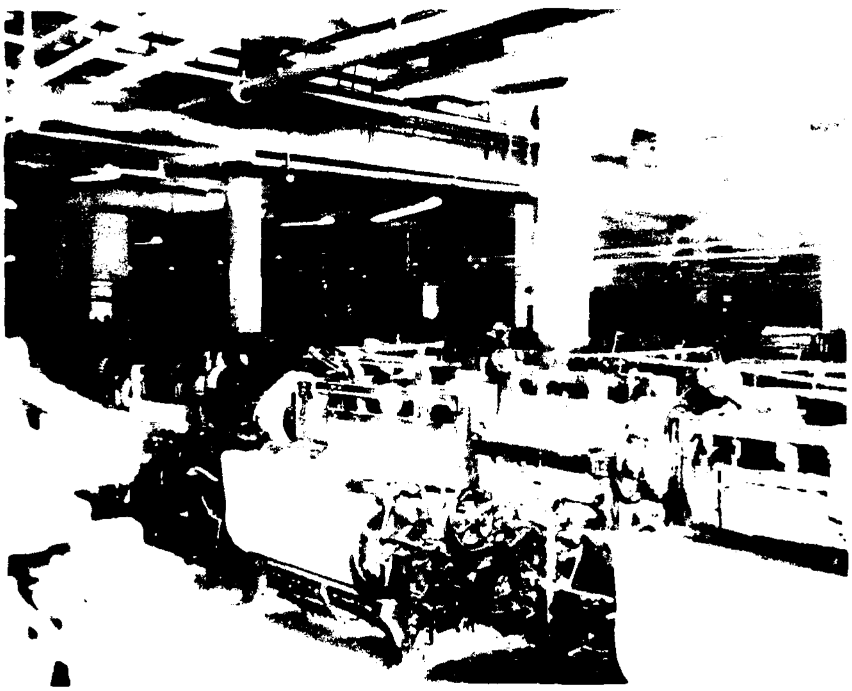

FIGURE 2. *Looms in weave room—Atlanta cotton mill*

There are 74 warp spinning frames and 6 filling spinning frames, with a total of 16,708 spindles. These frames are all 3½ gage except for one 3 and one 4½ gage. Also, there are 7 winders with a total of 700 spindles.

The *Twist and Weave Departments* are located in the same room of a one-story building. The size of this room is 270 feet by 470 feet. It has a sawtooth roof of concrete and glass construction and is 12 feet from the floor to the bottom of the sawtooth. The floor is concrete and the walls are brick.

The twisting operations are located along one side of this room, occupying a floor area 265 feet by 75 feet.

There are 72 twisters with a total of 8,928 spindles. The noise in this area is from the twisters, augmented by some from the adjacent weaving operations.

The weave department occupies the remainder of the room described under "Twist Department."

There are 587 looms located in this room, ranging in size from 37 to 72 inches. Also located in this department along the side nearest to the twist department are 23 quillers with 390 spindles, one 8-space tape loom, and one 32-space tape loom. The sound pressure levels are uniform throughout this area.

The *Beaming Department* is located in the basement of the building where the twist and weave departments are located. The room is 100 feet by 210 feet and is of masonry construction. Beaming, warping, and sizing are all done in this department.

Noise data.—Sound pressure level measurements were made at five different times over a 7-year interval. The results are shown in table 2. All of these sounds would be classified as continuous, even though in some areas the actual sound is produced by impacts. This is particularly true in the weave department, where the noise is produced principally by impacts; because of the large number of looms, the hundreds of thousands of impacts every second result in a continuous noise.

Measurements were made at various locations in each department to arrive at an exposure level which would represent the average exposure for a man working in a given department.

There were no major changes in equipment during the study period, and sound pressure levels were uniform over this time interval for a given operation.

Graphical presentations of some of the data from this and each of the other factories are contained in figures 22–35 at the end of this report.

Terre Haute

Woolen Mill

Description of operations.—At Terre Haute the woolen textile mill was the only industry included in the study. Although the woolen mill originally engaged in the manufacture of woolen blankets and suiting fabrics, during the last 1½ years of the study part of the equipment was used for the manufacture of cotton blankets.

TABLE 2. *Sound pressure level in decibels and loudness in sones by department in the cotton mill at Atlanta*

Department	Number of analyses	Percentile	Unit	Octave bands—cps 20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
Weave	18	25th	db	89	88	91	93	95	95	92	83	102
		Median	db	90	89	92	94	96	96	92	86	103
		75th	db	92	91	93	96	101	97	93	87	106
		Median	Sones	15	22	36	46	52	58	63	52	147
Beam	8	25th	db	90	84	89	83	80	79	72	65	95
		Median	db	91	90	90	87	83	80	73	67	97
		75th	db	93	93	91	87	84	81	75	70	98
		Median	Sones	16	24	31	28	21	20	17	14	73
Twist	14	25th	db	85	83	86	86	86	83	80	74	95
		Median	db	86	85	87	89	88	85	83	78	97
		75th	db	90	85	87	90	91	89	85	81	99
		Median	Sones	11	16	25	32	30	28	34	30	84
Spin	38	25th	db	79	82	84	83	81	77	72	68	94
		Median	db	83	84	87	88	86	84	81	78	96
		75th	db	90	86	90	93	89	86	85	83	100
		Median	Sones	8	15	25	30	26	26	30	30	78

The woolen mill is considerably smaller than the Atlanta cotton mill and could be classified as a medium-sized mill. It is located in a modern, one-story, brick building with a sawtooth-type roof. The interior walls are concrete blocks, the floor is concrete, and the roof is a combination of reinforced concrete and glass. The building is approximately 240 feet by 340 feet with a 20-foot ceiling. The various departments are located in separate rooms.

All windows and doors are kept closed the year around as the temperature and humidity must be controlled for the proper handling of materials.

The *Dyeing and Picking Department* is in a room 100 feet by 120 feet. There is an area for storage of raw materials and an area for the blending of the various wools. Equipment located in this room includes the following: one large picker, three small pickers, one large dryer, one small dryer, one wool baler, and four dye vats. A large part of the noise in this room is from the ventilation equipment and the pneumatic conveying system.

The *Carding and Spinning Department* encompasses two rooms. The carding is done in a room 60 feet by 120 feet. The eight carding machines are separated by 3-foot aisles, with a 4-foot aisle at each end of the machines.

The spinning is carried out in a room 90 feet by 120 feet. There are 15 spinning frames, with 8 in one row and 7 in another row.

The *Warping and Weaving Department* is in a room 120 feet by 150 feet. Two winding machines and 1 warping machine are located in one end of the room, and 42 looms are in the central portion. At the other end of the room the fabric is inspected. The looms are operated at either 128 picks per minute or 132 picks per minute, depending on the production needs. The sound pressure levels are about 2 to 3 decibels higher at the higher speed. Inspection is also done in this room.

The *Finishing Department* is located in a room 120 feet square which contains the following items of equipment: a soaper, two fulling machines, two washers, two dryers and scutchers, nappers, brusher, press, shear, rolling machine, and sewing machines. Much of the noise in this room is from the ventilation system.

Noise data.—Measurements of sound pressure levels were made at five different times during a 6-year period. The levels were essentially the same each time except in the weave and warping department, where the level varied with the speed of the looms. There appeared to be no difference in level whether cotton or woolen fabrics were being manufactured.

The sound pressure levels were fairly uniform throughout the departments, and men usually operated several machines and moved about considerably. Results of the noise analyses are shown in table 3. Levels are presented for each department, and the combined levels for carding, spin-

TABLE 3. *Sound pressure levels in decibels and loudness in sones by department in the woolen mill at Terre Haute*

Department	Number of analyses	Percentile	Unit	Octave bands—cps: 20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
Weave and warp	17	25th	db	75	73	79	85	87	88	87	79	95
		Median	db	76	75	81	87	89	90	87	81	97
		75th	db	79	77	84	89	91	93	92	84	99
		Median	Sones	4	8	16	28	32	40	45	35	94
Dye and pick	10	25th	db	79	80	81	77	75	70	63	58	87
		Median	db	85	85	89	83	79	74	68	62	94
		75th	db	90	89	97	87	83	77	77	69	99
		Median	Sones	10	16	29	21	16	13	12	10	58
Card and spin	10	25th	db	72	72	77	79	75	73	71	63	85
		Median	db	76	78	80	82	81	76	74	68	89
		75th	db	79	79	83	84	81	80	76	74	90
		Median	Sones	4	9	15	20	18	15	18	15	48
Finish	14	25th	db	80	79	78	79	77	73	65	57	86
		Median	db	84	81	82	80	78	77	68	62	90
		75th	db	85	85	87	84	83	79	74	67	94
		Median	Sones	9	12	18	17	15	16	12	10	45
Card, spin and finish	24	25th	db	76	77	79	79	78	74	66	62	87
		Median	db	80	79	81	81	79	76	71	66	90
		75th	db	84	83	82	83	81	78	76	72	92
		Median	Sones	6	10	16	18	16	15	15	13	45

FIGURE 3. *Looms in Terre Haute woolen mill.*

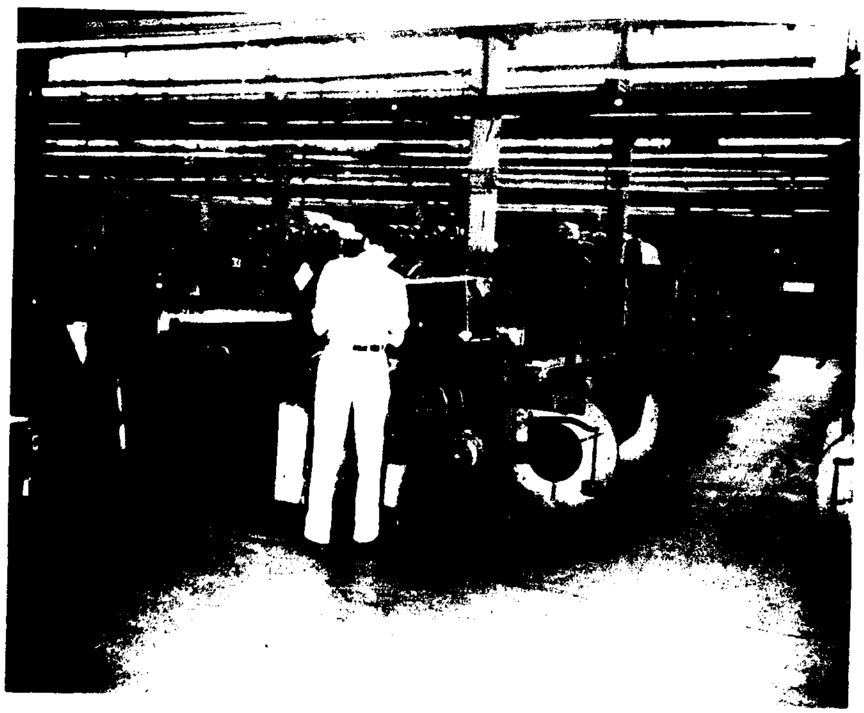

FIGURE 4. *Looms in Terre Haute woolen mill.*

ning, and finishing are then given. The findings are grouped because hearing data for workers in these departments are combined later in this report. The noise levels and frequency distribution are similar.

In all departments of the mill, music was played through a loudspeaker system. It could be heard above the machine noise everywhere except in the weave department where it was sometimes inaudible.

Leavenworth

The industries included in the study at Leavenworth were printing and shoe, brush, wooden furniture, and clothing factories. The factories are located in three 4-story brick buildings. One building is used entirely for shoe manufacturing. The other factories occupy complete floors of the other two buildings, isolating each from the others.

Shoe Factory

Description of operations.—The shoe factory manufactures slippers and shoes primarily for the military services. The factory occupies four floors, each having an area of approximately 16,000 square feet. The building is L-shaped and is 44 feet wide. There are windows on each side.

The *Cutting Department* occupies about one-half the area of the fourth floor. Here all of the leather used in the upper part of the shoe is cut into the proper shape and size. This operation is done by machines, clickers, which produce a large impact when the metal pattern is struck. Other machines located in this department are skibers, edgers, and burnishers, all of which produce a continuous noise.

The *Fitting Department* takes up the remainder of the fourth floor. Here the different parts of the upper shoe are stitched together to make a finished shoe upper. Other operations, such as punching of eyelets for the laces and insertion of metal eyelets and hooks, are also performed in this department. The large number of sewing machines in operation produces a continuous noise. The eyelet machine operations produce rapid impacts for about 5 seconds, followed by 5-second breaks.

The *Sole Leather Department* is located on the first floor. Here the pieces making up the lower part of the shoe are made and put together. These parts include insoles, outsoles, and counters. The

FIGURE 5. *Stitching machines in Leavenworth shoe factory.*

operations in this department are insole seaming, sole seaming, and inside channeling. They all produce a continuous-type noise.

The *Lasting Department* occupies about two-thirds of the third floor of the shoe factory. In the lasting room, the different shoe parts are assembled and shaped on all-wood lasts. The operations of this department are side lasting, heel seat lasting, toe lasting, tacking and tack pulling. Impact-type noises are produced.

The *Welting Department* occupies the other one-third of the third floor. Here the welt is attached to the uppers, and the insole is attached to the welt. The operations in this department include welt butting, tacking, stitching, beating, inseam sewing and welting, and insole tacking, seaming, and trimming. Most of these produce continuous-type noises.

The *Bottoming Department* is located on the second floor. Here the outsole is attached to the rest of the shoe, and the sole is trimmed to size. The following machines are located in this department: shank tacker, outsole stitcher, rough rounder, fiber nailer, and outsole trimmer. They all make a continuous noise, except the shank tacker and fiber nailer. The fiber nailer produces a very sharp impact.

The *Making Department* is also located on the second floor. Here the heel is attached to the shoe and trimmed. This department has the following equipment: heeler, heel trimmer, edge trimmer, and burnishers. A continuous noise is produced by all of the operations except the heeler, which makes a strong impact.

The *Treeing and Packing Department* occupies parts of the first and second floors. Here the

TABLE 4. *Sound pressure levels in decibels and loudness in sones by department in the shoe factory at Leavenworth*

Department	Number of analyses	Percentile	Unit	Octave bands—cps								
				20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
Fitting	16	25th	db	77	76	78	75	71	64	64	60	88
		Median	db	82	80	80	77	74	70	70	66	89
		75th	db	84	82	82	83	80	79	79	73	90
		Median	Sones	8	11	15	14	11	10	14	13	39
Lasting	21	25th	db	76	73	75	77	77	74	69	66	87
		Median	db	79	76	78	82	82	79	77	72	88
		75th	db	80	78	80	84	83	82	80	75	90
		Median	Sones	6	8	13	20	20	18	22	20	54
Cutting	13	25th	db	78	75	79	80	81	76	69	64	89
		Median	db	83	81	80	81	82	79	76	72	91
		75th	db	86	83	84	84	84	83	86	80	94
		Median	Sones	8	12	15	18	20	18	21	20	54
Lasting and cutting	34	25th	db	76	75	77	79	78	75	69	65	88
		Median	db	79	78	79	81	82	79	76	72	89
		75th	db	83	80	82	84	84	82	80	75	92
		Median	Sones	6	9	14	18	20	18	21	20	53
Sole leather	8	25th	db	75	70	77	82	81	78	74	72	88
		Median	db	80	75	81	84	86	84	80	75	93
		75th	db	82	77	82	88	88	86	84	80	97
		Median	Sones	6	7	16	22	26	26	28	20	65
Treeing and packing	5	25th	db	79	75	80	83	81	80	78	75	90
		Median	db	82	79	82	86	84	80	78	76	95
		75th	db	83	82	86	90	90	88	84	77	96
		Median	Sones	8	10	18	26	23	20	24	21	63
Making	19	25th	db	79	77	80	80	81	78	76	70	91
		Median	db	80	79	82	84	83	81	80	73	93
		75th	db	82	82	85	86	85	85	87	78	95
		Median	Sones	6	10	18	22	21	21	28	21	64
Welting	21	25th	db	77	76	80	83	84	78	73	67	91
		Median	db	80	78	83	85	86	82	80	73	93
		75th	db	82	80	85	86	87	85	83	77	95
		Median	Sones	6	9	19	24	26	22	28	21	66
Bottoming	17	25th	db	80	76	80	82	82	79	75	72	92
		Median	db	82	78	81	84	86	84	82	79	93
		75th	db	84	79	83	85	90	89	85	82	97
		Median	Sones	8	9	16	22	26	26	32	32	74
Making, treeing and packing, sole leather, welting, and bottoming.	70	25th	db	78	76	80	83	82	79	75	72	91
		Median	db	81	78	82	84	84	84	80	74	93
		75th	db	82	80	84	86	87	85	83	79	95
		Median	Sones	7	9	18	22	23	26	28	23	65

shoes are removed from the trees, given their final cleaning and dressing, and packed for shipment. The noises generated are all of a continuous type.

Noise data.—Sound pressure level measurements were made in the shoe factory at six different times during a 7-year interval. These data, presented in table 4, have been grouped by department, and some of the departments with similar noise levels and frequency distributions have been grouped to combine the hearing data of workers in these departments. In most cases both continuous and impact noises are included.

Brush Factory

Description of operations.—The brush factory is engaged in the manufacture of paint, sanitary, scrub, tooth, and typewriter brushes and push brooms.

The plant occupies the third floors of two buildings and is in three separate rooms.

The *Wire Drawn Department* is located in a room about 48 feet by 110 feet, with windows on three sides. Here push brooms are made, starting with the hardwood backs in which holes are drilled. The tufts are put in place manually, and the bristles are trimmed by machine. The machines located in this room are small horizontal and vertical drill presses and the brush trimmer. The major source of noise is the brush trimmer, which is in operation about one-third of the time.

The *Twist in Wire Department* occupies one corner of the same room as the wire drawn department. Here sanitary brushes are made by placing fibers between two wires, twisting the wires together to hold the fibers in place, and then trimming the brushes. Except for the trimming of the fibers, it is essentially a manual operation. The noise produced by the brush trimmer is only slightly higher than the background noise.

The *Staple Set Department* is located in a room 44 feet by 116 feet, with windows on three sides. Here, in making brushes, the backs are drilled, and the bristles are inserted into holes by machine. Types of brushes manufactured include scrub brushes of various kinds, typewriter and tooth brushes. Equipment in this department includes a variety of brush machines, which make two to four brushes at a time, and brush trimmers. All of the brush machines produce impacts, and the trimmers produce a continuous type of noise.

The *Ferrule Department* is located in the same room as the staple set department, occupying about one-half of the room. Here the ferrules, or metal bands, for paint brushes are manufactured. Equipment includes small metal shears, punch presses, riveting machine, and buffers. Except for the buffers, these machines all produce impact noises.

The *Bristle Department* is located in a room 44 feet by 234 feet and occupies about one-half of the room. Here the bristles are mixed, washed, sterilized, and sorted. Equipment located in this department includes a bristle-mixing machine, sterilizer, and ovens. The noise is of a continuous type.

The *Rubber Set Department* takes up the other half of the room in which the bristle department is located. Here paint brushes are assembled. Equipment in this area includes a cutoff saw, drill presses, nailers, bradders, crimpers, sanders, and buffers.

Noise data.—The data from sound pressure level measurements made on six different occasions during a 7-year interval are presented in table 5. The findings are given by department and are also shown for combined plant operations for comparisons with the hearing data, which are also included in this report.

Wood Furniture Factory

Description of operations.—The wood furniture factory is engaged in the manufacture of maple furniture and backs and handles for brushes. This factory occupies the first floor of one building and the first floor and part of the second floor of another.

The *Mill 1 Department* is located in a room 44 feet by 116 feet. Here the rough lumber is sawed to approximate size, glued when necessary, and planed to form the basic stock for Mill 2. The equipment used includes table saws, swing saws, shapers, and a planer. The planer is the major source of noise; the level varies with the width and hardness of the wood being planed.

The *Mill 2 Department* occupies part of a room 44 feet by 234 feet. Here the blank pieces of wood are shaped into the various shapes needed for the finished product. Almost all types of woodworking machines are used here, including saws, drill presses, shapers, routers, jointers, disk

TABLE 5. *Sound pressure levels in decibels and loudness in sones by department in the brush factory at Leavenworth*

Department	Number of analyses	Percentiles	Unit	Octave bands—cps 20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
Wire drawn	15	25th	db	72	74	77	76	76	70	68	67	84
		Median	db	74	78	82	80	79	74	71	68	89
		75th	db	81	92	85	86	84	80	79	75	94
		Median	Sones	3	9	18	17	16	13	15	15	44
Rubber set	10	25th	db	79	76	76	76	75	70	63	59	86
		Median	db	81	79	79	79	78	72	65	62	88
		75th	db	82	80	81	80	81	81	78	69	90
		Median	Sones	7	10	14	16	15	11	10	10	39
Twist in wire	4	25th	db	63	67	74	72	70	66	60	60	83
		Median	db	77	74	77	78	76	74	71	68	86
		75th	db	84	86	89	91	86	80	74	69	96
		Median	Sones	5	7	13	15	13	13	15	15	39
Bristle	7	25th	db	78	76	81	79	74	73	66	58	88
		Median	db	83	81	82	80	79	76	68	61	90
		75th	db	85	84	84	82	80	78	75	67	91
		Median	Sones	8	12	18	17	16	15	12	10	45
Staple set	13	25th	db	79	76	79	80	80	76	70	72	89
		Median	db	82	78	81	82	83	81	78	74	91
		75th	db	87	81	82	82	84	83	82	78	94
		Median	Sones	8	9	16	20	23	21	24	23	60
Ferrule	4	25th	db	79	77	78	78	79	78	72	63	88
		Median	db	81	78	80	81	80	79	75	69	90
		75th	db	82	78	82	82	81	81	76	73	91
		Median	Sones	7	9	15	18	17	18	20	16	50
All brush departments	53	25th	db	76	75	77	75	76	72	68	62	86
		Median	db	80	78	80	80	81	79	74	68	89
		75th	db	83	81	83	82	83	81	78	74	92
		Median	Sones	6	9	15	17	18	18	18	15	47

FIGURE 6. *Molder (foreground) and planer (background) in Mill 1 of furniture factory at Leavenworth.*

sanders, belt sanders, and drum sanders. All of these machines produce continuous types of noise, and because of the large number of machines in a small area the background noise is always high.

The *Cabinet Department* occupies the other portion of the room in which Mill 2 is located. Here the furniture is assembled and prepared for the final finish. The major source of noise originates in Mill 2. Hammers and other small handtools are sometimes used in this area.

The *Finish Department* is located on the second floor in a room 44 feet by 116 feet. Here the furniture receives its final finish, including spray painting or varnishing, hand sanding, and rubbing. Spray painting is done in water-curtain-type spray booths. The ventilation system and the spray guns are the major source of noise.

The *Brush and Handle Department* is located in the same room as the finish department, but is fairly well isolated from it by ovens and spray booths. Here the handles for brushes are hand dipped and dried. The major sources of noise are the impacts from material handling and the continuous noise from the ventilation equipment.

Noise data.—Sound pressure level measurements made on six different occasions during a 7-year period are shown in table 6. The exposures are given by department, with some departments grouped together. It is recognized that a sander, shaper, saw, and planer do not generate the same amount of noise, but where these machines are located in the same room adjacent to each other, it is impossible to arrive at a precise exposure level for the operator of a single type of machine. The values presented here should represent the average exposure in a cabinet shop handling hardwood.

Printing Plant

Description of operations.—The printing plant is essentially a jobshop which prints government forms, ledgers, and calendars. It is located on the second floor and occupies a room 44 feet by 234 feet. There are, on the average, 42 workers in the plant.

The *Composing Department* occupies about one-fourth of the area of the plant and is located at one end of the room. Machines used here are Monotypes, Linotypes, and metal saws. These

TABLE 6. *Sound pressure levels in decibels and loudness in sones by department in the wooden furniture factory at Leavenworth*

Department	Number of analyses	Percentile	Unit	Octave bands—cps								
				20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
Mill 1	20	25th	db	78	81	88	87	86	85	82	80	98
		Median	db	82	84	93	92	94	93	90	84	101
		75th	db	86	88	96	97	100	97	97	87	110
		Median	Sones	8	15	39	40	46	49	56	45	129
Mill 2	40	25th	db	80	80	84	86	85	83	82	77	95
		Median	db	84	83	86	89	87	85	87	83	98
		75th	db	90	87	90	92	90	89	92	86	101
		Median	Sones	9	14	23	32	28	28	45	42	98
Mill 1 and Mill 2	60	25th	db	79	80	83	86	84	83	83	78	96
		Median	db	83	83	88	90	88	86	88	83	99
		75th	db	89	87	93	92	94	90	92	86	102
		Median	Sones	8	14	37	34	30	30	49	42	105
Finish	4	25th	db	80	84	82	76	73	70	68	64	89
		Median	db	85	88	86	81	80	75	72	70	93
		75th	db	87	89	88	84	82	78	76	75	95
		Median	Sones	10	20	23	18	17	14	16	17	57
Cabinet	6	25th	db	75	75	76	75	72	69	74	62	84
		Median	db	80	76	79	76	76	73	75	65	85
		75th	db	84	78	79	78	78	75	76	66	88
		Median	Sones	6	8	14	13	13	12	20	12	43
Brushes and handles	3	25th	db	81	82	85	84	83	75	66	57	92
		Median	db	82	83	87	85	85	80	74	72	94
		75th	db	82	85	90	87	87	86	80	69	96
		Median	Sones	8	14	25	24	25	20	18	20	64
Cabinet, finish, brushes and handles	13	25th	db	76	76	78	75	72	70	66	62	85
		Median	db	82	79	80	78	77	75	74	66	88
		75th	db	86	88	88	84	82	79	77	70	94
		Median	Sones	8	10	15	15	14	14	18	13	45

machines are operated intermittently and are in use less than half of the time.

The *Press Department* occupies the center half of the printing plant area. Here various types of printing are done on presses ranging in size from small hand presses to a Miller Major automatic press. The noises generated are of a continuous nature, and the automatic presses are in operation the major portion of the time.

The *Binding Department* is located in the other quarter of the printing factory. Here the various printed materials are cut to size, bound when necessary, and packaged for shipping. A large part of this work is done manually. Noise is produced by intermittent use of paper cutters, a shaker, and a folding machine.

Noise data.—Surveys were made of this plant on six different occasions in 7 years. The data, shown in table 7, are given by department and also combined for the entire plant. The exposures are fairly uniform for all except those working in the composing room. Since the plant is a job-shop, not all of the equipment was operating during each survey, but during the course of the study analyses were made of the noises from all equipment.

TABLE 7. *Sound pressure levels in decibels and loudness in sones by department in the printing plant at Leavenworth*

Department	Number of analyses	Percentile	Unit	Octave bands—cps								
				20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
Composing	6	25th	db	75	73	75	78	72	67	62	61	85
		Median	db	78	75	76	78	80	83	85	79	91
		75th	db	81	75	78	78	82	86	86	84	93
		Median	Sones	5	7	12	15	17	24	39	32	73
Press	11	25th	db	77	78	82	81	78	71	66	64	89
		Median	db	78	80	86	85	82	76	71	67	91
		75th	db	81	85	87	87	84	80	75	71	93
		Median	Sones	5	11	23	24	20	15	15	14	55
Binding	6	25th	db	77	77		78	74	70	64	62	86
		Median	db	77	77	80	78	78	76	70	64	87
		75th	db	79	79	81	82	81	80	72	71	88
		Median	Sones	5	9	15	15	15	15	14	11	40
Composing, press, and binding	23	25th	db	76	77	78	78	78	70	64	62	87
		Median	db	78	79	82	81	80	76	71	69	91
		75th	db	80	82	86	86	84	80	75	71	93
		Median	Sones	5	10	18	18	17	15	15	16	47

Clothing Factory

Description of operations.—The clothing factory manufactures military-type cotton uniforms and some wool civilian dress suits which are issued to inmates on their release from prison. The factory is located on the fourth floor in a room 44 feet by 235 feet. All of the operations, collectively referred to as tailoring, are carried out in one room. About one-half of the room is used for material and pattern storage and material cutting. About one-quarter of the room is used for pressing and inspection, and the balance is used for sewing. The majority of the 80 men in the plant work in this area.

Noise data.—Noise surveys were made on six occasions during a 7-year interval. The noise was of a continuous type and the levels were essentially the same each time. The data are shown in table 8.

Lewisburg

At Lewisburg, the clothing and metal furniture factories were included in the orginal study group. They are located in three 3-story and one 1-story brick buildings, which are each 60 feet by 200 feet. They all have masonry interior walls and large window areas on all sides.

Clothing Factory

Description of operations.—The clothing factory is engaged primarily in the manufacture of cotton trousers and shirts. The factory occupies the second floor of one of the factory buildings. Approximately 60 men work in this department, the majority of them being sewing machine operators.

Noise data.—Sound pressure level measurements were made at four different times during a 5-year

TABLE 8. *Sound pressure levels in decibels and loudness in sones in the clothing factory at Leavenworth*

Department	Number of analyses	Percentile	Unit	Octave bands—cps								
				20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
Tailoring	10	25th	db	72	70	72	72	68	64	60	52	81
		Median	db	78	73	76	73	71	68	62	58	83
		75th	db	80	78	82	75	75	70	68	63	88
		Median	Sones	5	6	12	11	9	9	8	7	29

interval, and were essentially the same on each survey. The data are shown in table 9.

Metal Furniture Factory

Description of operations.—The furniture factory produces metal furniture and steel shelving for offices and institutions. The factory is located on eight floors of three 3-story buildings. Each floor is 60 feet by 200 feet. There is a one-story steel warehouse of approximately the same floor area.

The factory employs an average of 360 men and uses between 600 and 800 tons of steel per month.

The *Press Department*, where the sheet metal is cut, punched, and shaped for furniture, occupies the first floor of one of the factory buildings. Equipment used includes brakes up to 10 feet in size, punch presses, and hydraulic presses with up to 400–ton capacity. Hydraulic presses are also used for forming compartment-type food trays.

The *Shelving Department* is located on the ground floor of another building. Here sheet metal is cut, punched, and shaped for metal shelving, and the holes in the uprights for shelving are punched. As many as 72 quarter-inch holes are punched simultaneously in the 18-gage metal.

The *Assembly Department* is on the second floor of one of the buildings. Here the components for the furniture are assembled and spot welded, and some hand sanding and grinding are done. There are 16 spot welders ranging in size from 35 to 75 kilovolt-amperes.

The *Metal Finishing Department* is situated on the ground floor of the third building. Here bar stock is cut to size, and fittings for the furniture are plated and polished. Any necessary grinding is also done in this department.

The *Paint Finishing Department* is located on the third floor of one of the buildings. The furniture is cleaned, either spray painted or dipped, and sanded and repainted as necessary. The finish is then baked in large ovens. There are five spray booths, two paint dipping vats, and three ovens. The major portion of noise is from the ventilation systems.

The *Steel Warehouse* is a one-story building with the side open between it and the adjacent shelving department. The major sources of noise here are from the loading and unloading of steel and from shelving department operations.

Noise data.—Sound surveys, which were made of the metal furniture factory five times during a 5-year period, showed that operations varied greatly from one survey to the next. Impact-type noises, which are very difficult to evaluate, account for the high exposures in the plant. Because of the great variety in operations, it was decided in 1958 to discontinue this portion of the study. The data obtained up to that time are given in table 10. Peak sound pressure levels for selected operations as well as average values are presented in table 11.

TABLE 9. *Sound pressure levels in decibels and loudness in sones in the clothing factory at Lewisburg*

Department	Number of analyses	Percentile	Unit	Octave bands—cps								
				20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
Tailoring	8	25th	db	76	75	75	74	72	65	61	56	83
		Median	db	79	76	77	75	72	66	63	58	84
		75th	db	80	77	78	77	74	70	66	61	85
		Median	Sones	6	8	13	12	10	7	8	7	30

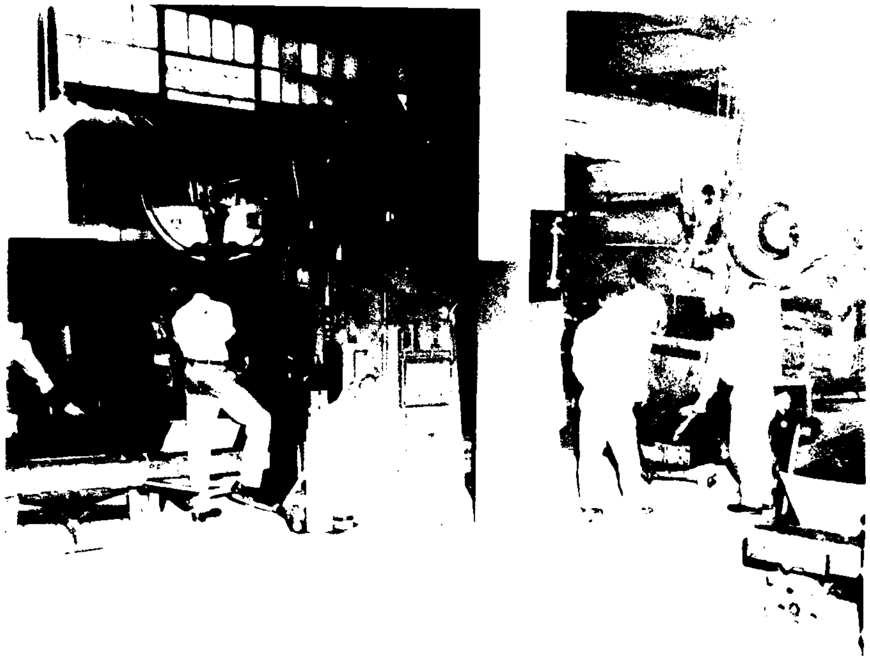

FIGURE 7. *Sheet metal operations — Lewisburg*

FIGURE 8. *Sheet metal operations — Lewisburg*

TABLE 10. *Sound pressure levels in decibels and loudness in sones by department in the metal furniture factory at Lewisburg*

Department	Number of analyses	Percentile	Unit	Octave bands—cps 20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
Steel warehouse	4	25th	db	73	73	75	75	75	69	62	57	83
		Median	db	75	74	77	78	78	72	64	60	86
		75th	db	77	76	80	79	79	76	70	65	88
		Median	Sones	4	7	13	15	15	11	9	8	35
Press	13	25th	db	79	80	83	84	86	80	75	66	92
		Median	db	82	84	84	86	88	84	79	74	94
		75th	db	87	88	92	95	93	88	83	76	98
		Median	Sones	8	15	21	26	30	26	26	23	74
Assembly	10	25th	db	72	72	75	77	76	76	76	72	88
		Median	db	77	75	79	80	81	78	79	74	91
		75th	db	82	80	84	82	82	84	80	76	93
		Median	Sones	5	7	14	17	18	17	26	23	56
Metal finishing	13	25th	db	80	77	82	81	80	74	67	60	91
		Median	db	82	80	84	83	81	78	75	74	92
		75th	db	87	86	86	85	83	84	84	78	96
		Median	Sones	8	11	21	21	18	17	20	23	58
Paint finishing	9	25th	db	75	77	79	76	75	71	71	68	86
		Median	db	78	80	82	82	80	76	75	74	91
		75th	db	82	83	85	84	85	83	80	78	93
		Median	Sones	5	11	18	20	17	15	20	23	55
Shelving	17	25th	db	83	85	87	87	87	82	75	70	94
		Median	db	85	90	92	90	90	85	80	73	100
		75th	db	90	92	93	93	92	88	82	76	101
		Median	Sones	10	24	36	40	35	28	28	21	95

TABLE 11. *Average and peak sound pressure levels for selected operations in the metal furniture factory at Lewisburg*

Machine	Instrument	Octave bands—cps 20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
Shear	OBA average [1]	83	86	89	90	85	80	76	66	96
	OBA peak [2]	88	89	94	96	98	92	90	78	102
	Peakmeter [3]	95	104	107	105	106	104	101	92	115
Punch press	OBA average	84	90	91	92	90	86	80	72	102
	OBA peak	88	100	102	104	101	96	88	83	109
	Peakmeter	104	106	115	113	113	108	107	104	121
Bending brake	OBA average	85	90	93	93	89	85	80	73	103
	OBA peak	93	100	98	99	97	93	95	82	110
	Peakmeter	102	107	114	116	114	106	108	108	120
Power brake	OBA average	88	90	95	93	89	84	78	70	100
	OBA peak	100	102	108	105	98	92	86	85	112
	Peakmeter	109	118	119	115	110	109	108	108	125

[1] Octave band analyzer average meter reading.
[2] Octave band analyzer peak meter reading.
[3] General Radio Co. Type 1556–A impact noise analyzer.

Audiometric Data: New Admissions

Hearing of Men at Time of Admission

During the period covered by this report, approximately 12,000 newly admitted inmates had their hearing tested. The numbers tested at each institution were as follows:

Location	*Number*
Atlanta	2, 299
Terre Haute	2, 632
Leavenworth	4, 668
Lewisburg	2, 346
Total	11, 945

The number of new admissions tested each year were:

Year	*Number*
1953	631
1954	753
1955	1, 801
1956	2, 417
1957	2, 906
1958	2, 549
1959 (6 months)	888

The median age of men admitted to Atlanta and Leavenworth was approximately 34 years, respectively, whereas the median age was about 25 years at Lewisburg and at Terre Haute. This 9-year difference is due to the type of institution involved.

In the first report of findings, which included the period through June 30, 1957, data were presented to indicate the degree of consistency in the yearly results obtained from each institution. These data were illustrated in part by figure 1, appendix. In that preliminary report, data were presented to justify the combining of results from the four institutions, so that a single set of control data could be used for making comparisons with the findings on the individual factories, regardless of location. In the present report, however, this simplification will not be made, and findings from each factory will be compared only against new admission data from the same institution.

The hearing data from each institution should properly be considered as representing an individual study, since the testing was done by different individuals using different audiometers and conducting the tests in different test environments. These data, as well as those obtained elsewhere by other investigators, are compared later in this report.

Table 12 presents data obtained from hearing

TABLE 12. *Percent of men, by age group, whose hearing levels, in db, did not exceed stated values at the time of admission to Atlanta*

Age	Number of men	Percent of men	Hearing level for each ear at stated frequency (cps)																	
			500			1,000			2,000			3,000			4,000			6,000		
			Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average
20-29	515	25	1.9	1.4	1.7	−2.3	−2.3	−2.3	−0.3	−2.1	−1.2	1.0	−1.0	0.0	4.8	2.7	3.8	0.3	−0.7	−0.2
		50	6.5	6.3	6.4	1.6	1.8	1.7	4.7	2.9	3.8	7.3	5.2	6.3	10.9	8.6	9.8	7.5	6.2	6.9
		75	11.4	11.0	11.2	5.9	6.5	6.2	10.2	8.1	9.2	17.1	11.8	14.5	25.3	18.9	22.1	19.6	17.0	18.3
30-39	1, 005	25	2.0	2.2	2.1	−1.9	−1.7	−1.8	1.3	−1.0	.2	3.4	1.4	2.4	8.3	5.5	6.9	4.7	3.0	3.9
		50	6.3	6.7	6.5	2.2	2.4	2.3	6.5	4.2	5.4	10.1	7.9	9.0	16.6	12.0	14.3	13.1	10.2	11.7
		75	11.2	11.4	11.3	6.9	7.2	7.1	12.3	9.9	11.1	21.9	16.5	19.2	32.5	27.5	30.0	27.4	24.5	26.0
40-49	541	25	3.7	3.6	3.7	−1.2	.3	− .5	4.2	2.0	3.1	7.7	4.5	6.1	13.5	9.7	11.6	10.1	8.2	9.2
		50	8.2	10.0	9.1	4.3	6.0	5.2	9.6	7.7	8.7	17.0	12.5	14.8	27.0	21.3	24.2	23.9	20.9	22.4
		75	13.7	14.6	14.2	9.3	11.8	10.6	18.5	14.4	16.5	34.2	29.2	31.7	46.2	42.0	44.1	45.3	41.0	43.2
50+	238	25	6.7	7.1	6.9	3.0	3.0	3.0	8.2	6.9	7.6	13.2	11.5	12.4	24.8	19.1	22.0	22.0	17.7	19.9
		50	12.6	12.2	12.4	8.3	8.6	8.5	17.0	13.7	15.4	30.0	24.2	27.1	44.7	36.2	40.5	41.2	37.1	39.2
		75	22.0	19.4	20.7	17.2	15.5	16.4	31.5	26.1	28.8	48.4	45.3	46.9	54.4	49.8	52.1	53.8	54.4	54.2
Total	2, 299																			

tests given 2,299 men at the time they were admitted to the Atlanta penitentiary. The 25th, median, and 75th percentile hearing levels at each of the six test frequencies are shown according to age group. Data are given for each ear, and the averages are also included.

Tables 13, 14, and 15 provide similar information on men admitted to Terre Haute, Leavenworth, and Lewisburg, respectively.

As would be expected, examination of the data shows a decline in hearing acuity, or an *increased* hearing level, with increasing age, with the greatest loss in the higher frequencies, particularly at 4,000 cps and 6,000 cps. This is demonstrated in figures 9, 10, and 11. Figure 9 shows the differences by institution in hearing levels (average of both ears) of men 30 to 39 from the hearing levels of men 20 to 29 years of age at the time of admission. Figure 10 shows the differences in hearing levels of men 40 to 49 from the 20-to-29 age group, and figure 11 shows the differences in hearing levels of men of 50 or more years of age from the 20-to-29 age group. It will be observed from figure 9 that the 30-to-39 group shows comparatively

TABLE 13. *Percent of men, by age group, whose hearing levels, in db, did not exceed stated values at the time of admission to Terre Haute*

Age	Number of men	Percent of men	Hearing level for each ear at stated frequency (cps)																	
			500			1,000			2,000			3,000			4,000			6,000		
			Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average
20-29	1,182	25	6.3	7.5	6.9	0.9	1.3	1.1	−3.9	−2.9	−3.4	−1.4	−2.0	−1.7	0.3	0.2	0.3	0.4	−1.6	−0.6
		50	11.0	12.7	11.9	5.0	5.6	5.3	.8	1.9	1.4	4.5	3.7	4.1	7.7	7.0	7.4	8.9	6.4	7.7
		75	17.0	18.5	17.8	10.0	10.3	10.2	6.8	7.3	7.1	13.6	11.8	12.7	20.0	17.4	18.7	23.9	19.6	21.8
30-39	919	25	6.5	7.4	7.0	1.6	1.7	1.7	−2.9	−2.2	−2.5	1.6	.4	1.0	4.5	2.3	3.4	4.6	2.0	3.3
		50	12.0	12.9	12.5	6.1	6.3	6.2	2.7	3.0	2.9	9.3	7.5	8.4	13.6	12.0	12.8	13.8	11.1	12.5
		75	18.0	19.3	18.7	11.7	11.5	11.6	10.0	9.4	9.7	23.0	17.5	20.3	31.7	28.4	30.1	33.4	29.2	31.3
40-49	334	25	7.6	9.0	8.3	2.4	1.7	2.1	−.6	−.2	−.4	6.6	5.3	6.0	11.3	10.4	10.9	11.8	9.0	10.4
		50	13.1	14.0	13.6	7.9	6.0	7.0	5.7	5.5	5.6	15.1	13.5	14.3	22.6	20.8	21.7	23.4	19.8	21.6
		75	19.4	22.1	20.8	13.1	13.4	13.3	14.3	14.8	14.6	31.7	28.1	29.9	39.9	38.8	39.4	45.8	40.2	43.0
50+	197	25	11.0	11.4	11.2	6.0	5.8	5.9	4.8	3.9	4.4	13.2	10.5	11.9	17.2	15.9	16.6	22.9	19.0	21.0
		50	17.0	17.6	17.3	11.2	10.9	11.1	13.2	11.4	12.3	29.9	27.0	28.5	36.9	36.2	36.6	40.5	37.1	38.6
		75	24.0	26.0	25.0	19.3	19.1	19.2	28.7	14.2	21.5	48.0	45.3	46.7	51.5	49.1	50.3	55.0	52.9	54.0
Total	2,632																			

TABLE 14. *Percent of men, by age group, whose hearing levels, in db, did not exceed stated values at the time of admission to Leavenworth*

Age	Number of men	Percent of men	Hearing level for each ear at stated frequency (cps)																	
			500			1,000			2,000			3,000			4,000			6,000		
			Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average
20-29	1,422	25	1.0	0.4	0.7	0.2	−0.9	−0.3	1.1	−0.7	0.2	2.0	0.5	1.3	2.6	0.7	1.7	2.0	1.5	1.8
		50	4.9	3.7	4.3	5.3	2.8	4.1	6.0	3.0	4.5	7.2	4.5	5.9	8.7	6.0	7.4	9.0	7.3	8.2
		75	9.0	8.0	8.5	11.1	7.0	9.1	10.3	7.2	8.8	13.4	10.0	11.7	18.6	14.2	16.[illegible]	19.0	16.4	17.7
30-39	1,923	25	1.6	.9	1.3	.5	−.2	.2	2.0	.1	1.1	4.0	1.8	2.9	5.0	2.5	3.8	4.3	3.4	3.9
		50	6.4	4.4	5.4	5.7	3.4	4.6	6.6	5.2	5.9	10.8	6.7	8.8	12.1	8.9	10.5	11.9	10.2	11.1
		75	11.3	9.0	10.2	9.9	7.9	8.9	11.3	9.0	10.2	17.3	14.0	15.7	27.0	22.5	24.8	26.0	25.3	25.7
40-49	867	25	3.1	1.9	2.5	2.4	1.1	1.8	5.3	1.8	3.6	7.5	4.1	5.8	9.9	6.6	8.3	9.0	7.8	8.4
		50	7.5	6.1	6.8	7.4	4.8	6.1	9.4	6.0	7.7	14.2	10.0	12.1	20.5	15.5	18.0	19.7	17.1	18.4
		75	12.3	11.2	11.8	13.0	9.7	6.4	11.9	12.5	12.2	28.7	22.5	25.6	37.0	33.0	35.0	35.4	34.2	34.8
50+	456	25	5.7	4.5	5.1	5.1	3.2	4.2	8.2	5.1	6.7	13.2	9.0	11.1	18.4	13.7	16.1	18.2	15.2	16.6
		50	9.3	10.0	9.7	.2	7.8	5.0	15.7	10.0	12.9	23.9	18.3	21.6	33.6	27.7	30.7	34.4	30.0	32.2
		75	14.5	14.8	14.7	18.0	13.7	15.9	26.7	20.9	23.8	41.8	37.9	39.9	47.0	45.7	46.4	48.2	47.0	47.6
Total	4,668																			

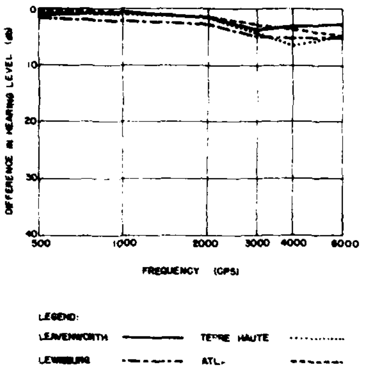

Figure 9. *Differences in median hearing levels, for stated frequencies, at time of admission, between men 30–39 years of age and men 20–29 years of age, by institution.*

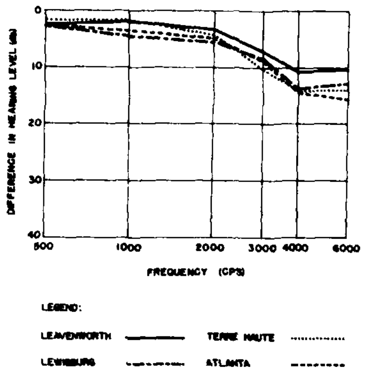

Figure 10. *Differences in median hearing levels, for stated frequencies, at time of admission, between men 40–49 years of age and men 20–29 years of age, by institution.*

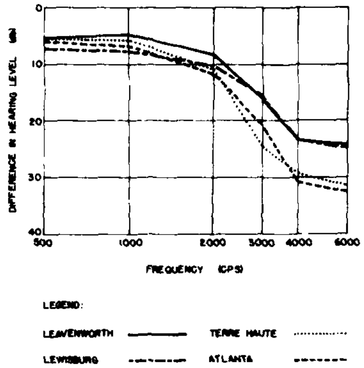

Figure 11. *Differences in median hearing levels, for stated frequencies, at time of admission, between men over 50 years of age and men 20–29 years of age, by institution.*

Table 15. *Percent of men, by age group, whose hearing levels, in db, did not exceed stated values at the time of admission to Lewisburg*

Age	Number of men	Percent of men	Hearing level for each ear at stated frequency (cps)																	
			500			1,000			2,000			3,000			4,000			6,000		
			Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average	Left	Right	Average
20–29	1,250	25	5.7	3.5	4.6	4.4	2.5	3.5	2.6	0.7	1.7	0.5	−1.0	−0.2	1.2	−0.5	0.4	0.1	−1.0	−0.4
		50	9.8	8.5	9.2	8.8	7.0	7.9	7.9	6.1	7.0	6.5	4.4	5.5	10.9	7.0	9.0	8.0	6.2	7.1
		75	15.5	14.3	14.9	14.3	12.0	13.2	14.1	11.4	12.8	13.7	11.0	12.4	19.4	16.4	17.9	19.1	15.5	17.3
30–39	705	25	5.9	4.9	5.4	6.4	4.8	5.6	5.6	3.8	4.7	6.0	3.1	4.6	7.3	4.5	5.9	5.7	3.6	4.7
		50	12.0	9.5	10.8	11.6	8.4	10.0	11.3	8.2	9.8	12.0	8.7	10.4	16.1	12.5	14.3	13.6	11.0	12.3
		75	18.1	15.3	16.7	17.7	13.9	15.8	18.0	13.6	15.8	22.2	17.1	19.7	31.8	25.4	28.6	28.0	25.5	26.8
40–49	257	25	7.7	6.4	7.1	7.5	6.5	6.0	8.9	5.3	7.1	9.0	5.5	7.3	13.3	10.1	11.7	11.4	8.5	10.0
		50	13.0	10.9	12.0	13.7	11.0	12.4	15.1	9.9	12.5	18.1	9.4	13.8	24.8	20.3	22.6	22.1	18.0	20.1
		75	19.9	16.8	18.4	20.6	16.5	18.6	23.9	16.8	0.4	31.5	24.2	27.9	42.0	38.5	40.3	39.1	35.2	37.2
50+	134	25	11.9	9.3	10.6	10.9	7.9	9.4	11.7	8.1	9.9	13.2	7.4	10.3	18.2	15.1	16.7	18.2	16.0	17.1
		50	17.7	15.0	16.4	18.0	13.1	15.6	20.5	13.7	17.1	23.7	18.4	21.1	34.3	30.1	32.2	33.5	30.0	31.8
		75	27.8	24.9	26.4	27.8	19.4	23.6	33.0	25.5	27.3	41.0	39.0	40.0	46.6	45.2	45.9	47.0	44.4	45.7
Total	2,346																			

little change from to 20-to-29 age group, the differences at 4,000 cps being considerably less than 10 db. Figure 10 shows a more marked shift for men in their forties, with differences of 10 to 15 db in frequencies above 3,000 cps. In figure 11, however, the differences with age are seen to be much greater, with the men in their fifties having hearing levels at 4,000 cps and 6,000 cps that differ by 25 to 30 db from those of men 20 to 29 years of age. The shift is substantial also in lower frequencies, amounting to 10 db at 2,000 cps and 15 to 25 db at 3,000 cps. These changes are particularly significant because they extend into the speech range.

Comparisons With Other Studies

The differences in hearing levels of different age groups have been studied by a number of investigators. In a recent report (*2*), Riley et al. presented hearing data obtained at Eastman Kodak Co. and made comparisons with presbycusis data developed in two other investigations—the 1954 report of the American Standards Association Exploratory Subcommittee Z24–X–2 (*3*) and British data reported in 1959 by Hinchcliffe (*4*).

If the data from these three studies, as presented by Riley, are plotted and adjusted so that hearing at age 25=0, the following comparisons can be made with the data in this report:

Study	1,000 cps			4,000 cps		
	Age					
	35	45	55	35	45	55
Eastman	1.3	3.4	7.0	6.8	13.5	24.5
ASA	.8	3.0	6.3	5.8	14.6	24.5
Hinchcliffe	.9	2.8	4.7	4.5	12.0	24.5
Atlanta	.6	3.45	6.75	4.55	14.4	30.7
Terre Haute	.9	1.65	5.75	5.45	14.35	29.2
Leavenworth	.5	2.05	4.95	3.15	15.15	23.3
Lewisburg	2.1	4.4	7.65	5.35	13.6	23.25

There appears to be good correlation between the seven different population groups, except that for some reason we cannot explain, the men beyond age 50 at Atlanta and Terre Haute show a 5 or 6 db greater loss at 4,000 cps than the other groups.

As Glorig and Nixon (*5*) have pointed out, valid comparisons of different populations present many difficulties. The comparisons with the Eastman, Hinchcliffe, and American Standards Association data are given here only to show the absence of any pronounced differences in hearing levels between other populations and those covered in this study.

Audiometric Data: Study Groups

Except in certain described special investigations at Atlanta, the hearing tests were all conducted during the day shift with the men usually being taken off their jobs to be tested. As previously pointed out, in some cases this could result in higher hearing levels due to temporary threshold shift.

Many of the operations included in these studies were not expected to cause significant noise-induced hearing loss, and the data obtained confirm this assumption. Furthermore, men working in these moderate noise environments probably sustain very little temporary threshold shift. In other words, the greater the hazard of permanent loss, the greater the accompanying temporary threshold shift is likely to be. Except where otherwise stated, the data reported represent the combined shift.

These points should be kept in mind when appraising the data which will be presented.

In most instances, the following tables present data only when available for at least 20 men having noise exposures of similar severity and duration. For this reason, the periods covered will not be the same for each department or operation. The principal exception to this rule is in the data for workers in the Leavenworth furniture factory, where findings for smaller groups of workers are reported.

Unless otherwise stated, the hearing levels given are the averages of the left and right ears. Also, except where indicated, the noise data given in these tables are the median values for all measurements made in the given locations.

Atlanta

Cotton Mill

Spin.—Table 16 presents data on hearing after various periods of employment in the spin department of the cotton mill. Workers in this operation are exposed to a steady state noise having an overall sound pressure level of 96 db, with a peak octave band of 88 db between 300 and 600 cps and with values above 85 db also in the 150–300-cps and 600–1,200-cps octaves.

One hundred and fifty-nine workers with 3 months' employment in this department show slightly higher average hearing levels at all six frequencies at the 25th, median, and 75th percentiles. The maximum shift of the median was 7 db and took place at 4,000 cps. The shift at 4,000 cps was progressively higher after 6 months and 12 months of exposure, showing a maximum of 11 db for the median of 76 men. This trend, however, reversed itself at longer exposure periods, dropping back to only 2.5 db after 48 months of work for the median of 20 men. A similar pattern of increase for about a year, followed by some decrease, is also observed at the other frequencies.

The reasons, if any, for this apparent partial recovery are not known. It could be theorized that more susceptible individuals might be inclined to seek transfer to other work, so that a higher percentage of those remaining would be those whose hearing is less affected. We have no evidence, however, to substantiate this theory. Another possibility, likewise without proof, is that the temporary threshold shift is greatest during the first weeks or months of employment, and gradually decreases as the ears become accustomed to the environment. If this proposition were correct, it would be possible for the combined shift to be greater in the beginning, even though the permanent increase in hearing level was greater later on.

Twist.—Table 17 contains data on men in the twist department after various periods of employment. The total sound pressure level of this steady state noise environment is 97 db. Median values exceed 85 db in the 20–75 cps, 150–300 cps, 300–600 cps, and 600–1,200 cps octave bands, with the highest figure, 89 db, at 300–600 cps.

After 12 months of employment in this department, 38 men showed increased hearing levels in all frequencies, the apparent increases ranging from 1.5 db at 500 cps to 18.5 db at 4,000 cps. Most of the increases appeared in the first 3 months of exposure. Twenty men with 24 months on job showed approximately the same hearing levels as the men with only 12 months' exposure.

TABLE 16. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Atlanta; factory: cotton mill; department: spin

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
195	0	25	1.5	−1.0	−1.0	3.5	7.0	2.5
		50	6.0	3.0	4.5	9.5	14.0	10.5
		75	9.5	8.0	11.0	19.0	31.0	28.0
159	3	25	3.0	.5	1.0	5.5	9.5	5.0
		50	7.0	5.0	7.0	13.0	21.0	14.5
		75	11.5	9.5	13.5	30.0	37.5	30.5
126	6	25	3.5	.5	1.0	4.0	10.0	7.0
		50	7.5	5.5	7.5	13.0	22.5	15.0
		75	12.5	9.5	13.0	26.0	38.5	34.0
76	12	25	3.0	1.0	1.0	5.0	10.0	5.5
		50	7.0	4.5	6.5	15.5	25.0	16.5
		75	11.0	8.5	13.5	30.5	43.0	35.0
48	24	25	2.0	−.5	1.0	3.0	7.5	6.5
		50	4.5	4.5	6.0	12.5	19.0	15.0
		75	9.0	9.0	11.0	24.5	35.5	30.0
23	36	25	2.0	.5	−1.0	3.5	7.0	7.0
		50	5.5	4.0	5.5	10.5	18.0	14.0
		75	9.0	7.5	9.0	28.0	35.0	27.0
20	48	25	2.5	.0	−1.0	6.0	10.0	5.5
		50	6.5	3.5	5.5	12.5	16.5	11.5
		75	9.5	7.0	9.5	23.0	36.0	27.5

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	83	84	87	88	86	84	81	78	96
Sones	8	15	25	30	26	26	30	30	78

TABLE 17. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Atlanta; factory: cotton mill; department: twist

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
45	0	25	1.5	−2.0	−1.5	2.0	4.5	1.0
		50	6.0	2.5	4.5	6.5	9.5	7.5
		75	11.0	7.0	9.0	15.5	23.5	21.0
33	3	25	4.5	2.0	3.0	7.0	13.0	9.5
		50	7.5	6.0	7.5	15.0	22.0	11.5
		75	12.0	9.5	14.5	33.5	40.0	27.5
32	6	25	4.0	3.0	5.5	10.0	11.5	11.0
		50	8.5	7.0	10.0	16.5	22.0	18.5
		75	14.0	10.5	15.0	32.5	37.5	29.5
38	12	25	3.0	.0	4.0	9.5	11.5	7.0
		50	7.5	5.5	8.5	17.0	28.0	16.5
		75	12.5	9.5	13.5	29.0	40.0	31.5
20	24	25	2.5	1.0	2.0	7.0	10.0	5.0
		50	7.0	6.0	7.5	19.0	27.5	20.0
		75	11.5	9.5	11.5	26.5	41.5	35.0

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	86	85	87	89	88	85	83	78	97
Sones	11	16	25	32	30	28	34	30	84

The noise pattern in the twist department is very similar to that found in the spin area. The exposure, however, is slightly more severe, as shown by somewhat greater shifts in hearing level at all frequencies. In making these comparisons, it should be noted that men assigned to the spin department had a 14.0-db median level at 4,000 cps, while those in the twist department showed only 9.5 db in this frequency prior to exposure.

The twist department is adjacent to and in the same room as the weave department, which has higher noise levels. While the noise levels in the twist area are as reported, it is possible that workers in this department are occasionally in the weave area, thereby subjecting themselves to a more severe exposure.

Weave.—Weave department data are given in table 18. The noise exposure in this operation is the most severe at the Atlanta cotton mill. The total sound pressure level is consistent, with a median value of 103 db. Every octave band exceeds 85 db, with six of the eight bands being 90 db or more. The highest value, 96 db, is found at both 600–1,200 cps and 1,200–2,400 cps.

One hundred twenty-eight men in the weave room showed very substantial increases in hearing level after 3 months of exposure. Comparisons with the hearing of 174 men who were tested before beginning work in this department indicate median shifts at each of the test frequencies as follows:

Cps	*db*
500	3.0
1,000	5.0
2,000	12.5
3,000	17.5
4,000	22.5
6,000	15.5

TABLE 18. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Atlanta; factory: cotton mill; department: weave

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
174	0	25	2.0	−2.0	0.0	4.5	9.0	5.0
		50	6.0	3.0	6.0	11.0	17.5	13.0
		75	10.0	8.0	12.5	23.5	35.5	29.0
128	3	25	6.0	3.0	11.0	18.0	26.5	15.5
		50	9.0	8.0	18.5	28.5	40.0	28.5
		75	14.0	13.0	26.5	44.5	47.5	41.5
96	6	25	5.5	3.5	9.0	13.0	26.5	18.0
		50	9.0	8.0	15.5	29.5	39.5	26.0
		75	13.0	12.5	24.5	42.5	47.5	40.5
76	12	25	5.0	3.5	8.0	17.5	28.5	17.0
		50	8.5	7.5	15.5	29.0	40.5	27.0
		75	12.0	11.5	25.5	42.5	47.5	42.0
45	24	25	5.5	2.5	10.5	22.0	31.0	22.0
		50	9.0	7.5	17.5	34.0	44.0	32.5
		75	13.5	12.5	28.5	48.0	49.0	46.5
33	36	25	3.0	1.0	8.5	25.5	34.5	21.0
		50	7.5	6.0	16.5	37.0	45.0	32.0
		75	12.5	11.5	24.5	47.0	50.5	42.0
24	48	25	5.0	3.5	6.5	20.0	38.5	21.5
		50	9.0	7.5	13.0	35.0	46.0	32.0
		75	13.5	11.0	23.0	46.0	51.0	43.0
28	60	25	4.5	4.0	7.5	57.0	35.0	26.5
		50	7.5	8.0	12.5	37.0	46.0	33.5
		75	12.0	11.0	20.5	46.0	51.0	45.0

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	90	89	92	94	96	96	92	86	103
Sones	15	22	36	46	52	58	63	52	147

The tests after 6 months and 12 months of employment show no appreciable change from the 3-month tests. The 45 men tested after 24 months on the job, however, show additional increases of approximately 5 db at 3,000, 4,000, and 6,000 cps, as compared with 76 men tested after 12 months of exposure. Men with 3, 4, and 5 years in this noise environment show little further change in hearing level.

Individual shifts in hearing level.—The data presented in tables 16, 17, and 18 show trends for *groups* of men. Table 19 shows, at least in limited fashion, the proportions of individual men whose hearing levels shifted at least 10 db after 3 months' employment in the spin, twist, or weave departments in Atlanta. These figures are for 103 men selected at random.

Of 86 ears in the weave department, 66, or 76.7 percent, showed increases in hearing levels at 4,000 cps, while 3 showed decreases and 17 did not change. Approximately 60 percent of the ears in this department had increased levels at 2,000 cps and 6,000 cps, and 65 percent at 3,000 cps. At least a quarter of the ears showed increased levels at 500 cps and 1,000 cps.

Although smaller percentages of increased levels occurred in the twist and spin departments, appreciable numbers of ears showed shifts, the minimum being 14.8 percent at 1,000 cps in the spin department. At least 20 percent showed higher levels in all other cases in these two operations. Only 2.8 percent of tests showed improved levels, the greatest number being 9 out of 206, or 4.4 percent, at 6,000 cps.

Temporary threshold shift.—Tables 16, 17, and 18 show increases in hearing level among workers in the cotton mill, with the greatest change appearing in the first 3 months. Because testing had to be done during the work period, some of these increases are undoubtedly due to temporary threshold shift.

Two special investigations were conducted in an attempt to determine the magnitude of this temporary shift. The first of these was made during the summer of 1958 when word was received that the cotton mill would be shut down for a week. Arrangements were immediately made for a series of tests to be conducted with 60 men from the mill study group. The men were picked by the penitentiary staff solely on the basis of age and job exposure. All those selected were born between 1920 and 1930. Fifteen currently worked in the weave department 3 to 6 months; 15, in other departments 3 to 6 months; 15, in the weave department 12 to 24 months; and 15, in other departments 12 to 24 months. By chance, in each of the two nonweave groups selected there was one man from the beaming department, with all of the others from spin or twist.

Each of the 60 men had his hearing tested during the middle of the workweek before the plant was closed. The shutdown took place the afternoon of Friday, July 18. All 60 men were retested on Saturday, July 19, and 30 were tested

TABLE 19. *Number of ears showing shifts of at least 10 db in hearing level at stated frequencies after 3 months' employment of 103 men in various departments of Atlanta cotton mill*

Department	Number of ears	Frequency																	
		500			1,000			2,000			3,000			4,000			6,000		
		+	=	−	+	=	−	+	=	−	+	=	−	+	=	−	+	−	−
Spin	88	18	68	2	13	74	1	18	69	1	29	56	3	31	55	2	26	27	5
Percent		20.4	77.3	2.3	14.8	84.1	1.1	20.4	78.5	1.1	32.9	63.7	3.4	35.2	62.5	2.3	29.5	64.8	5.7
Twist	32	7	25	0	6	25	1	8	23	1	10	22	0	17	14	1	14	16	2
Percent		21.8	78.2	0	18.7	78.2	3.1	25.0	71.9	3.1	31.2	68.8	0	53.2	43.7	3.1	43.7	50.0	6.3
Weave	86	24	60	2	22	59	5	51	33	2	56	28	2	66	17	3	52	32	2
Percent		27.9	69.8	2.3	25.6	68.6	5.8	59.3	38.4	2.3	65.2	32.5	2.3	76.7	19.8	3.5	60.5	37.2	2.3
Total	206	49	153	4	41	158	7	77	125	4	95	106	5	114	86	6	92	105	9
Percent		23.8	74.3	1.9	19.9	76.7	3.4	37.4	60.7	1.9	46.2	51.4	2.4	55.3	41.8	2.9	44.7	50.9	4.4

NOTE.
+ is an increase of at least 10 db.
− is a decrease of at least 10 db.
= is no change of less than 10 db.

each day thereafter, those from the weave department being tested every other day beginning July 20, and the men from the other departments on the alternate days, continuing through Sunday, July 27. The mill resumed operations the morning of July 28. Each of the men was tested again later in that workweek and once more 3 weeks later. With the shutdown period including two weekends, a 9-day respite from the noise was provided.

Table 20 presents the data obtained from these special tests. The day-by-day recovery pattern for the four groups is shown graphically in figures 12, 13, 14, and 15.

Of the 15 men from the weave room with 12 to 24 months' exposure (fig. 13), 8 had worked the

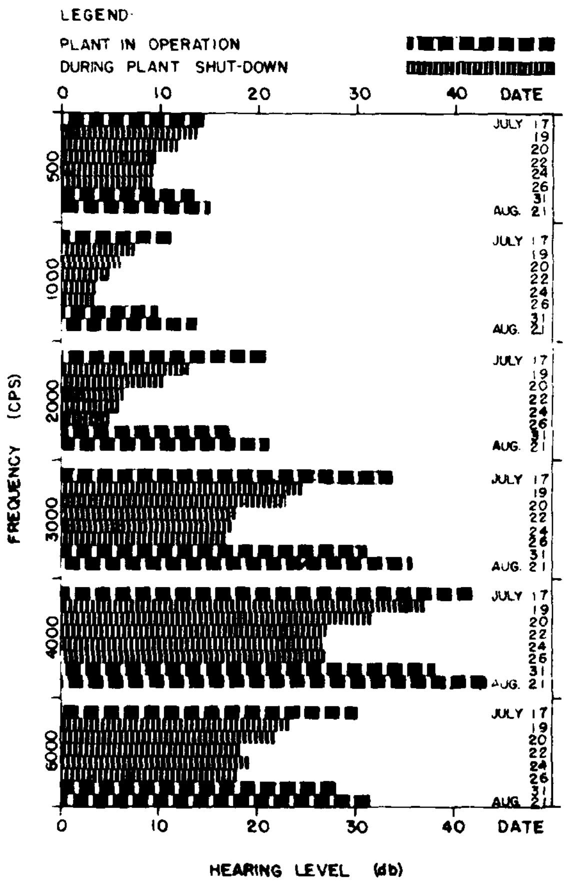

FIGURE 12. *Average day-by-day recovery of temporary threshold shift, for stated frequencies, with time away from noise exposure, of 15 men after working 3 to 6 months in the weave department at the Atlanta cotton mill.*

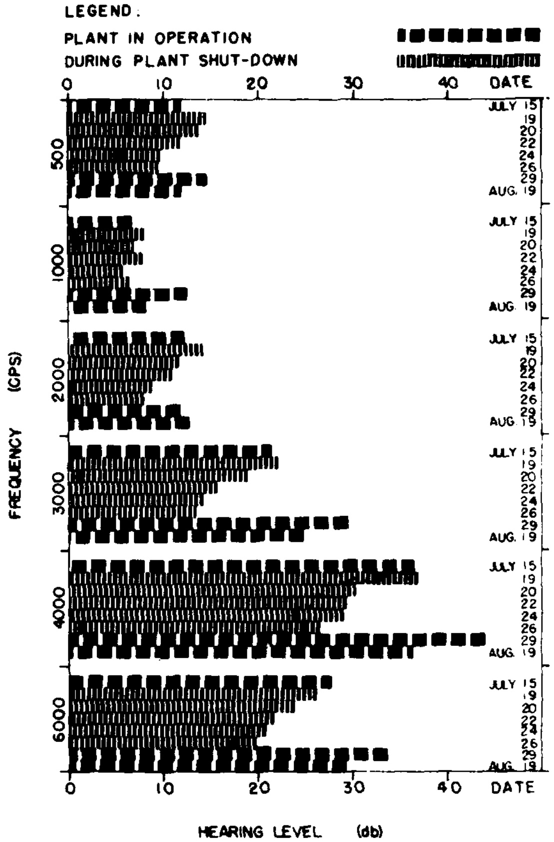

FIGURE 13. *Average day-by-day recovery of temporary threshold shift, for stated frequencies, with time away from noise exposure, of 15 men after working 12 to 24 months in the weave department at the Atlanta cotton mill.*

evening shift on July 14, and consequently had had approximately 12 hours' rest from the noise exposure when they were tested on July 15. The median values for this group on July 15 are therefore undoubtedly several db lower than they would have been had all of the men worked the day shift.

Examination of the data shows the day-by-day recovery pattern. Most of the recovery occurred within 48 to 72 hours, and there are indications, particularly from group 4 (fig. 15), that little more would have taken place after 1 week away from the noise. The tests given after the mill resumed operations showed a complete reappearance of the temporary shift almost immediately.

In figure 16 the solid line shows the average hearing level of the 30 weave department workers

TABLE 20. *Recovery of temporary threshold shift with time, during period in 1958 away from noise exposure, of 4 groups of 15 men. Noise exposure stopped after work on July 18 and began again on July 28*

Group No.	Department	Months employed	500 Left	500 Right	500 Average	1,000 Left	1,000 Right	1,000 Average	2,000 Left	2,000 Right	2,000 Average	3,000 Left	3,000 Right	3,000 Average	4,000 Left	4,000 Right	4,000 Average	6,000 Left	6,000 Right	6,000 Average	Date of test	Remarks
			Average hearing level of group for each ear at stated frequency (cps)																			
1	Weave	3 to 6	13.3	15.6	14.5	11.3	11.0	11.2	24.0	17.3	20.7	35.0	32.3	33.7	43.3	40.6	41.8	33.0	27.3	30.2	July 17	Tested in p.m. Plant operating
			14.0	13.6	13.8	6.6	8.0	7.3	15.3	10.6	13.0	25.3	23.6	24.5	37.3	36.6	37.0	25.3	19.3	22.3	July 19	1 day after plant shutdown.
			11.6	12.0	11.8	5.0	7.0	6.0	13.0	7.6	10.3	24.0	21.6	22.8	31.6	31.3	31.5	25.3	18.6	22.0	July 20	2 days after plant shutdown.
			8.3	11.0	9.7	4.3	5.0	4.7	8.0	4.3	6.2	19.0	16.6	17.8	28.0	26.0	27.0	22.3	14.0	18.2	July 22	4 days after plant shutdown.
			9.0	10.0	9.5	3.0	4.0	3.5	7.0	4.6	5.8	18.0	16.6	17.3	26.0	27.0	26.5	21.0	17.3	19.2	July 24	6 days after plant shutdown.
			8.3	10.3	9.3	2.3	4.3	3.3	6.0	3.3	4.7	18.0	15.6	16.8	27.0	27.0	27.0	18.6	17.3	18.0	July 26	8 days after plant shutdown.
			12.6	14.3	13.5	11.3	8.3	9.8	19.0	15.0	17.0	32.6	29.6	31.1	39.3	37.0	38.2	30.0	26.0	28.0	July 31	Operating. 4th day of exposure.
			13.3	16.3	14.8	12.3	15.0	13.7	23.6	18.3	21.0	37.3	34.3	35.8	43.6	43.0	43.3	33.3	29.7	31.5	Aug. 21	Operating. 25th day of exposure.
2	Weave	12 to 24	11.0	13.0	12.0	6.0	7.6	6.8	13.6	10.6	12.1	24.6	18.3	21.5	38.6	34.3	36.5	31.0	24.3	27.7	July 15	Tested in a.m. Plant operating.
			15.6	13.6	14.6	7.6	8.3	8.0	17.6	10.6	14.1	26.0	18.3	22.2	40.3	33.3	36.8	32.0	20.6	26.3	July 19	1 day after plant shutdown.
			15.3	12.3	13.8	7.3	6.6	7.0	15.3	8.0	11.7	23.3	14.6	19.0	33.0	27.3	30.2	28.6	19.0	23.8	July 20	2 days after plant shutdown.
			12.3	11.6	12.0	8.6	7.0	7.8	13.3	8.6	11.0	19.6	11.3	15.5	33.0	25.3	29.2	26.6	16.3	21.5	July 22	4 days after plant shutdown.
			12.0	9.6	10.8	5.3	[illegible]	5.7	12.6	5.0	8.8	18.3	10.0	14.2	35.3	22.6	29.0	27.0	14.6	20.8	July 24	6 days fater plant shutdown.
			11.3	10.0	10.7	5.6	7.0	6.3	11.0	5.0	8.0	18.0	9.0	13.5	31.3	21.6	26.5	24.3	15.3	19.8	July 26	8 days after plant shutdown.
			13.6	15.6	14.6	10.3	14.6	12.5	20.0	13.6	11.8	31.3	27.6	29.5	45.3	40.6	43.0	36.6	30.3	33.5	July 29	Operating. 2d day of exposure.
			11.0	13.0	12.0	7.3	9.0	8.2	15.6	10.0	12.8	26.6	23.0	24.8	38.0	34.6	36.3	33.3	25.0	29.2	Aug. 19	Operating. 23d day of exposure.
3	Spin, twist, and beam.	3 to 6	15.6	12.3	14.0	9.3	6.3	7.8	12.0	8.3	10.2	16.0	16.3	16.2	27.0	29.6	28.3	21.6	23.6	22.6	July 15	Tested in p.m. Plant operating.
			19.3	13.0	16.2	10.3	8.3	9.3	13.3	7.6	10.5	14.3	13.3	13.8	25.0	26.0	25.5	18.0	22.3	20.2	July 19	1 day after plant shutdown.
			15.6	12.6	14.1	9.3	5.3	7.3	12.3	6.0	9.2	12.0	13.0	12.5	22.6	23.3	23.0	14.3	15.6	15.0	July 21	3 days after plant shutdown.
			12.3	11.6	12.0	7.3	4.6	6.0	9.6	5.3	7.5	10.0	11.3	10.7	20.3	25.0	22.7	15.6	16.0	15.8	July 23	5 days after plant shutdown.
			12.3	11.0	11.7	6.6	4.0	5.3	9.0	5.3	7.2	10.0	10.0	10.0	19.0	20.6	19.8	13.3	14.6	14.0	July 25	7 days after plant shutdown.
			11.3	9.3	10.3	4.6	4.3	4.5	7.6	4.6	6.1	8.6	9.3	9.0	17.0	21.0	19.0	12.3	14.6	13.5	July 27	9 days after plant shutdown.
			11.3	15.6	13.5	7.6	7.3	7.5	9.3	6.3	7.8	12.0	15.6	13.8	23.6	27.0	25.3	19.0	20.6	19.8	July 29	Operating. 2d day of exposure.
			11.6	10.0	10.8	9.3	7.3	8.3	11.6	7.6	9.8	12.6	15.3	14.0	23.0	28.0	25.5	17.3	19.6	18.5	Aug. 19	Operating. 23d day of exposure.
4	Spin, twist and beam	12 to 24	13.6	12.3	13.0	7.3	8.0	7.7	9.6	6.0	7.8	17.3	15.3	16.3	30.0	26.6	28.3	20.0	18.6	19.3	July 17	Tested in a.m. Plant operating.
			14.0	13.0	13.5	6.3	7.3	6.8	7.3	4.6	6.0	15.3	14.6	15.0	28.6	25.0	26.8	16.6	18.6	17.6	July 19	1 day after plant shutdown.
			11.0	9.6	10.3	4.6	6.0	5.3	6.6	4.0	5.3	12.3	13.0	12.7	25.3	22.3	23.8	13.6	15.3	14.5	July 21	3 days after plant shutdown.
			12.3	11.6	12.0	3.6	5.3	4.5	7.3	3.0	5.2	11.6	10.6	11.2	23.6	21.6	22.6	13.3	17.3	15.3	July 23	5 days after plant shutdown.
			9.0	10.0	9.5	4.0	6.6	5.3	4.3	3.6	4.0	11.0	11.0	11.0	22.0	21.0	21.5	9.6	14.3	12.0	July 25	7 days after plant shutdown.
			9.6	11.0	10.3	4.3	5.3	4.8	4.6	3.3	4.0	9.0	9.3	9.2	22.0	21.0	21.5	11.0	14.3	12.7	July 27	9 days after plant shutdown.
			12.0	13.0	12.5	5.6	6.6	6.1	11.0	8.3	9.7	19.0	20.6	19.8	34.3	29.6	32.0	22.6	25.0	23.8	July 31	Operating. 4th day of exposure.
			9.6	10.3	10.0	7.0	7.3	7.2	9.0	5.6	7.3	16.0	18.0	17.0	27.0	27.3	27.2	16.6	18.3	17.5	Aug. 21	Operating. 25th day of exposure.

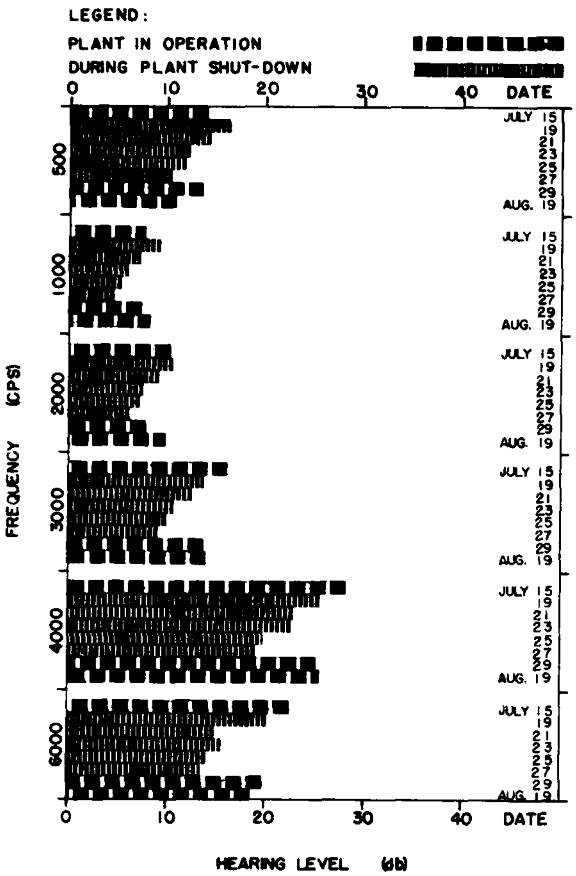

FIGURE 14. *Average day-by-day recovery of temporary threshold shift, for stated frequencies, with time away from noise exposure, of 15 men after working 3 to 6 months in the spin, twist, and beam departments at the Atlanta cotton mill.*

prior to the mill shutdown, while the dashed line shows the minimum level measured at any time during the period away from the noise exposure. Figure 17 presents similar data for the other 30 men.

In figure 18 the solid line shows the net recovery of the 30 men who had been on the job 3 to 6 months, while the dashed line indicates recovery of the 30 men who had exposures of 12 to 24 months. The men with the shorter exposure period recovered from 5 to 10 db more than did the other group. Since the levels of all four groups gave evidence of stabilizing after 1 week away from the noise, there are indications that more of the shift accompanying the longer work interval is not temporary.

The other special study concerned with recovery from temporary threshold shift was carried out at Atlanta in February 1960. At that time a hearing test was performed on every man still in the institution who had formerly been in the study group but had been removed from the cotton mill for any reason. The number of such men was comparatively small. Nevertheless, there were 18 men remaining who had worked in the weave department at one time, and who had had preplacement tests as well as tests while employed. Eighteen additional men from other departments, with similar tests, were also available.

Figure 19 shows findings for the 18 men who had once worked in the weave room. The dotted line is the median hearing level of the group prior

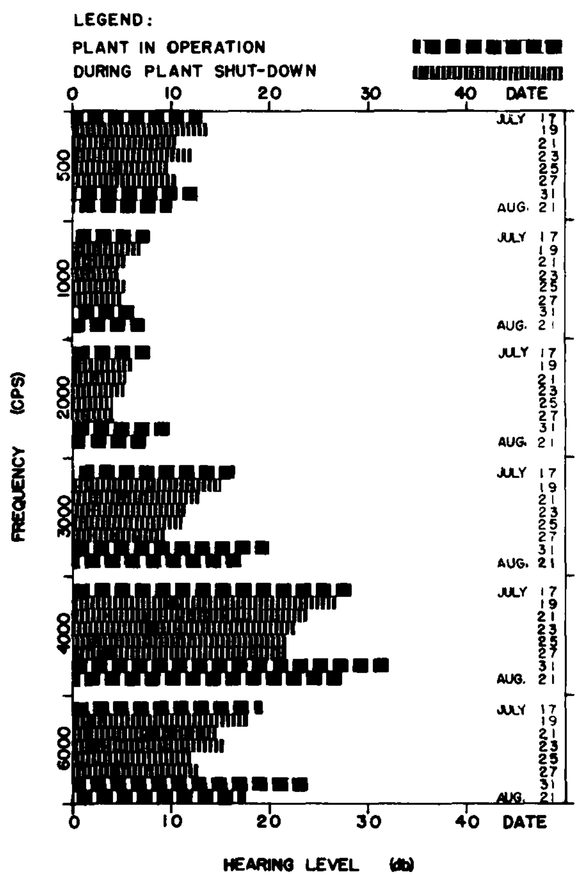

FIGURE 15. *Average day-by-day recovery of temporary threshold shift, for stated frequencies, with time away from noise exposure, of 15 men after working 12 to 24 months in the spin, twist, and beam departments at the Atlanta cotton mill.*

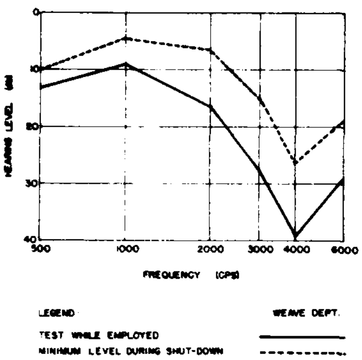

FIGURE 16. *Average maximum recovery of temporary threshold shift, for stated frequencies, during 8-day period without noise exposure, of 30 employees from the weave department of the Atlanta cotton mill.*

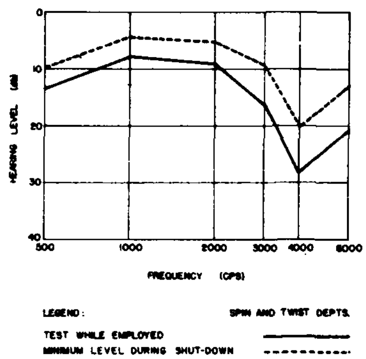

FIGURE 17. *Average maximum recovery of temporary threshold shift, for stated frequencies, during 9-day period without noise exposure, of 30 employees from the spin, twist, and beam departments of the Atlanta cotton mill.*

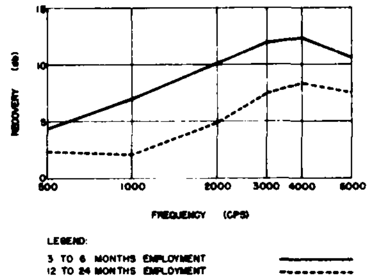

FIGURE 18. *Net recovery of temporary threshold shift, for stated frequencies, during 8- or 9-day period without noise exposure, of one group of 30 men with 3 to 6 months of employment and another group of 30 men with 12 to 24 months of employment in the cotton mill at Atlanta. Each group contained 15 men from the weave department and 15 men from the spin, twist, and beam departments.*

to starting work in this department. The dashed line is the median of their final tests while still employed, and the solid line is the median of their tests in February 1960. Figure 20 presents similar information for the 18 men from the other departments.

At first glance it appears from figures 19 and 20 that there was almost complete recovery after removal from the noise exposure, particularly among the men from the weave department. Although this somewhat inconsistent finding may be due in part to the relatively small number of men involved, another possibility should not be overlooked.

As was pointed out in our first report (appendix, p. 65), "in classifying inmates for work in the prison industries, consideration is given to previous experience in given jobs. Bureau of Prisons officials have advised us that many of the men assigned to the cotton mill have had previous experience in the textile industry. In other words, these men could have already suffered some hearing loss because of previous employment."

The following figures are of interest:

Group	Median hearing level in db at stated frequencies					
	500	1,000	2,000	3,000	4,000	6,000
1,055 men (age 30-39) at time of admission to Atlanta	6.5	2.3	5.4	9.0	14.3	11.7
174 men at time of assignment to weave department	6.0	3.0	6.0	11.0	17.5	13.0
18 men (from fig. 19) at time of assignment to weave department	4.0	2.2	10.0	13.5	23.0	15.0
18 men (from fig. 19) after removal from noise (February 1960)	3.8	2.0	4.0	13.0	25.0	20.0

Comparison of the two top lines of figures indicates a slightly but definitely higher median hearing level for the 174 men assigned to the weave department than was found for all men of similar age entering the institution. This difference might be attributed in large measure to the work placement policies at the institution. The 18 men who had postemployment tests show even higher levels in the 3,000- to 6,000-cps range at the time of assignment, as well as after removal from the noise. Whatever the cause, the postemployment hearing level of this group is inferior to that of men of similar age who enter the institution.

It is worth noting that there is remarkable agreement between the recovery curves of the two studies of temporary threshold shift, as seen by

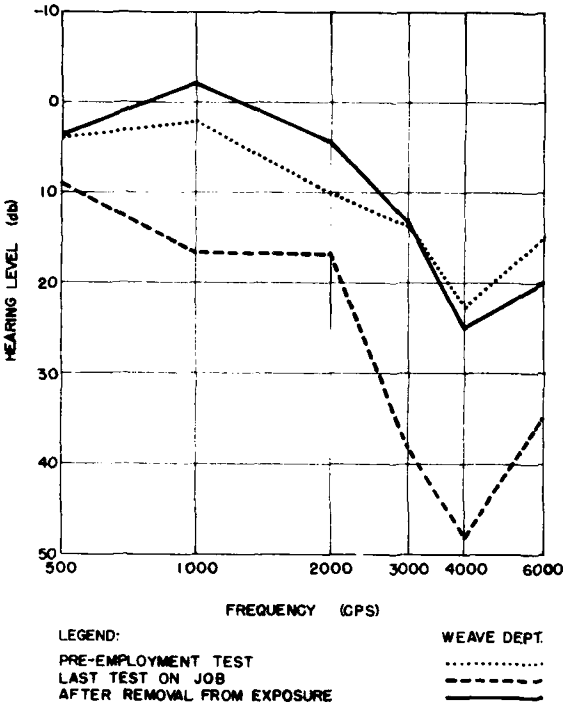

FIGURE 19. *Median hearing levels, at stated frequencies, after extended but indefinite periods of removal from noise exposure, of 18 former employees of the weave department of the Atlanta cotton mill, compared with the median levels obtained during their last hearing tests while still employed, and their median hearing levels prior to their assignment to that employment.*

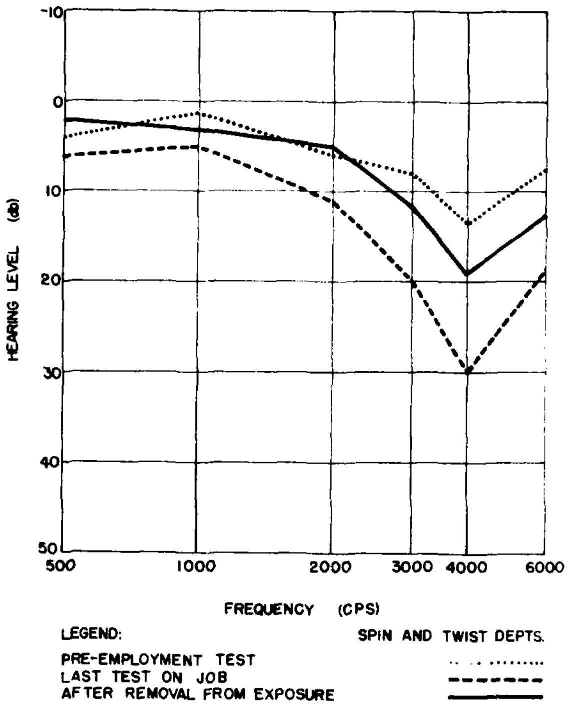

FIGURE 20. *Median hearing levels, at stated frequencies, after extended but indefinite periods of removal from noise exposure, of 18 former employees of the spin and twist departments of the Atlanta cotton mill, compared with the median levels obtained during their last hearing tests while still employed, and their median hearing levels prior to their assignment to that employment.*

comparing figure 16 with figure 19 and figure 17 with figure 20.

Terre Haute

Woolen Mill

Card, spin, and finishing.—Table 21 shows data on the hearing of men after various periods of employment in the carding and spinning department of the woolen mill. The men from the finishing department are also included in this group, since the noise environments are similar and the number of men in finishing was too small to consider alone. The median total sound pressure level in these combined operations is 90 db, with no octave band exceeding 81 db.

Only nominal changes in hearing levels are noted for the men in these departments, even after 24 months of exposure. At 4,000 cps, where the first and greatest change normally occurs, the total variation of the median was only 1 db. At 3,000 cps, 38 men with 24 months on the job showed 6.5-db increase of the median over 78 men with 12 months in the same environment. There was an increase of 3.5 db at 6,000 cps for men with 3 months of exposure. Considering the overall pattern of changes, there is no evidence of significant hazard.

Dye and pick.—Hearing levels of men with up to 1 year of employment in dyeing and picking operations are shown in table 22. These men are exposed to a median total sound pressure level of 94 db. The level for the 150–300-cps octave is 89 db, and the two lower octaves are 85 db each.

Audiometric tests of men with 3 months or 6 months of exposure reveal no particular indications of noise-induced changes in hearing levels. Twenty-six men with 12 months on the job show a slightly increased level at the higher frequencies for the medians and also for the 75th percentile

Table 21. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Terre Haute; factory: woolen mill; departments: Card, spin, and finishing

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
123	0	25	6.5	2.5	−3.0	1.0	4.0	3.0
		50	11.5	5.0	2.0	6.5	12.0	9.5
		75	16.0	9.0	7.5	14.0	21.0	23.5
157	3	25	5.5	1.0	−2.5	1.5	5.0	4.0
		50	10.5	4.5	2.5	7.0	12.5	13.0
		75	15.0	10.0	9.0	15.5	27.0	27.0
141	6	25	5.0	.5	−3.0	1.0	4.5	3.5
		50	10.5	5.5	2.5	7.0	12.0	11.5
		75	17.5	10.0	8.0	18.0	28.0	24.5
78	12	25	7.0	2.5	−1.0	2.5	4.5	4.5
		50	12.5	7.5	5.5	9.0	12.0	12.0
		75	18.5	12.5	12.5	18.5	27.0	23.5
38	24	25	4.5	−3.0	−3.5	3.0	5.0	3.0
		50	10.0	3.5	2.5	15.5	13.0	14.5
		75	21.5	11.0	10.0	22.5	25.0	25.0

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	80	79	81	81	79	76	71	66	90
Sones	6	10	16	18	16	15	15	13	45

Table 22. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Terre Haute; factory: woolen mill; department: dyeing and picking

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
37	0	25	7.0	1.0	−4.5	1.0	2.0	1.5
		50	12.5	5.5	2.5	6.5	11.0	13.0
		75	18.5	11.0	11.5	20.5	28.5	31.0
46	3	25	4.0	1.5	−5.5	1.0	2.5	1.5
		50	10.5	5.0	1.0	7.5	9.0	11.0
		75	17.0	9.0	9.0	18.0	24.0	29.0
32	6	25	7.5	2.5	−5.5	2.0	6.0	3.5
		50	14.5	7.0	2.0	9.0	13.5	12.0
		75	19.0	12.0	9.0	22.0	33.0	30.0
26	12	25	3.5	.5	−2.5	2.0	6.0	5.0
		50	11.0	5.5	3.5	11.0	17.5	16.0
		75	16.0	12.0	12.0	27.0	37.5	40.0

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	85	85	89	83	79	74	68	62	94
Sones	10	16	29	21	16	13	12	10	58

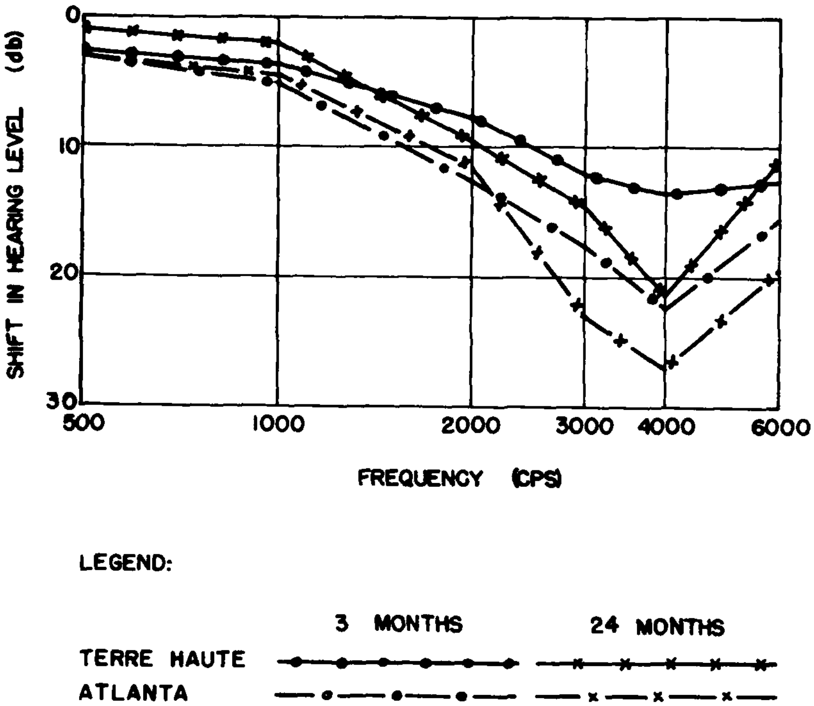

FIGURE 21. *Median hearing levels, at stated frequencies, of two groups of men at Terre Haute with 3 months and 24 months of employment, respectively, in the woolen mill weave department, compared with two groups of men at Atlanta with similar periods of employment in the cotton mill weave department.*

values. No changes are apparent at 2,000 cps or less.

Because of the small number of men and the short period of observation, only limited conclusions or observations are indicated. There are signs that some increase in hearing threshold at high frequencies might take place with prolonged exposure, but much of this change might represent temporary threshold shift.

Weave and warp.—The most severe noise exposures in the woolen mill occur in the weaving and warping department. While generally similar to the weave room noise pattern at Atlanta, the operations are on a smaller scale and the noise levels are lower. The median total sound pressure level found was 97 db. The four octave bands between 300 and 4,800 cps each measured 87 db or more, the peak being 90 db for the 1,200–2,400-cps octave.

Table 23 gives hearing data on men employed up to 24 months in this environment. A definite shift in hearing level appears with 3 months of exposure, with 113 men showing median changes of at least 12 db at 3,000, 4,000, and 6,000 cps. Again, there is a slight reversal of trend with 12 months' work. Another increase, however, appears after 24 months in this noise environment, particularly at 4,000 cps.

The pattern of shift, while not as severe, is similar to that observed among workers in the weave room at Atlanta. This similarity is shown in figure 21, which presents the shifts in hearing levels after 3 months and 24 months for weave room employees at both institutions from the levels found prior to beginning such work.

Leavenworth

Shoe Factory

Fitting.—Table 24 presents data for the hearing of men after various periods of work in the fitting department of the shoe factory. The total sound pressure level in this department is 89 db. The highest median octave band level is 82 db and is in the 20- to 75-cps band.

No great changes in hearing levels were recorded in this department. Shifts of only 2 to 3 db are

TABLE 23. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Terre Haute; factory: woolen mill; departments: weaving and warping

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
80	0	25	2.0	1.0	−3.5	−0.5	2.0	−0.5
		50	9.5	5.0	1.5	5.5	9.0	8.0
		75	15.0	11.5	8.0	14.0	18.5	22.5
113	3	25	6.5	3.0	2.0	6.5	10.0	9.5
		50	12.0	8.5	9.0	17.5	22.5	20.5
		75	18.0	13.5	16.5	33.0	38.0	34.0
82	6	25	5.0	3.5	1.0	7.0	9.5	8.5
		50	9.0	8.5	9.0	17.0	21.0	18.0
		75	14.0	14.0	17.0	33.0	38.5	36.5
49	12	25	2.0	1.0	1.0	5.5	8.5	7.5
		50	7.5	7.5	7.5	16.0	18.5	16.5
		75	12.0	13.5	14.0	27.0	32.0	31.0
26	24	25	5.5	2.0	0	8.0	20.0	8.0
		50	10.5	7.0	11.0	20.0	30.5	19.0
		75	17.0	12.0	17.0	33.5	39.0	38.0

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	76	75	81	87	89	90	87	81	97
Sones	4	8	16	28	32	40	45	36	94

found for the higher test frequencies after 24 months' employment. These shifts seem to continue at about the same rate during the next 2 years of exposure.

Lasting and cutting.—Data for lasting and cutting operations are grouped together in table 25. The median total sound pressure level in these operations is 89 db, with a peak octave band value of 82 db at 600 to 1,200 cps.

Men working in these areas for periods up to 36 months show only slight increases in hearing level, with no marked pattern of change in median values. The maximum differential is 5 db at 6,000 cps after 6 months' exposure. Somewhat more consistent increases in levels are observed for the 75th percentile values in the higher frequencies.

Other operations.—Because the noise environments are similar, data for making, treeing, sole leather, welting, and bottoming operations are combined in table 26. The median total sound pressure level for these departments is 93 db. The highest median octave band level is 84 db, and is found in the three octaves between 300 and 2,400 cps.

Men with periods of employment up to 48 months show slight and gradual increases in hearing level at all frequencies. The largest median difference found is 6 db at 3,000 cps after 36 months. Increases in the 75th percentile are likewise comparatively slight.

Brush Factory

Table 27 provides data on hearing of men in the brush factory for various periods of employment up to 60 months. All operations are combined in this table since most of the noise exposures are similar. The median overall sound pressure level is 89 db, and the highest median octave band level is 83 db at 600 to 1,200 cps.

A fairly consistent pattern of moderate gradual increase in hearing level with time is observed from the data in this table. Twenty-eight men with 48 months of exposure show median levels that exceed those of 89 newly assigned workers as follows:

cps	*db*
500	4
1,000	3.5
2,000	3
3,000	8
4,000	10.5
6,000	14.5

TABLE 24. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Leavenworth; factory: shoe; department: fitting

Number of men	Months employed	Percent employed	Hearing level at stated frequency (cps) 500	1,000	2,000	3,000	4,000	6,000
79	0	25	0.5	−0.5	0.0	1.5	0.5	1.5
		50	4.0	3.5	4.0	5.5	7.0	8.0
		75	8.0	7.5	9.0	14.0	18.5	18.0
70	3	25	2.0	1.0	.5	1.5	2.5	3.0
		50	5.5	4.0	4.0	7.0	9.0	10.5
		75	9.5	8.5	10.5	17.5	22.5	20.0
95	6	25	2.0	.5	1.0	2.5	3.0	3.0
		50	6.0	4.0	4.5	9.5	10.5	9.5
		75	11.5	9.5	10.0	17.5	24.0	23.0
[illegible]	12	25	2.5	.5	1.0	2.0	3.0	3.0
		50	7.0	4.5	4.5	7.0	9.0	9.5
		75	11.0	9.5	10.0	17.0	26.0	21.0
62	24	25	2.5	2.0	.5	.5	2.5	3.5
		50	6.5	7.0	6.0	7.5	10.0	11.0
		75	12.0	12.0	11.5	18.5	28.0	23.0
35	36	25	3.0	3.0	2.0	1.5	5.0	4.0
		50	7.0	7.0	7.0	7.5	14.5	13.0
		75	11.0	10.5	13.0	21.0	27.5	29.0
23	48	25	.5	4.0	2.5	3.0	3.5	8.5
		50	4.5	7.5	7.5	8.5	13.5	15.0
		75	10.5	12.5	19.0	26.0	28.0	24.5

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps 20-75	75-150	150-300	300-600	600-1,200	1,200-2,400	2,400-4,800	4,800-10,000	Overall
db	82	80	80	77	74	70	70	66	89
Sones	8	11	15	14	11	10	14	13	39

TABLE 25. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Leavenworth; factory: shoe; departments: lasting and cutting

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps) 500	1,000	2,000	3,000	4,000	6,000
52	0	25	0.5	0.5	−0.5	3.0	6.0	6.5
		50	4.5	4.5	5.0	8.0	14.0	12.5
		75	8.5	8.5	10.5	18.0	23.5	28.5
53	3	25	2.5	1.5	1.0	2.5	5.0	7.0
		50	6.5	5.0	4.5	8.0	12.5	14.0
		75	10.0	9.5	9.5	17.5	32.5	29.0
72	6	25	2.5	2.5	1.0	3.5	5.5	7.5
		50	7.0	6.0	4.5	9.0	17.5	17.0
		75	12.0	11.5	9.5	21.5	32.5	35.5
77	12	25	2.5	1.5	1.5	3.5	.5	8.0
		50	6.5	5.5	6.0	10.0	14.5	16.5
		75	11.5	11.5	14.5	23.0	27.5	34.0
54	24	25	5.0	3.5	2.0	2.5	6.5	8.0
		50	8.5	7.0	6.0	8.5	17.0	16.5
		75	13.0	11.5	11.0	18.0	33.5	35.0
33	36	25	2.5	2.5	2.5	2.5	5.5	8.0
		50	7.0	6.0	7.0	9.0	15.0	15.0
		75	12.0	12.5	11.0	24.0	35.0	43.5

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps 20-75	75-150	150-300	300-600	600-1,200	1,200-2,400	2,400-4,800	4,800-10,000	Overall
db	79	78	79	81	82	79	76	72	89
Sones	6	9	14	18	20	18	21	20	53

TABLE 26. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Leavenworth; factory: shoe; departments: making, treeing, sole leather, welting, and bottoming

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
59	0	25	1.0	1.5	1.5	3.0	2.5	2.5
		50	5.5	4.5	6.0	8.5	10.0	11.0
		75	9.0	10.5	12.0	17.5	29.0	24.5
59	3	25	2.5	1.5	1.0	3.5	5.0	6.0
		50	6.5	5.5	6.0	9.5	14.5	13.5
		75	10.0	11.0	12.0	23.0	27.5	29.0
81	6	25	4.0	3.0	2.0	3.5	6.0	6.0
		50	7.5	6.5	6.0	8.5	12.5	13.5
		75	12.0	10.5	11.0	16.0	28.5	27.5
93	12	25	3.5	2.0	2.0	3.5	6.0	6.5
		50	7.5	6.0	6.5	9.5	16.0	15.5
		75	11.5	9.5	12.0	19.0	32.5	28.0
66	24	25	4.0	3.0	1.5	3.5	6.0	7.0
		50	7.5	6.5	4.0	10.0	15.0	14.0
		75	12.0	9.5	13.5	22.5	32.5	27.0
39	36	25	3.5	3.0	2.5	3.5	5.5	6.5
		50	7.5	7.5	7.5	14.5	15.0	14.0
		75	13.5	13.5	16.5	26.0	32.0	30.0
31	48	25	4.0	3.0	2.5	5.5	5.5	8.0
		50	8.0	7.0	9.0	14.5	15.0	14.5
		75	13.0	12.0	15.0	24.0	32.0	29.0

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	81	78	82	84	84	84	80	74	93
Sones	7	9	18	22	23	26	28	23	65

Furniture Factory

Although data are available for only small numbers of men in this plant, they are included because of the severity of some of the noise exposures.

Mills.—Mill 1 presents the most severe noise exposure at Leavenworth. A median overall noise level of 101 db was found here, with the 75th percentile reaching 110 db (table 6). Mill 2 has slightly lower noise levels, the overall median being 98 db.

Table 28 presents combined data for Mills 1 and 2. The median total sound pressure level for these operations is 99 db. The peak octave band value is 90 db at 300 to 600 cps. All octave bands between 150 cps and 4,800 cps exceed 85 db.

Hearing levels in every frequency are found to be higher after exposure to this noise environment. The 19 men with 12 months of employment in the mills had levels higher than 12 newly assigned men by amounts ranging from 4 db at 1,000 cps to 16.5 db at 6,000 cps. Eleven men with 24 months of this noise exposure show levels approximately 10 db higher at 3,000, 4,000, and 6,000 cps than the men with 12 months on the job.

The shifts in level after 24 months are approximately the same as were found for workers with 24 months' exposure to the weave room noise in Atlanta. Peak levels in Mill 1 are much higher than any at Atlanta, but while weave room exposures are continuous, there is some intermittency in the woodworking schedule.

Other operations.—Data for other furniture factory operations are combined in table 29. Included are the finish, cabinet, and brush and handle departments. A variety of noise exposures are combined here. Even so, hearing data on only small numbers of men are available. The median overall sound pressure level for these operations is 88 db, the highest median octave band level being 82 db at 20 to 75 cps. Some of the operations occasionally have considerably higher noise

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TABLE 27. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Leavenworth; factory: brush; departments: all

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
89	0	25	0.0	0.5	0.5	−2.0	3.0	1.0
		50	4.0	3.5	4.0	5.0	9.5	8.0
		75	8.5	8.0	10.0	15.0	29.0	25.5
83	3	25	2.0	.5	1.5	2.5	4.0	3.0
		50	5.5	4.5	6.0	8.0	10.0	9.5
		75	9.0	9.5	11.5	14.5	23.0	22.0
101	6	25	2.0	1.5	3.5	2.0	2.5	2.5
		50	5.0	4.5	7.5	7.0	11.0	10.0
		75	10.0	9.0	12.5	17.5	25.0	24.0
95	12	25	2.5	1.5	2.0	2.5	5.0	3.0
		50	6.5	6.0	5.5	9.5	14.0	13.0
		75	10.0	10.0	10.5	19.5	30.0	28.0
71	24	25	1.5	1.5	1.0	2.0	4.0	3.0
		50	5.5	5.0	5.5	8.0	13.5	13.0
		75	9.5	9.5	10.0	18.0	25.0	27.0
50	36	25	3.0	2.5	.5	2.5	3.5	3.5
		50	7.0	6.5	6.5	9.0	16.0	16.5
		75	9.5	10.0	10.2	20.0	28.0	29.0
28	48	25	5.0	3.0	2.5	4.5	7.0	10.0
		50	8.0	7.0	7.0	13.0	20.0	22.5
		75	11.0	10.0	12.0	22.5	29.5	34.0
20	60	25	3.5	3.0	4.0	3.5	6.0	5.0
		50	7.0	7.5	9.0	9.5	20.0	20.0
		75	10.0	10.5	15.0	25.0	37.0	42.5

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	80	78	80	80	81	79	74	68	89
Sones	6	9	15	17	18	18	18	15	47

levels (table 6). Most of the extreme noise conditions, however, are intermittent in nature, thus lessening the degree of hazard.

The absence of sustained high noise levels probably explains why 21 men with 12 months of employment show median hearing levels essentially the same as those of 13 men at the time of assignment to these departments. Even 12 men with 24 months' exposure show similar levels, except at 4,000 cps where there is an increase of 7 db.

Printing Plant

Table 30 presents hearing data for men having various periods of employment in the printing plant. The median total sound pressure level in this shop is 91 db, with the median peak octave band level being 82 db at 150 to 300 cps.

No evidence of significant shift of hearing threshold is apparent in the groups of men with 6, 12, 24, or 36 months of exposure. Men with only 3 months on the job show slightly higher levels at 4,000 and 6,000 cps than the men with no exposure, but each of these groups has fewer than 20 men, and the data are not felt to be meaningful.

Clothing Factory

Data on hearing levels of groups of men with various periods of employment in the clothing factory are given in table 31. The median overall sound pressure level in this plant is 83 db, with no octave band reaching the 80-db level.

Twenty-five men with 3 months' exposure show somewhat higher median hearing levels in the high frequencies than new employees, the maximum difference being 7 db at 6,000 cps. The difference for 4,000 cps is 4.5 db. Although this value remains constant with groups having longer exposure, the level at 6,000 cps, after reaching

TABLE 28. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Leavenworth; factory: furniture; departments: mills 1 and 2

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
12	0	25	−1.5	−0.5	3.5	6.0	8.0	8.0
		50	3.0	6.5	8.5	9.5	16.0	13.5
		75	6.5	10.0	15.0	25.0	37.0	41.5
7	3	25	6.0	6.0	5.5	4.0	9.0	9.0
		50	11.0	11.5	10.0	15.0	32.5	20.0
		75	14.0	17.5	37.5	51.5	52.5	51.5
11	6	25	6.5	6.0	6.0	8.0	9.5	9.5
		50	9.5	10.0	9.5	22.5	27.5	22.5
		75	16.0	16.0	16.5	42.5	47.0	48.0
19	12	25	6.5	6.5	8.0	13.5	15.0	13.0
		50	9.5	10.5	13.0	25.0	30.0	30.0
		75	15.0	15.5	21.0	41.5	46.0	45.5
11	24	25	6.0	6.5	8.0	17.5	34.0	27.5
		50	8.5	9.5	13.0	37.5	41.5	39.0
		75	12.5	13.0	19.0	44.5	49.0	46.5
10	36	25	6.0	6.5	7.0	20.0	25.0	25.0
		50	8.5	8.5	11.0	37.5	42.5	38.5
		75	12.5	12.5	20.0	48.0	49.0	45.0

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	83	83	88	90	88	86	88	83	99
Sones	8	14	27	34	30	30	49	42	105

TABLE 29. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Leavenworth; factory: furniture; departments: finish, cabinet, brushes, and handles

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
13	0	25	−0.5	0.5	0.5	0.5	3.0	7.0
		50	6.0	6.5	6.0	9.0	13.0	15.5
		75	11.5	13.0	10.5	13.5	22.5	22.0
12	3	25	2.5	2.0	3.0	2.0	4.0	3.0
		50	6.5	6.5	7.0	10.0	13.0	10.0
		75	10.0	12.5	11.0	20.0	22.5	19.0
18	6	25	2.0	1.5	2.0	4.0	8.0	11.5
		50	6.0	5.0	6.0	11.0	14.5	17.5
		75	10.0	12.5	10.0	21.5	30.0	27.5
21	12	25	3.5	2.0	2.5	3.5	9.0	8.5
		50	7.0	5.5	7.0	11.0	15.5	16.0
		75	10.0	13.0	12.0	21.5	24.0	25.0
12	24	25	3.0	1.5	2.5	3.0	12.0	11.0
		50	7.0	5.0	6.0	12.5	22.5	15.0
		75	12.5	14.0	11.0	28.0	34.0	30.0

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	82	79	80	78	77	75	74	66	88
Sones	8	10	15	15	14	14	18	13	45

TABLE 30. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Leavenworth; factory: printing; departments: all

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
13	0	25	1.5	1.0	1.5	2.5	0.5	3.0
		50	5.5	4.5	5.0	9.0	11.0	10.0
		75	8.5	8.0	9.5	14.5	17.5	26.0
16	3	25	3.0	2.0	1.5	6.0	5.0	6.0
		50	6.0	5.0	4.5	9.0	14.5	15.0
		75	8.5	7.5	9.5	14.0	22.5	25.0
21	6	25	1.5	.5	1.5	5.5	3.5	3.5
		50	5.5	5.0	7.0	9.5	12.0	12.0
		75	8.5	8.0	13.0	17.5	24.0	23.0
24	12	25	1.0	.5	.5	4.5	3.5	3.5
		50	5.0	4.0	6.0	10.0	10.0	11.0
		75	8.5	7.5	11.0	15.0	20.0	22.5
26	24	25	1.5	1.0	1.0	3.5	4.0	6.0
		50	5.0	5.0	4.5	9.0	10.0	13.5
		75	8.5	8.5	9.5	19.0	22.5	23.0
20	36	25	1.5	3.0	2.5	4.0	4.5	5.5
		50	5.0	6.5	9.5	11.5	10.0	12.0
		75	8.5	10.0	14.0	25.0	25.0	20.0

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	78	79	82	81	80	76	71	69	91
Sones	5	10	18	18	17	15	15	16	47

a peak for men with 6 months' employment, decreases for men with 12 or 24 months' work, showing little difference from the level for new men. The levels at 3,000 cps show a similar regression pattern. It is unlikely that the moderate noise levels in this plant are responsible for the somewhat erratic data obtained.

Lewisburg

Shortly after the publication of our preliminary report (appendix), it was decided to discontinue the collection of hearing data from the study group in Lewisburg. The general nature of the noise environment in the metalworking operations, including its variability not only from hour to hour, but also from day to day, precluded a suitable estimate of weighted average exposure without continuous noise monitoring, and even such monitoring might be ineffectual.

The other noise exposure being studied at Lewisburg was in the clothing factory. Since the preliminary data analysis showed results similar to those obtained at the Leavenworth clothing factory, and since the noise levels were comparatively low, it was decided to relieve the institution of any further burden with this project.

Consequently, only the findings on the study group from Lewisburg which appear in the appendix are included in this report.

TABLE 31. *Percent of men, after various periods of employment, whose hearing levels, in db, did not exceed stated values*

Institution: Leavenworth; factory: clothing; department: tailoring

Number of men	Months employed	Percent of men	Hearing level at stated frequency (cps)					
			500	1,000	2,000	3,000	4,000	6,000
26	0	25	−1.5	−2.0	−1.0	1.0	1.0	3.5
		50	2.5	2.0	3.5	6.0	9.0	10.5
		75	7.5	9.0	9.5	11.5	16.5	20.0
25	3	25	2.5	1.0	1.0	2.5	5.5	5.5
		50	9.0	7.5	7.0	10.0	13.5	17.0
		75	14.0	15.0	14.5	21.5	27.5	29.0
33	6	25	2.0	2.0	2.5	5.0	6.0	6.5
		50	6.5	7.0	7.5	11.5	13.5	19.0
		75	12.5	15.0	13.0	20.5	27.5	33.0
45	12	25	4.0	1.5	3.5	2.5	4.5	4.0
		50	9.5	5.5	7.5	9.0	13.5	12.5
		75	15.0	11.0	15.0	18.5	23.5	29.0
28	24	25	1.0	1.0	4.0	2.5	3.0	4.5
		50	5.0	5.5	7.5	8.0	13.5	12.0
		75	15.5	12.0	13.0	17.0	20.0	27.0
14	36	25	1.5	1.5	1.5	2.5	2.0	4.0
		50	4.0	4.0	4.0	7.0	8.0	9.5
		75	7.5	7.5	8.5	11.5	15.0	18.5

MEDIAN NOISE EXPOSURE

Unit	Octave bands—cps								
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–10,000	Overall
db	78	73	76	73	71	68	62	58	83
Sones	5	6	12	11	9	9	8	7	29

Criteria: Review and Comparisons

Questions Involved

How do the findings from these studies fit with various proposed criteria? Before attempting to answer this question, it is necessary to clarify the meaning and objectives of such criteria.

Although criteria have been suggested by many authorities, these are not always intended for the same purpose. In one instance a criterion may be desired to assist in determining eligibility for compensation, while another may be needed to determine where protective measures are indicated. An important distinction is whether criteria are intended to define a hazardous situation or, conversely, to define a safe environment. There are considerable differences between these criteria and their applications.

Developing criteria for any purpose is difficult because of the variability and largely unknown nature of the relationships between hearing changes and the innumerable types of noise, particularly since the duration of exposure is of such great importance. There are many technical difficulties in making proper measurements of noise or hearing, but these are far from being the most difficult problems involved. The Research Center of the Subcommittee on Noise, and others, are currently making important contributions to knowledge in such areas as temporary threshold shift (*6–8*), but a deeper probing of the problem is needed.

Eldredge (*9*) has recently prepared probably the best review of the problems involved in establishing criteria for noise exposure. In this report he considers, among others, such questions as the purposes of criteria, how noise exposure should be measured and described, and how hearing impairment and loss of hearing should be measured and evaluated.

In his discussion of purposes of criteria, he states:

The ultimate decisions ... based on social and humane values. These questions cannot be answered by direct recourse to scientific method. The most common goal for criteria states, or implies, that the hearing to be protected is the hearing for speech (American Medical Association, 1955), and that this hearing should be protected in most, but not necessarily all, personnel exposed to noise. Criteria based on this goal further state, or imply, that persons with ears specially sensitive to injury by noise should be detected by a hearing conservation program, and removed from excessive exposure before hearing for speech is impaired (American Academy of Ophthalmology and Otolaryngology, 1957).

Normal sensitivity of hearing, especially sensitivity for high-frequency tones, diminishes with age. The amount of this kind of loss of hearing varies considerably from person to person. Another possible goal for criteria is that exposure to noise should not alter the distribution of loss of hearing from the distribution found in unexposed populations. This is the most rigorous goal society can set. A concrete example of the implications of this most conservative decision is demonstrated in the report by Rosenwinkel and Stewart (1957). Even for quite moderate continuous exposures to steady noises at about 80 db per octave band, personnel showed, on the average, more loss of hearing sensitivity for the audiometric test tones at 3 kc, 4 kc, and 5 kc than did a nonexposed control population. For the audiometric frequencies 500 cps, 1 kc, and 2 kc, the differences between the exposed and control groups were smaller. Further, the hearing levels for the speech frequencies indicate, on the average, no impairment for hearing everyday speech in either group. The goal set for the hearing to be protected will determine whether or not this exposure to noise is considered to be hazardous.

In his discussion of methods of describing noise exposure, Eldredge states:

The most important point to emphasize is that noise exposure includes the dimension of duration as well as the more usual acoustic dimensions. Ears have been exposed, in psychophysical experiments, to noise levels that are known to be harzardous when the exposures are repeated daily for years. Temporary, rather than permanent, changes in sensitivity of hearing are the rule for these experiments. Apparently, exposures of short durations at these levels will not produce permanent injuries. At the other extreme, field studies (American Standards Association, 1954; Webster and Solomon, 1955) show clearly a direct relation between years of exposure to noise and loss of hearing.

Duration as a single dimension can be very difficult to measure and to express in simple numbers. Noise may be regular and continuous throughout a working day. Or, more commonly, the noise level of the exposure may fluctuate greatly throughout the working day.

With regard to methods for evaluating hearing impairment, he writes:

Strictly speaking, there is no way to describe or to measure injury to the living inner ear in the same sense that we can measure the length of a cut on the face, X-ray the fracture of a bone in a leg, or count the fingers remaining on a hand. The sensory cells of the inner ear are deeply embedded in the bone of the skull and are inaccessible except for post mortem examination. Accordingly, we must infer injury from impairment as measured by comparing the hearing ability of an injured ear to that of a "normal" ear.

Measurements of impaired hearing can be no better than, and are limited by, the measurements that can be made of the ability of the normal ear to hear. The best standardized and most commonly used measure is that of sensitivity, the threshold of hearing for pure tones. Fortunately, this measure relates reasonably well on the average to other measures of hearing. The measure has the further advantage that some impairment of threshold sensitivity, which is not in itself an important part of the ability to hear in daily life, usually appears before more severe impairment which may be a handicap to the individual in carrying out the affairs of his daily life.

In a subsequent section on the relations of noise exposure to hearing impairment, he comments:

Many observers agree that permanent threshold shifts are often observed after prolonged occupational exposures to higher noise levels, while the same threshold shifts are rarely observed following exposures to lower levels. Similarly, short exposures to very high levels (Kopra, 1957; Ward, 1957) seldom lead to large permanent threshold shifts. . . . In man, temporary threshold shifts have been used to compare the severities of different exposures to noise, and lawful relations have been established between different parameters of exposure and temporary changes in hearing (Spieth and Trittipoe (1958a, 1958b; Ward, Glorig, and Sklar, 1958, 1959a, 1959b). These temporary threshold shifts are measured with an audiometer in the same way as the permanent threshold shifts. But, as the name implies, the threshold returns to normal preexposure usually within 48 hours. The relation between temporary and permanent threshold shifts is not known, but it is usually assumed that an exposure to noise that will not produce a temporary threshold shift also will not produce a permanent threshold shift. Some observers have assumed a significant relation between the sensation of loudness of the noise and the production of threshold shift (Hardy, 1952). Others (Kryter, 1950) have assumed, with some justification, a fundamental relation between the sound energy in a critical band and the likelihood of hearing impairment.

Proposed Criteria

Kryter

In his discussion, Eldredge reviews in chronological order various criteria which have been suggested, and points out the contribution made by each toward the eventual realization of suitable standards. He begins with a proposal made in 1950 by Kryter (*10*) that hearing loss probably could not be attributed to noise exposure if the sound pressure levels of the noise did not exceed 85 db in any critical band* of frequencies. Eldredge concludes his discussion of this proposal by stating: "Kryter's principal contribution was to recognize a need to consider the component frequencies and their band-width relations in evaluating the hazard of a given exposure to noise. Nearly all subsequent criteria reflect these ideas."

Hardy

Eldredge next reviews a criterion published by Hardy (*11*) in 1952 based on the loudness of noise in sones. Hardy concluded:

. . . the spectrum level which exceeds 100 sones per octave band is very probably damaging for long time daily exposure. For occasional exposure, spectrum levels of perhaps 200 sones or more are probably safe. All evidence indicates that when no octave band level exceeds 60 sones, there is very little likelihood that hearing damage will occur, even when the daily exposure persists over many years.

In his evaluation, Eldredge concludes that Hardy's principal contribution was the concept of a hazardous "zone" of noise levels instead of a single level. Within this zone, the hazard increases from a very slight to an almost certain hazard.

Rosenblith and Stevens

Eldredge then proceeds to a well-known criterion introduced by Parrack about a year after the Kryter monograph and elaborated upon by Rosenblith and Stevens (*12*) in 1953. With regard to their criteria, Eldredge states:

Rosenblith and Stevens considered the necessary decisions described in the body of the present report more carefully than had their predecessors. The goal se. for

*"Aural Critical Band" is defined in American Standard Acoustical Terminology (ASA S1.1–1960) as "that frequency band of sound, being a portion of a continuous-spectrum noise covering a wide band, that contains sound power equal to that of a simple (pure) tone centered in the critical band and just audible in the presence of the wideband noise."

the criterion was that the hearing threshold levels, as measured with pure tones in a noise-exposed population, should not differ significantly from those of a matched control population. The concepts of monitoring audiometry were not yet fully developed when this criterion was written, and most experts were still striving for complete protection of hearing. Rosenblith and Stevens recognized that it would be difficult to know when complete protection had been achieved. The threshold shifts associated with normal aging [presbycusis] are not always distinguishable from the threshold shifts produced by noise exposure. Furthermore, among normal persons not exposed to noise, presbycusis varies greatly, and the threshold shifts from age and other causes can be as great as severe noise-induced threshold shifts. It is important to note that these variations are so large that complete protection of hearing can only be specified statistically. These decisions of "no statistical difference" and "thresholds for pure tones" were more than goals in this criterion. They were also proposed as a scientific method for testing the tentative criterion under field conditions.

The authors decided further that the noise levels should be measured in octave bands and used directly, as long as the spectrum of the noise was relatively continuous, but should be converted to the equivalent of critical bands for special cases. A few other assumptions and decisions are apparent in the qualifications stated for the criteria. These qualifications have already been quoted many times, but are repeated here because they are considered an essential complement to the numbers included in table I.*

1. These contours are not to be taken too literally since deviations of the order of 1 or 2 db in either direction could probably be disregarded. Contours such as these should be interpreted as zones with some uncertainty attending the measurement of the exposure stimulus, and biological variability modifying the probability of damage. We feel, however, that contours 10 db lower would involve negligible risks indeed, while contours 10 db higher would result in significant increases in hearing loss.

2. The levels are considered to be safe in terms of exposures during working days for durations up to a lifetime.

3. The criterion levels apply to exposure to noise that has a reasonably continuous time character with no substantial sharp energy peaks.

4. For wide-band noise, the curve designated "octave bands" should be used. For pure tones or for noise in which the major portion of the energy is concentrated in a band narrower than the critical band, the curve designated "critical bands" should be used. In the latter case, the abscissa should be interpreted as a logarithmic frequency scale rather than a scale of octave bands of frequency.

5. The criterion should be considered as tentative only, and is subject to further revision as new laboratory and field data are reported.

*A portion of the table referred to is presented in table 32.

The most important contribution of Rosenblith and Stevens was *their statement of the statistical nature of* the relation between noise exposure and *threshold shift*. They also introduced more clearly the concept of specific goals for criteria.

Air Force Regulation 160–3

Another of the criteria reviewed by Eldredge is Air Force Regulation (AFR) 160–3, "Hazardous Noise Exposure" (USAF, 1956) (*13*). He points out that this regulation is an example of specific decisions made in a practical context, the key decision being to institute a hearing conservation program that included monitoring audiometry. This decision and others became integral parts of the criterion. The established goal was preservation of hearing threshold levels of 15 db or better for pure tone at the test frequencies of 500 cps, 1,000 cps, and 2,000 cps. From available information it was determined that except on rare occasions there would be negligible hazard if the criteria were not exceeded in any one of the four octave bands between 300 cps and 4,800 cps. The regulation states that ear protection is recommended when the band pressure level exceeds 85 db in any one of the four octave bands, and that such protection is mandatory when any one of the band levels exceeds 95 db. These limits were for continuous daily exposures of 8 hours. For shorter periods of exposure, the assumption was made that exposures to equal amounts of acoustic energy are equally injurious. Since, in the decibel scale, a doubling of the energy results in an increase of 3 db, the allowable sound pressure level can be increased by 3 db if the length of exposure is cut in half. Eldredge writes that studies of various investigators suggest that short exposures to even higher sound pressure levels can usually be tolerated without injury and that the equal energy assumption may thus err on the side of over protection. An advantage of the equal-energy rule is the elimination of many common, brief, but harmless exposures to noise from the hazardous class and reduction of the task of the hearing conservation program. AFR 160–3 retains the more important features of the Rosenblith and Stevens criterion to specify the operation of monitoring audiometry and to use a definite rule for the variable durations of many noise exposures.

Subcommittee on Noise

In this report we shall refer to only one other criterion reviewed by Eldredge, the criterion contained in the "Guide for Conservation of Hearing in Noise" (1957) (*14*) issued by the Subcommittee on Noise of the Committee on Conservation of Hearing, American Academy of Ophthalmology and Otolaryngology. In reviewing that publication, Eldredge states:

> The subcommittee's statement on criteria demonstrates fairly clearly a decision about criteria that is always made, but is not often stated explicitly. The available data point to a danger zone, rather than a danger limit, for noise exposure. We can ask "What is a hazardous exposure?" or we can ask "What is a safe exposure?"
>
> The relations between the answers to these questions are demonstrated by the qualifying statements of Rosenblith and Stevens with respect to their own criterion: "We feel, however, that contours 10 db lower would involve negligible risks indeed, while contours 10 db higher would result in significant increases in hearing loss." A criterion for noise exposure can be selected either because it is clearly hazardous, or because it is clearly safe, or because it is somewhere in between. The decision is not trivial, because design goals for control of noise are often set by the criterion chosen. Reduction of noise by an additional 10 decibels may easily double or triple the cost of noise control.
>
> The name of the parent committee is the Committee on Conservation of Hearing. The subcommittee shares the implied goal, and accordingly chose to write a limited criterion that emphasized safety rather than accepted any risk of danger. Their statement reads: "*If* the sound energy of the noise is distributed more or less evenly throughout the eight octave bands, and *if* a person is to be exposed to this noise regularly for many hours a day, 5 days a week for many years, then: *if* the noise level in either the 300–600-cycle band or the 600–1200-cycle band is 85 db, the initiation of noise-exposure control and tests of hearing is advisable. The more the octave band levels exceed 85 db the more urgent is the need for hearing conservation."
>
> Short exposures and exposures to impact noise or narrow-band noises were specifically excluded from this criterion.

Comparisons With Data

Table 32 presents specific figures for proposed criteria. Let us now review the findings from our studies and see how they relate to these criteria.

Atlanta

Continuous spectrum noise.—The most severe noise exposure at Atlanta occurs in weaving, where all the median octave band levels are over 85 db, with 90 db or more in six of the eight octaves. The peak value is 96 db at 600–1,200 cps and at 1,200–2,400 cps. On a loudness basis these are 52 and 58 sones, respectively. However, the octave band with the maximum loudness is 2,400–4,800 cps, where 92 db contribute 63 sones.

Noise in this department would probably be classified as potentially hazardous, regardless of the criteria employed. The use of ear protection would be mandatory under the Air Force regulation.

From the data in table 18 and the temporary threshold shift studies, there is substantial evidence that this noise actually produces hearing loss, and that the amount increases as the duration of exposure increases. Our hearing data thus

TABLE 32. *Selected proposed noise level limits, in db, for repeated, long exposures*

Authority	Sound pressure level in octave band equivalents							
	20–75	75–150	150–300	300–600	600–1,200	1,200–2,400	2,400–4,800	4,800–9,600
Rosenblith and Stevens:								
Continuous spectrum noise	110	102	97	95	95	95	95	95
Narrow band noise [1]		96	88	85	84	83	82	81
Air Force Regulation 160-3: [2]								
Continuous spectrum noise				95	95	95	95	
Narrow band noise				85	85	85	85	
Subcommittee on Noise, continuous spectrum noise				85	85			
Hardy:								
50 sones/octave to 100 sones/octave [3]	104–115	100–112	97–108	95–106	92–104	87–95	85–91	95–102
50 sones/octave to 100 sones/octave [4]	105–116	100–111	97–108	95–106	95–106	93–104	88–99	85–96

[1] Octave band level equivalents were published in this form with the note that the frequency scale should be interpreted as a logarithmic frequency scale, rather than a scale of octave bands of frequency.

[2] Ear protection mandatory at these levels. Protection recommended at 10 db below these levels.

[3] Octave band level equivalents assumed to have been used by Hardy.

[4] Octave band level equivalents computed by Stevens' method "The Calculation of The Loudness of Complex Noise," Journal of the Acoustical Society of America, vol. 28, 1956. This is the method used throughout this report.

confirm all of the criteria for a noise exposure of this magnitude.

The other operations at Atlanta do not present such high noise levels. The highest median octave band level in the twist department is 89 db at 300–600 cps. All six octaves below 2,400 cps have levels of 85 db or more. The greatest loudness, however, is at 2,400–4,800 cps, where 83 db correspond to 33 sones.

Table 17 indicates moderate shifts in hearing levels for periods up to 24 months of employment in the twist department. Smaller increases are found for exposures in the spin department (table 16), where slightly lower noise levels prevail, the median values averaging approximately 1 db less than in the twist department. The three octave bands between 150 cps and 1,200 cps exceed 85 db in the spin department, thus producing a noise environment where hearing conservation measures are advisable, according to the Subcommittee on Noise recommendations and the Air Force regulation. The levels in this area, however, do not reach the hazardous zone as defined by Hardy's 50-sone limit. These conditions are also true of the twist department. Likewise, the median octave band pressure levels do not reach the Rosenblith and Stevens criteria for continuous spectrum noise. As discussed further on, however, their criteria for narrow band noise may be exceeded on occasion.

While hearing data on workers from the spin and twist departments are included in the investigations we made on temporary threshold shift, the small number of men available made it necessary to combine the findings from these groups. Thus, although the data show a greater apparent shift among the twist department men, we do not know how much temporary threshold shift they had or how it compares with the men from the spin area. Figure 20 indicates that some of the high frequency shift of the combined departments may be permanent. Since the total shift in the spin department was relatively slight (table 16), it can be assumed that the permanent elevation of hearing level for twist department workers may be somewhat greater than shown in figure 20. If this assumption is correct, the twist department findings tend to support the criteria of the Subcommittee on Noise, with the spin department findings less conclusive, but not contradictory.

Narrow band noise.—The Rosenblith-Stevens and Air Force criteria include more stringent requirements for narrow band noise. The presence of such noise is not always easily determined. In the following discussion we shall use the definition employed in Air Force Regulation 160–3. This states:

> 16.g. Limits for pure tone or narrow band components:
> (1) *Identifying "pure tone" components.*—The limits on noise exposure in the preceding paragraphs apply only to broad band type noise, where the noise energy is distributed rather uniformly in all octave frequency bands. However, the noise energy in such noises as the compressor whine of a jet engine at "idle" is concentrated in one or more frequency components, called pure tone or narrow band components. These components may be in one octave band or they may spread through several octave bands. A noise of this type sounds rather like a musical note or a "pure tone," in contrast to the roaring sound of a broad band noise. The sound pressure level of the octave band with the pure tone component will usually be 3 db or more higher than the levels of the other adjacent bands. If the pure tone components are an octave apart, the sound pressure levels in two or three adjacent pure tone octave bands will not differ more than 1 or 2 db; however, they will usually be 3 db or more higher than the levels of the other adjacent bands. In many cases, the octaves containing the pure tone can be identified simply by listening to the sound and examining data on the octave band sound pressure level.

The regulation then gives the following examples:

Sample of noise level in different octave bands containing a pure tone

Noise	300–600 cps	600–1,200 cps	1,200–2,400 cps	2,400–4,800 cps
1	108 db	122 db	118 db	114 db.
2	81 db	92 db	93 db	88 db.

(a) For noise No. 1, the sound pressure level of the 600–1,200-cps octave band (122 db) is more than 3 db greater than the sound pressure levels in the two adjacent octave bands. This identifies the 600–1,200-cps band as the one containing the pure tone component.

(b) For noise No. 2, the sound pressure level of 92 db in the 600–1,200 cps differs by only 1 db from the sound pressure level of 93 db in the 1,200–2,400-cps octave band. However, both are more than 3 db greater than the sound pressure levels of the adjacent bands. This means there are pure tone components in both of the 600–1,200-cps and 1,200–2,400-cps bands.

While there is some question whether our *median* levels for octave bands in the Atlanta data would be considered to contain pure tone or narrow band noise in accordance with these definitions, many of the individual analyses in the weave, twist, and spin departments definitely qualify. The following are samples with the narrow bands indicated by *italics:*

Operation	20-75	75-150	150-300	300-600	600-1,200	1,200-2,400	2,400-4,800	4,800-9,600
Weave	85	85	91	96	*101*	98	92	86
	86	86	92.5	97	*102*	*100.5*	97.5	92
Twist	86	85	91	*95*	*96*	91	85	80.5
	83	82	90	*93*	*91*	82	83	74
Spin	78	83	89	*94*	86	85	84	84
	82	85	89	*94*	*92*	86	80	76.5

If these are narrow band noises, then all of them would be classed hazardous under the Rosenblith-Stevens criteria, and hearing protection would be mandatory under the Air Force Regulation 160-3. While the Rosenblith-Stevens criteria are aimed at protection for "a working lifetime" and our data cover only 4 years, the relatively small shifts of hearing levels in the spin department, particularly in the speech frequencies, indicate that the narrow band provisions may be considerably more conservative than those for continuous spectrum noise.

Terre Haute

Continuous spectrum noise.—The weaving and warping operations at Terre Haute provide the most intense noise exposure. Median octave band pressure levels are at least 87 db for the four octaves between 300 cps and 4,800 cps, the peak being 90 db at 1,200–2,400 cps. None of the loudness values reaches Hardy's lower limit of 50 sones, the maximum being 45 sones at 2,400–4,800 cps.

As previously discussed, the audiometric data on workers in this department indicate a considerable shift in hearing level. This substantiates the recommendations of the Subcommittee on Noise and AFR 160-3 that hearing conservation measures be employed in such an environment. The noise levels, however, are below the Rosenblith-Stevens criteria for continuous spectrum noise.*

One year of exposure in the dyeing and picking department, as seen in table 22, brought slight increases in hearing levels in the high frequencies. The peak median octave band pressure level here is 89 db at 150–300 cps, with the 20–75 cps and 75–150 cps bands having 85 db. There is a sharp decrease beyond 300 cps. The median band pressure levels are all below the various criteria for continuous spectrum noise. However, individual analyses gave readings of 97 and 98 db at 150–300 cps. According to most of the individual analyses, as well as the median for all of them in this department, the noise is a narrow band type with the peak at 150–300 cps. The card, spin, and finishing operations have still lower noise levels, with every octave band pressure level below 85 db, and thus below any of the proposed criteria. The negligible increases in hearing levels observed in men with up to 24 month's exposure are not in conflict with these criteria.

Narrow band noise.—As stated above, the dyeing and picking department has a narrow band noise environment. This peak occurs between 150 cps and 300 cps, a band not included in either the AFR 160-3 or the Subcommittee on Noise criteria. While some individual values were over 95 db, the median for this band was 89 db, just past the 88-db value proposed by Rosenblith and Stevens for narrow band noise in this octave. The hearing data, table 21, are not sufficient as a basis for any strong conclusions concerning the narrow band criteria in this range of frequencies.

Some of the individual sound analyses made in the weaving and warping department indicate narrow band noise, particularly in the 1,200–2,400-cps octave. If, as implied in AFR 160-3, three contiguous bands having adjacent bands at each end 3 db lower are classified as narrow band noise, then most of the analyses made in this department would be considered as such. The three octaves included would be between 300 cps and 2,400 cps, or, more frequently, between 600 cps and 4,800

*Except for 1 analysis out of 17 made.

cps. In this department the criteria for narrow band noise are exceeded, but the continuous spectrum noise criteria are not.

Leavenworth

Continuous spectrum noise.—Only small, gradual increases in high frequency hearing levels were obtained for workers performing most of the shoe factory operations. The highest median octave band level in this plant was 86 db, found in the welting and sole leather departments at 600–1,200 cps and in the treeing and packing department at 300–600 cps. The only 85-db value was at 300–600 cps in welting. The octave band levels are all well below the continuous spectrum noise levels of the Rosenblith-Stevens criteria. The highest loudness value, 36 sones at 2,400–4,800 cps in the sole leather department, is also below the Hardy criteria.

Table 27 shows a moderate, steady increase in hearing levels of workers exposed to brush factory noise. Data from all departments were combined in this table. The noise spectra are similar in most operations, being rather evenly distributed in the lower frequencies, with a steady decrease above 1,200 cps. Very few machines or processes produce narrow band noise patterns, but in the wire drawn department these are common, with most peaks between 150 and 600 cps.

All median values for octave band levels in this plant are low, the maximum being 83 db at 600–1,200 cps in the staple set department. Two individual analyses out of 53 in this plant gave octave band readings over 100 db at 300–600 cps. Only one other analysis produced even a total sound pressure level over 99 db.

The hearing level shifts found in this plant are somewhat surprising, since the sound pressure levels are well below any of the criteria, even for hearing conservation, and since much of the sound energy is below 300 cps. Even where narrow band noise was found, the octave band levels were generally below 85 db.

The noise in Mills 1 and 2 in the furniture factory is almost entirely of the narrow band variety, produced primarily by planers and saws. Most individual analyses in Mill 1 and many in Mill 2 exceeded the Rosenblith-Stevens criteria for continuous spectrum noise and virtually all of them exceeded their narrow band noise criteria. While the median octave band level exceeds the Hardy 50-sone criterion only in the 2,400–4,800-cps octave in Mill 1, many individual analyses show band loudness values over 50 sones. The hearing levels reported in table 28 confirm the hazardous environment of these operations as predicted by all of the criteria under consideration.

Because of small number of men involved and the variety and intermittency of their noise exposures, no conclusions concerning validity of criteria will be attempted for the data in table 29.

With regard to continuous spectrum noise, the printing plant noise data are substantially below the Rosenblith-Stevens criteria. The levels, particularly in the press department, are at the point where the Subcommittee on Noise and AFR 160–3 recommended starting hearing conservation measures. The median values in this department include 86 db at 150–300 cps and 85 db at 300–600 cps. The hearing data in table 30 show very little shift in hearing levels with exposure.

The noise levels in the clothing factory are far below any of the suggested criteria. As implied previously, we doubt that this noise had any connection with the hearing data shown in table 31.

Narrow band noise.—Much of the shoe factory noise meets the AFR 160–3 definition for narrow band noise, particularly in welting and sole leather departments, where median octave band values of 86 db exceed the Rosenblith-Stevens criteria at 600–1,200 cps. Over half of the individual octave band analyses in these departments are in excess of their narrow band noise criteria, primarily in the 300–600-cps and 600–1,200-cps octaves, but also including some up to 4,800 cps. Many similar results are found for the making and bottoming departments. Octave band values go up to 99 db, with many over 90 db.

The hearing data in tables 24, 25, and 26, however, do not indicate the development of substantial changes in hearing level. The degree of hazard thus appears to be exaggerated by application of such narrow band criteria.

As previously stated, the wire drawn department of the brush factory has a number of operations producing noise classified as narrow band. The octave band levels of most of these operations do not exceed the Rosenblith-Stevens criteria, but occasional values as high as 101 and 102 db are found. These do not occur throughout the work shift. It is possible, however, that these noises, produced principally by brush trimmer and twist-in-wire machines, contribute to the hearing level shifts found in this factory.

The planer, molder, and saw noises in the furniture factory are definitely classifiable as pure tone or narrow band noises. Many octave band levels over 100 db are found, the maximum recorded being 112 db at 300–600 cps. There is no question about the hearing loss hazard in this environment.

Occasional narrow band noise levels which exceed the suggested criteria are found in various frequency bands in the printing plant, but these are not continuous, and on a time-weighted basis would probably be acceptable under AFR 160–3. The highest value recorded was 91 db at 150–300 cps.

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Criteria: Discussion and Conclusions

Shift in Hearing Level

From tables 16–18 and 21–30, we are able to obtain 12 groups of workers with 24 months of employment in various factories at Atlanta, Terre Haute, and Leavenworth. For each of these groups we have taken the sum of their median hearing levels at 3,000, 4,000, and 6,000 cps and subtracted from this total the sum of the median hearing levels of these same frequencies of the pre-employment tests of men assigned to these departments. In other words, we have computed the difference between the levels of men with 0 month's and the men with 24 months' employment. In this discussion we shall call this difference "shift in hearing level."

These shifts have been listed in ascending order in table 33. It will be noted that they range from a minimum of 2.5 db for printing plant employees at Leavenworth to 79 db for mill employees in the furniture factory at the same institution. It is also apparent that eight of the groups have comparatively small shifts, while the other four have much larger ones. The eighth group in the list, woolen mill card and spin workers, has a shift of only 15 db, while the ninth group, cotton mill twist department employees, shows a 43-db shift.

This sharp difference in shifts of high frequency hearing levels probably indicates a meaningful difference in the effects of the respective noise environments. It is appropriate, therefore, to look for possible correlations with proposed hearing criteria (table 33).

Continuous Spectrum Noise

One column of table 33 gives the number of octave band analyses made of the noise in each location, the total being 364. Under the heading "Continuous spectrum" are tabulated the number and percent of analyses in which any of the octave band criteria, as suggested by Rosenblith and Stevens, have been exceeded. It will be observed that in less than 10 percent of the cases were the criteria exceeded, except in the two departments where the greatest shifts in hearing level occurred.

A total shift, after 24 months' exposure, of 15 db for the sum of the three highest test frequencies

TABLE 33. *Relationships of Rosenblith and Stevens continuous spectrum noise and narrow band noise[1] criteria to order of hearing level shifts after 24 months' exposure to noise, by department*

Factory and departments	Shift in hearing level[2]	Number of analyses	Analyses exceeding criteria: Continuous spectrum, Number	Continuous spectrum, Percent	Narrow band, Number	Narrow band, Percent
Printing, all	2.5	19	0	0	5	26
Shoe, lasting and cutting	7.5	34	0	0	5	15
Shoe, fitting	8.0	16	0	0	2	12.5
Shoe, making, etc	9.5	53	1	2	31	58
Brush, all	12.0	53	3	6	8	15
Cotton mill, spin	12.5	38	3	8	16	42
Furniture, miscellaneous	12.5	12	0	0	1	8
Woolen mill, card and spin	15.0	10	0	0	0	0
Cotton mill, twist	43.0	14	1	7	7	50
Woolen mill, weave	47.0	17	1	6	14	82
Cotton mill, weave	71.0	18	13	72	7	39
Furniture, mills	79.0	60	18	30	49	82
Total	....	364	41	11.3	150	41.2

[1] Employing AFR 160-3 definition for narrow band noise, but not including any involving the 20–75-cps band.
[2] Sum of median shifts at 3,000, 4,000, and 6,000 cps.

does not seem indicative of a serious noise hazard, particularly if some of this change may consist of temporary threshold shift. Nevertheless, inauguration of a hearing conservation program to prevent appreciable additional decline in hearing acuity is certainly appropriate in such situations.

While some of our data on groups of men with exposures of 4 or 5 years show shifts in hearing levels greater than after only 2 years, it appears that the rate of additional change is likely to be slow in moderate noise environments. This is in accord with such findings as reported by Rosenwinkel and Stewart (*15*).

In our opinion, the data in table 33 provide considerable support for the continuous spectrum noise criteria proposed by Rosenblith and Stevens. The low percentage of sound analyses exceeding their criteria in the first eight departments listed indicates that their suggested band levels are not too low. Similarly the substantial percentages of analyses exceeding their criteria in the two departments listed last in table 33 show that their recommended figures are not excessively high. The two departments in between, that is, the cotton mill twist and woolen mill weave, present data which are probably less definitive. While the shifts in hearing levels are considerably less than those in the two departments below them, they are of sufficient magnitude that we would have expected the noise criteria to be exceeded somewhat more frequently.

Narrow Band Noise

Examination of the figures in table 33 under "Narrow band" does not reveal signs of consistency that were noted for continuous spectrum noise. The percentage of analyses exceeding the criteria fluctuates widely as one proceeds down the column. Significantly, reliance on the data from such areas as the cotton mill spin or miscellaneous shoe departments would result in judging these to be much more hazardous than our hearing data indicate.

It is again emphasized that the definition employed here for narrow band noise is not a part of the Rosenblith-Stevens criteria, and we are quite confident that when they developed their proposals they did not intend for such an application to be made.

The Air Force Regulation 160–3, however, which attempts to retain the principal features of the Rosenblith-Stevens recommendations, does employ this definition. It is understandable why this was done since it would be very difficult, if indeed not impracticable, to routinely evaluate on-the-job noise situations in greater detail than is attainable with an octave band analysis. For Air Force purposes, Regulation 160–3 may be entirely practicable and desirable, and we do not suggest that they revise it because of the findings presented in this report.

The discussion here is primarily for the guidance of other agencies or organizations contemplating the establishment of standards. Since AFR 160–3 is probably the only specific regulation of a detailed nature in force at this time, it is only natural to expect many groups planning regulations or standards to examine it, and possibly, since little else is available, to copy its criteria, or, alternatively, the Rosenblith-Stevens criteria, on the assumption that they are essentially the same.

It is our impression that many individuals interested in industrial noise problems concentrate their attention on criteria for continuous spectrum noise, thinking that those for pure tones or critical bands would be applicable only in occasional, exceptional situations. Whether or not this is correct *depends upon the definition of such narrow band noise.* At this time AFR 160–3 presents the only clear-cut procedure for identifying such noise with the generally available equipment and techniques.

Of our 364 octave band analyses in table 33, 150, or 41.2 percent, exceeded the narrow band criteria by the AFR 160–3 definition. This percentage is not unduly high. An examination of the noise analyses made by Karplus and Bonvallet (*16*) in about 600 locations of 40 plants of widely different manufacturing industries shows at least as high a proportion of "narrow band noise" situations.

Conclusions

From the foregoing discussion, we offer in summary the following conclusions:

1. Our data support, in most instances, the continuous spectrum noise criteria proposed by Rosenblith and Stevens.

2. Using the Air Force Regulation 160–3 definition for narrow band noise components, our data

do not substantiate the theory that more stringent criteria are required where such noise is present. Further investigations are needed concerning the validity of this theory.

3. Using the AFR 160–3 definition, narrow band noise will be found in about half of the common industrial environments.

4. Development of a practical, acceptable definition for narrow band noise and a field method to determine such noise in industry is needed, particularly if special criteria are to apply to such noise.

5. Our data support the recommendations of the Subcommittee on Noise in Industry and AFR 160–3 on the desirability of instituting hearing conservation measures where the work environment includes regular, prolonged exposure to steady-state continuous spectrum noise reaching octave band levels of 85 db.

6. Our da' indicate that the lower limit of 50 sones per octave band, suggested by Hardy, does not always provide sufficient protection.

7. If a steady-state type of noise exposure is severe enough to produce eventually a marked adverse effect on hearing in the speech range, a definite elevation, or deterioration, of the hearing level in the test frequencies of 3,000, 4,000, and 6,000 cps will usually appear within a few months after the exposure begins.

8. With increased duration of the exposure, less of such elevation of hearing level will disappear after the noise exposure is discontinued.

Graphical Representations of Noise Environments Studied

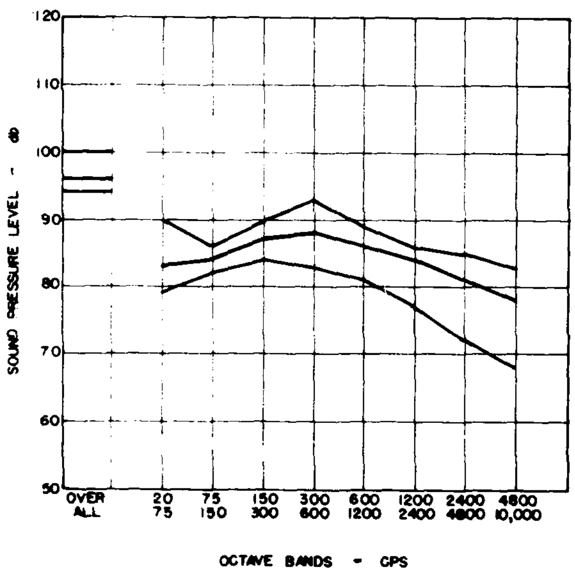

FIGURE 22. *Octave band analyses, showing the median, 25th, and 75th percentile values for the spin department in the cotton mill at Atlanta.*

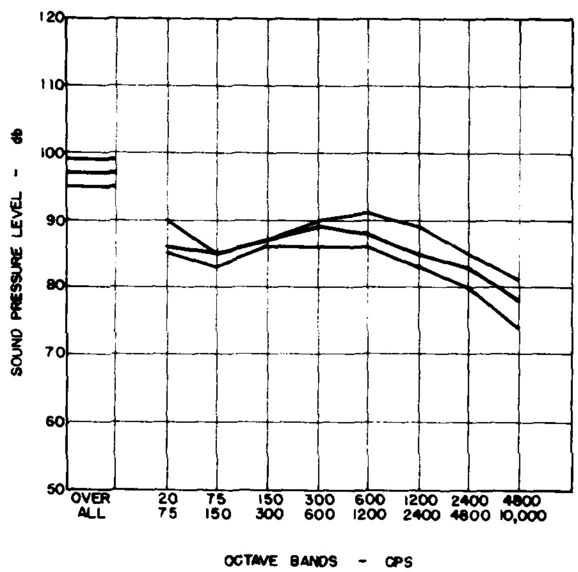

FIGURE 23. *Octave band analyses, showing the median, 25th, and 75th percentile values for the twist department in the cotton mill at Atlanta.*

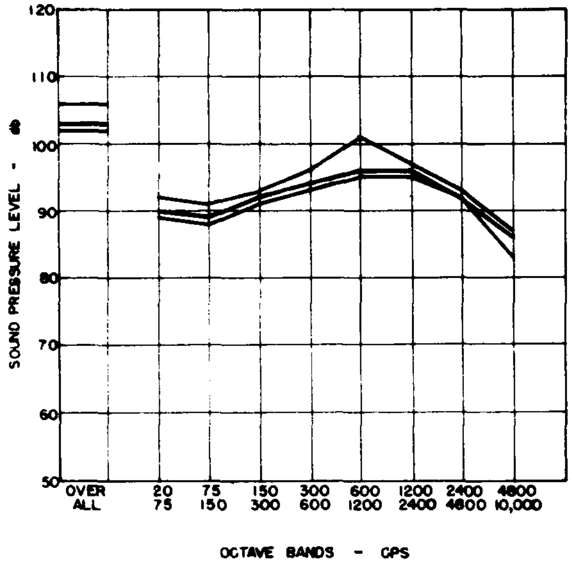

FIGURE 24. *Octave band analyses, showing the median, 25th, and 75th percentile values for the weave department in the cotton mill at Atlanta.*

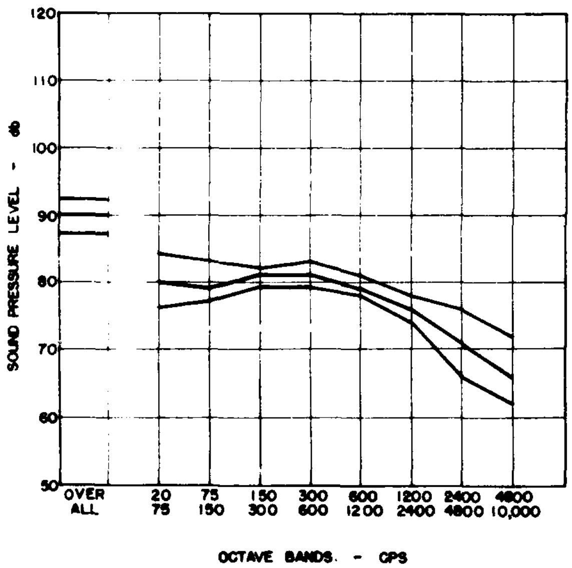

FIGURE 25. *Octave band analyses, showing the median, 25th, and 75th percentile values for the carding and spinning, and finish departments in the woolen mill at Terre Haute.*

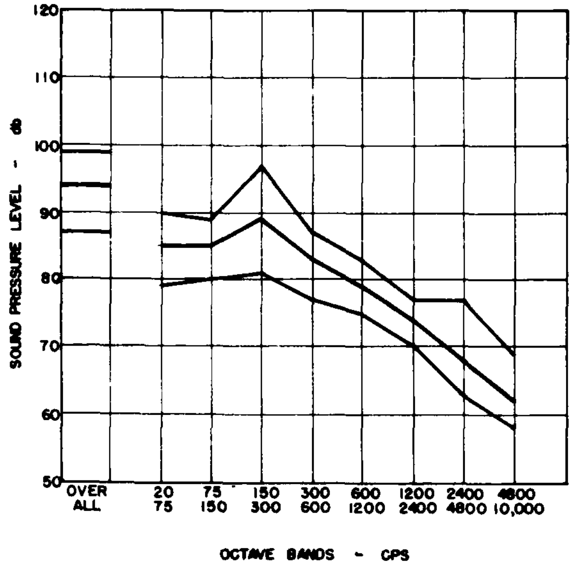

FIGURE 26. *Octave band analyses, showing the median, 25th, and 75th percentile values for the dyeing and picking department in the woolen mill at Terre Haute.*

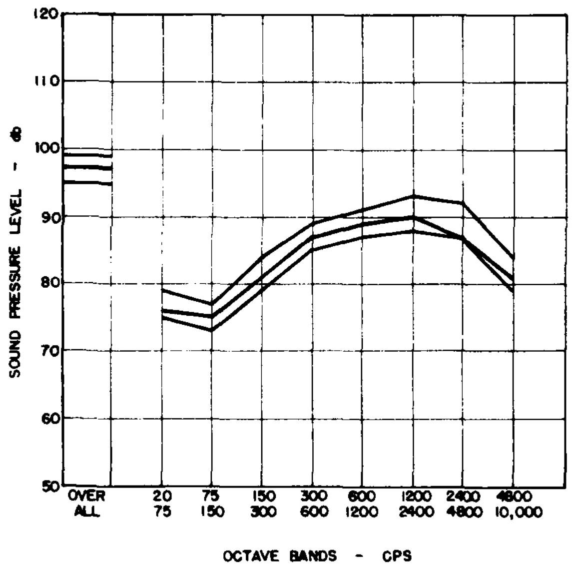

FIGURE 27. *Octave band analyses, showing the median, 25th, and 75th percentile values for the warping and weaving department in the woolen mill at Terre Haute.*

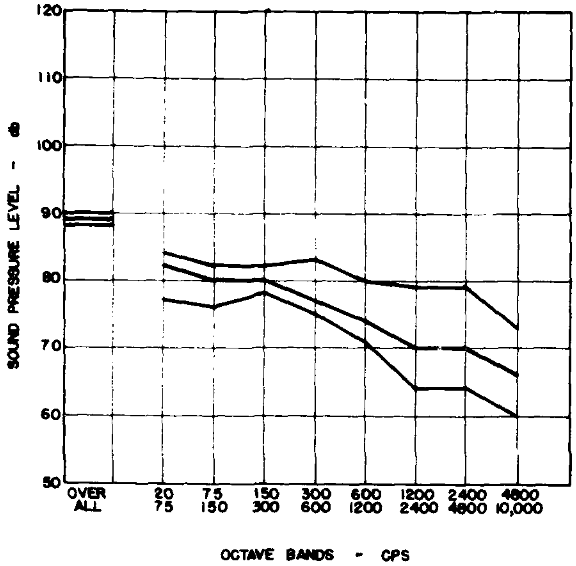

FIGURE 28. *Octave band analyses, showing the median 25th, and 75th percentile values for the fitting department in the shoe factory at Leavenworth.*

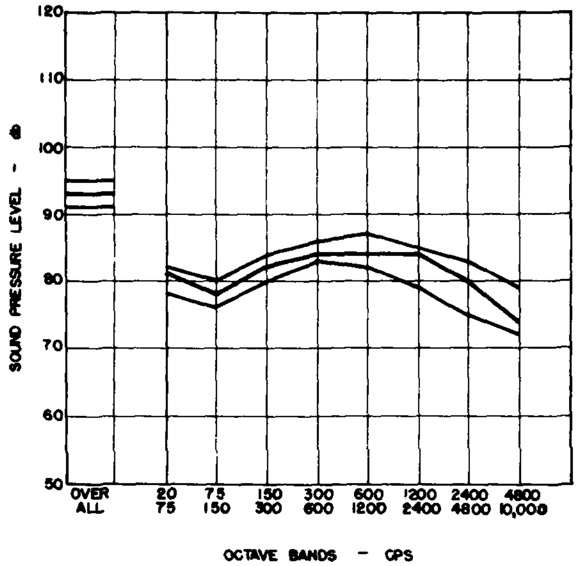

FIGURE 30. *Octave band analyses, showing the median, 25th, and 75th percentile values for the making, treeing and packing, sole leather, welting, and bottoming departments in the shoe factory at Leavenworth.*

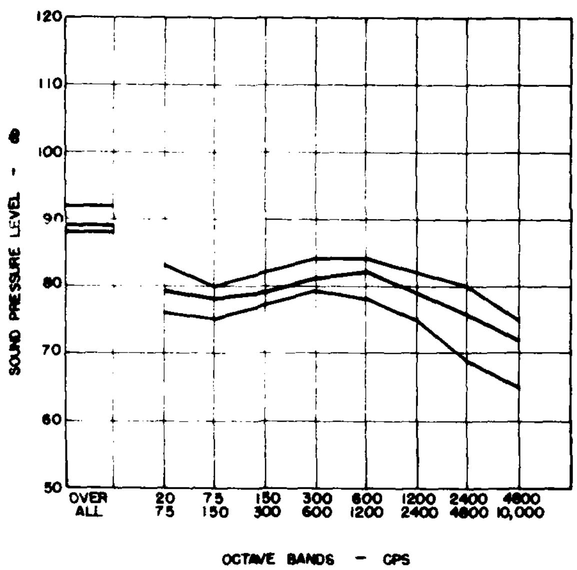

FIGURE 29. *Octave band analyses, showing the median, 25th and 75th percentile values for the lasting and cutting departments in the shoe factory at Leavenworth.*

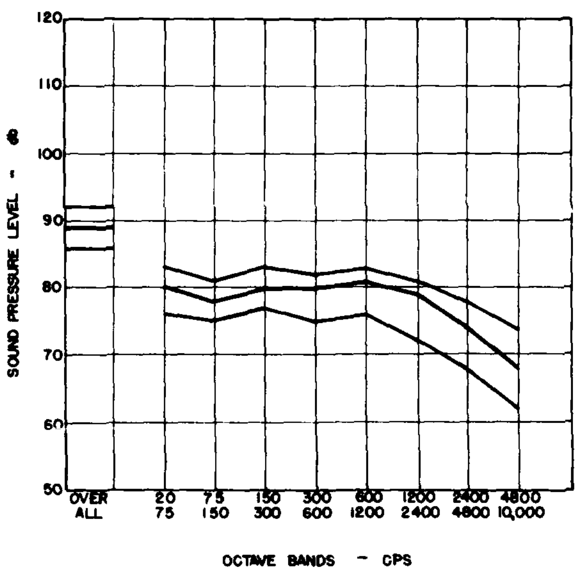

FIGURE 31. *Octave band analyses, showing the median, 25th, and 75th percentile values for all departments in the brush factory at Leavenworth.*

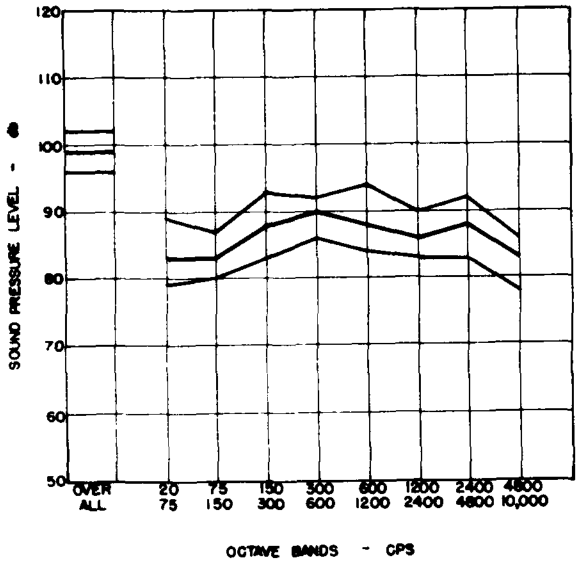

FIGURE 32. *Octave band analyses, showing the median, 25th, and 75th percentile values for Mill 1 and Mill 2 in the wooden furniture factory at Leavenworth.*

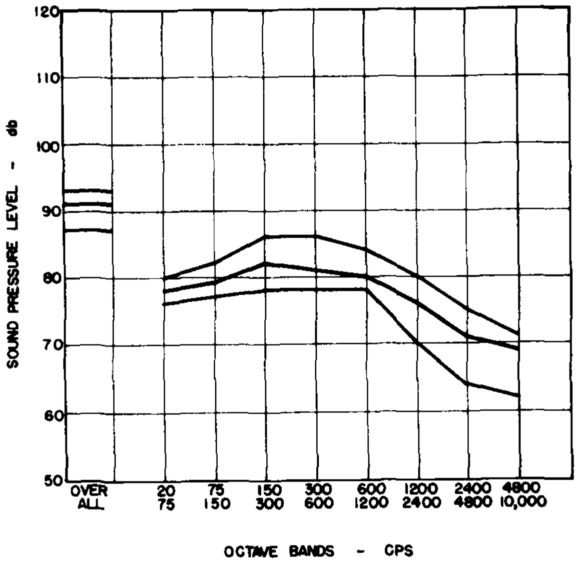

FIGURE 34. *Octave band analyses, showing the median, 25th, and 75th percentile values for all departments in the printing plant at Leavenworth.*

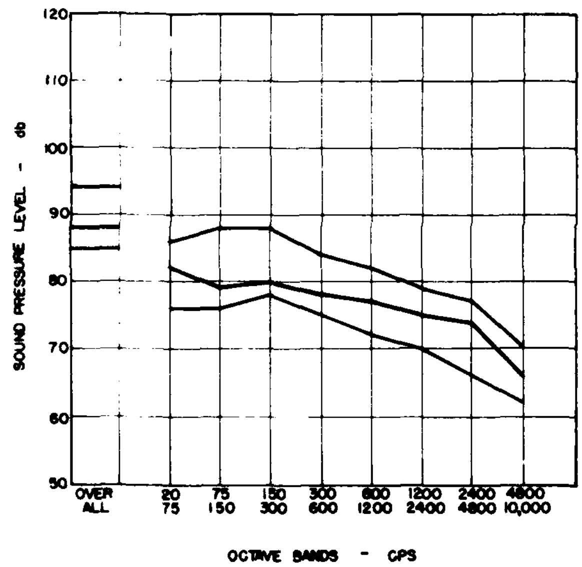

FIGURE 33. *Octave band analyses, showing the median, 25th, and 75th percentile values for cabinet, finish, and brush and handle departments in the wooden furniture factory at Leavenworth.*

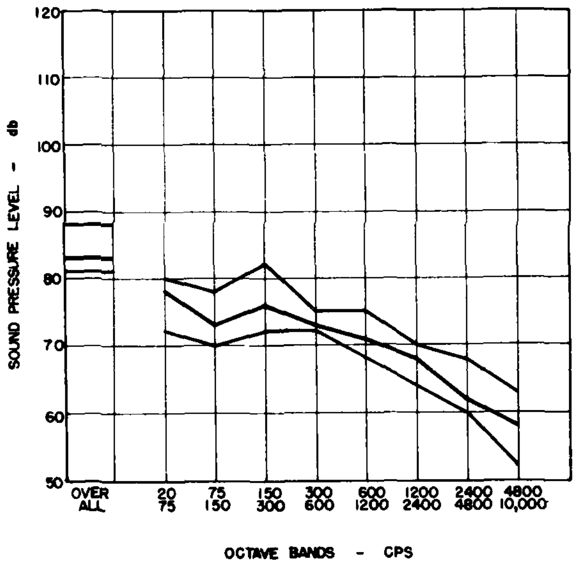

FIGURE 35. *Octave band analyses, showing the median, 25th, and 75th percentile values in the clothing factory at Leavenworth.*

References

(*1*) Carhart, R.: Critiques of present efforts to develop a damage risk criterion. Am. Ind. Hyg. Assn. Jour. 20: 441–446, 1959.

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Glossary of Terms*

Air Conduction. Air conduction is the process by which sound is conducted to the inner ear through the air in the outer ear canal as part of the pathway.

Ambient Noise. Ambient noise is the all-encompassing noise associated with a given environment, being usually a composite of sounds from many sources near and far.

Audiogram (Threshold Audiogram). An audiogram is a graph showing hearing loss as a function of frequency.

Audiometer. An audiometer is an instrument for measuring hearing sensitivity.

Aural Critical Band. The aural critical band is that frequency band of sound, being a portion of a continuous-spectrum noise covering a wide band, that contains sound power equal to that of a simple (pure) tone centered in the critical band and just audible in the presence of the wide-band noise.

NOTE 1: By "just audible" is meant audible in a specified fraction of the trials.

NOTE 2: The use of the aural critical band to estimate masking should be limited to masking by noises having continuous spectra without excessive slopes or irregularities and to cases where masking exceeds 15 db.

NOTE 3: In order to be just audible in a wide-band continuous noise, the level of a simple tone in decibels must exceed the spectrum level of the continuous noise (at the same frequency) by 10 times the logarithm to the base 10 of the ratio of the critical bandwidth to unit bandwidth.

Band Pressure Level. The band pressure level of a sound for a specified frequency band is the sound pressure level for the sound contained within the restricted band. The reference pressure must be specified.

NOTE: The band may be specified by its lower and upper cutoff frequencies, or by its geometric center frequency and bandwidth. The width of the band may be indicated by a prefatory modifier; e.g., octave band (sound pressure) level, half-octave band level, third-octave band level, 50-cps band level.

Bel. The bel is a unit of level when the base of the logarithm is 10. Use of the bel is restricted to levels of quantities proportional to power.

Continuous Spectrum. A continuous spectrum is the spectrum of a wave the components of which are continuously distributed over a frequency region.

Cycle. A cycle is the complete sequence of values of a periodic quantity that occur during a period.

Decibel. The decibel is one-tenth of a bel. Thus, the decibel is a unit of level when the base of the logarithm is the 10th root of 10, and the quantities concerned are proportional to power.

NOTE 1: Examples of quantities that qualify are power (any form), sound pressure squared, particle velocity squared, sound intensity, sound-energy density, voltage squared. Thus the decibel is a unit of sound-pressure-squared level; it is common practice, however, to shorten this to sound pressure level because ordinarily no ambiguity results from so doing.

NOTE 2: The logarithm to the base the 10th root of 10 is the same as 10 times the logarithm to the base 10: e.g., for a number X^2, $\log_{10^{1/10}} X^2 = 10 \log_{10} X^2 = 20 \log_{10} X$. This last relationship is the one ordinarily used to simplify the language in definitions of sound pressure level, etc.

Effective Sound Pressure (Root-Mean-Square Sound Pressure). The effective sound pressure at a point is the root-mean-square value of the instantaneous sound pressures, over a time interval at the point under consideration. In the case of periodic sound pressures, the interval must be an integral number of periods or an interval that is long compared to a period. In the case of nonperiodic sound pressures, the interval should be long enough to make the value obtained essentially independent of small changes in the length of the interval.

NOTE: The term "effective sound pressure" is frequently shortened to "sound pressure."

Frequency. The frequency of a function periodic in time is the reciprocal of the primitive

*The definitions given here are quoted from American Standard Acoustical Terminology S1.1–1960.

period. The unit is the cycle per unit time and must be specified.

NOTE: In many European countries the cycle per second is called the hertz (Hz).

Hearing Loss (*Hearing Level*) (*Hearing-Threshold Level*). The hearing loss of an ear at a specified frequency is the amount, in decibels, by which the threshold of audibility for that ear exceeds a standard audiometric threshold.

NOTE 1: See American Standard Specification for Audiometers for General Diagnostic Purposes. Z24.5–1951. (See sec. 15.)

NOTE 2: This concept was at one time called deafness; such usage is now deprecated.

NOTE 3: Hearing loss and deafness are both legitimate qualitative terms for the medical condition of a moderate or severe impairment of hearing, respectively. Hearing level, however, should only be used to designate a quantitative measure of the deviation of the hearing threshold from a prescribed standard.

Loudness. Loudness is the intensive attribute of an auditory sensation, in terms of which sounds may be ordered on a scale extending from soft to loud.

NOTE: Loudness depends primarily upon the sound pressure of the stimulus, but it also depends upon the frequency and wave form of the stimulus.

Noise. (1) Noise is any undesired sound. By extension, noise is any unwanted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device. (2) Noise is an erratic, intermittent, or statistically random oscillation.

NOTE 1: If ambiguity exists as to the nature of the noise, a phrase such as "acoustic noise" or "electric noise" should be used.

NOTE 2: Since the above definitions are not mutually exclusive, it is usually necessary to depend upon context for the distinction.

Noise Level. (1) Noise level is the level of noise, the type of which must be indicated by further modifier or context.

NOTE: The physical quantity measured (e.g., voltage), the reference quantity, the instrument used, and the bandwidth or other weighting characteristic must be indicated.

(2) For airborne sound, unless specified to the contrary, noise level is the weighted sound pressure level called sound level; the weighting must be indicated.

Octave. (1) An octave is the interval between two sounds having a basic frequency ratio of two.

(2) An octave is the pitch interval between two tones such that one tone may be regarded as duplicating the basic musical import of the other tone at the nearest possible higher pitch.

NOTE 1: The interval, in octaves, between any two frequencies, is the logarithm to the base 2 (or 3.322 times the logarithm to the base 10) of the frequency ratio.

NOTE 2: The frequency ratio corresponding to an octave pitch interval is approximately, but not always exactly, 2:1.

Peak Sound Pressure. The peak sound pressure for any specified time interval is the maximum absolute value of the instantaneous sound pressure in that interval.

NOTE: In the case of a periodic wave, if the time interval considered is a complete period, the peak sound pressure becomes identical with the maximum sound pressure.

Simple Tone (*Pure Tone*). (1) A simple tone is a sound wave, the instantaneous sound pressure of which is a simple sinusoidal function of the time.

(2) A simple tone is sound sensation characterized by its singleness of pitch.

NOTE: Whether or not a listener hears a tone as simple or complex (see 13.3 below) is dependent upon ability, experience, and listening attitude.

Sone. The sone is a unit of loudness. By definition, a simple tone of frequency 1,000 cycles per second, 40 decibels above a listener's threshold, produces a loudness of 1 sone. The loudness of any sound that is judged by the listener to be n times that of the 1-sone tone is n sones.

NOTE 1: A millisone is equal to 0.001 sone.

NOTE 2: The loudness scale is a relation between loudness and level above threshold (12.15) for a particular listener. In presenting data relating loudness in sones to sound pressure level, or in averaging the loudness scales of several listeners, the thresholds (measured or assumed) should be specified.

Sound Analyzer. A sound analyzer is a device for measuring the band-pressure level or pressure-spectrum level of a sound as a function of frequency.

Sound Level. Sound level is a weighted sound pressure level, obtained by the use of metering characteristics and the weightings A, B, or C specified in American Standard Sound Level Meters for Measurement of Noise and Other Sounds, Z24.3–1944. (See sec. 15.) The weighting employed must always be stated. The reference pressure is 0.0002 microbar.

NOTE: A suitable method of stating the weighting is, for example, "The A-sound level was 43 db."

Sound-Level Meter. A sound-level meter is an instrument including a microphone, an amplifier, an output meter, and frequency weighting networks for the measurement of noise and sound levels in a specified manner.

NOTE: Specifications for sound-level meters are given in American Standard Sound Level Meters for Measurement of Noise and Other Sounds, Z24.3–1944. (See sec. 15.)

Sound Pressure Level. The sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure. The reference pressure shall be explicitly stated.

NOTE 1: The following reference pressures are in common use:

(*a*) 2×10^{-4} microbar.
(*b*) 1 microbar.

Reference pressure (*a*) is in general use for measurements concerned with hearing and with sound in air and liquids, while (*b*) has gained widespread acceptance for calibration of transducers and various kinds of sound measurements in liquids.

NOTE 2: Unless otherwise explicitly stated, it is to be understood that the sound pressure is the effective (rms) sound pressure.

NOTE 3: It is to be noted that in many sound fields the sound pressure ratios are not the square roots of the corresponding power ratios.

Threshold of Audibility (*Threshold of Detectability*). The threshold of audibility for a specified signal is the minimum effective sound pressure level of the signal that is capable of evoking an auditory sensation in a specified fraction of the trials. The characteristics of the signal, the manner in which it is presented to the listener, and the point at which the sound pressure level is measured must be specified.

NOTE 1: Unless otherwise indicated, the ambient noise reaching the ears is assumed to be negligible.

NOTE 2: The threshold is usually given as a sound pressure level in decibels, relative to 0.0002 microbar.

NOTE 3: Instead of the method of constant stimuli, which is implied by the phrase "a specified fraction of the trials," another psychophysical method (which should be specified) may be employed.

Appendix

The first report of findings in this study appeared as an article in the American Industrial Hygiene Association Journal, Volume 19, No. 4, August 1958. It is reproduced here with permission from the Journal.

Industrial Noise and Hearing Loss in a Controlled Population—First Report of Findings*

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Four years ago at the Industrial Health Conference, we presented a description of a study which had just been undertaken by the Occupational Health Program of the Public Health Service for the purpose of obtaining some information about the relationship of industrial noise to hearing loss. It would be better to speak of this work as a number of concurrent studies, rather than as one study. We shall not review here the importance of the problem of industrial noise, but state merely that most of the questions concerning the subject are still not satisfactorily answered despite the large amount of worthwhile work which various investigators have performed in the interval.

The data reported here were obtained from studies conducted on workers in certain of the factories in Federal penitentiaries at Lewisburg, Pa., Leavenworth, Kans., Atlanta, Ga., and Terre Haute, Ind. This study, which is still in progress, could not have been done without the complete cooperation of the U.S. Bureau of Prisons and the Federal Prison Industries, Inc., and we wish to acknowledge our gratitude not only for their contributions, but the spirit in which they have been made.

Currently there is in preparation a detailed report of the findings for the first 4 years of this investigation. We are presenting here only a portion of the material to be included in that report.

The industries included in the studies and the approximate number of employees in each are as follows:

Lewisburg, Pa.:	
Metal furniture, including steel shelving	360
Clothing	60
Leavenworth, Kans.:	
Clothing	80
Shoes	450
Brushes	180
Wood furniture	90
Printing	40
Atlanta, Ga.: Cotton textiles	400
Terre Haute, Ind.: Woolen textiles	175

Total employment in these plants is approximately 1,800. At the beginning of the studies, approximately 600 men were selected for periodic hearing tests. Those picked were chosen on the basis of the amount of additional time for which they were likely to be employed. Workers definitely eligible for release from the institutions in less than 18 months were not included in the original group to be tested. As men from the original study group were transferred out of the industries, they were replaced by newly assigned workers, so that the total number under study at any one time was relatively constant. The overall number of industry workers studied in the period included in this report is about 1,600.

The workers in the group studied were given periodic audiometric tests. At the beginning of the study, all men were examined at 3-month intervals. Later the test schedule was modified so that testing was done 3 months, 6 months, and 12 months after assignment to a job and then annually thereafter.

Audiometric testing is done in acoustically treated test facilities located in the prison hospitals. Testing is performed, under the super-

*Presented at the Industrial Health Conference, Atlantic City, N.J., Apr. 22, 1958.

vision of the chief medical officer of each institution, either by medical technical assistants employed in the hospitals or by inmates assigned to hospital duties. The test procedures employed were established by Dr. Aram Glorig, who serves in a consultant capacity to the Public Health Service. Dr. Glorig personally provided instructions on audiometric procedures at the time that the study was started at each institution.

In addition to the hearing tests performed on the industry workers being studied, each of the institutions eventually incorporated an audiometric test into the physical examination performed on all newly admitted inmates. Approximately 7,000 newly admitted inmates were tested during the period in question. Data obtained from these tests are useful not only for control purposes in evaluating hearing loss from noise exposure, but also for comparisons with other large populations which have been studied elsewhere by other investigators. Data from this group are also of value in comparing findings of one institution with those of another.

The numbers of newly admitted men tested in each institution were as follows:

Location	*Number*
Lewisburg	2,108
Leavenworth	2,539
Atlanta	1,231
Terre Haute	1,120
Total	6,998

The number of new admissions tested each year was:

Year	*Number*
1953	631
1954	753
1955	1,801
1956	2,417
1957 (6 months)	1,396
Total	6,998

The median ages of men at Atlanta and Leavenworth are approximately 34 years compared to medians of about 25 years at Lewisburg and Terre Haute. This 9-year difference is due to the types of institutions involved.

When the studies were begun, the question arose as to whether data obtained from one institution properly could be combined with data from others. Our original feeling was that they should not be combined since testing was not done under identical conditions in each institution. If data from different institutions could be combined, however, it would provide larger groups for comparisons. Often only a handful of men of a given age group with a given noise exposure are available in a single institution. In such small groups, there are serious limitations to the conclusions which can be drawn from findings about their hearing. The data from the various institutions were examined closely therefore to see whether such combining of data would be justifiable and acceptable for certain comparisons.

In a long-term study of this nature, changes in personnel or equipment and other factors may exert an influence on findings, particularly if the testing is being performed at a number of geographical locations distant from the individuals having primary responsibility for the project. An evaluation of these factors is not included in this paper.

The data from each institution were first examined for general consistency. This was done, as shown in figure 1, by observing how much the distribution of hearing loss at 4,000 cycles in the left ear varied from year to year. The curves show the cumulative percentage of individuals whose hearing loss did not exceed the indicated number of decibels. Loss at 4,000 cycles was chosen because this is the point at which greatest loss most often occurs. The left ear was chosen because, on the average, left ears are found to show more loss. Where a single point is to be employed for detecting change in hearing due to noise, 4,000 cycles in the left ear is the most sensitive index. While some variability is demonstrable through statistical tests, it was felt that, on the whole, each institution's results were reasonably consistent from year to year.

Figure 2 shows the distribution, at each institution, of hearing loss at 4,000 cycles in the left ear for the total period of this report, classified according to age group. As would be expected, there is a progressive loss with age in each instance.

Figure 3 presents a comparison of the findings of all of the institutions for each age group. It is from an examination of this figure that the decision can probably best be made as to whether

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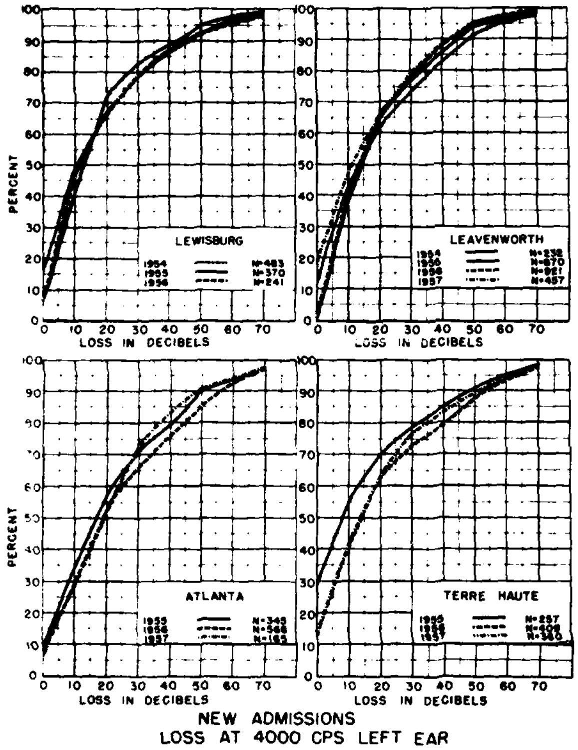

FIGURE 1

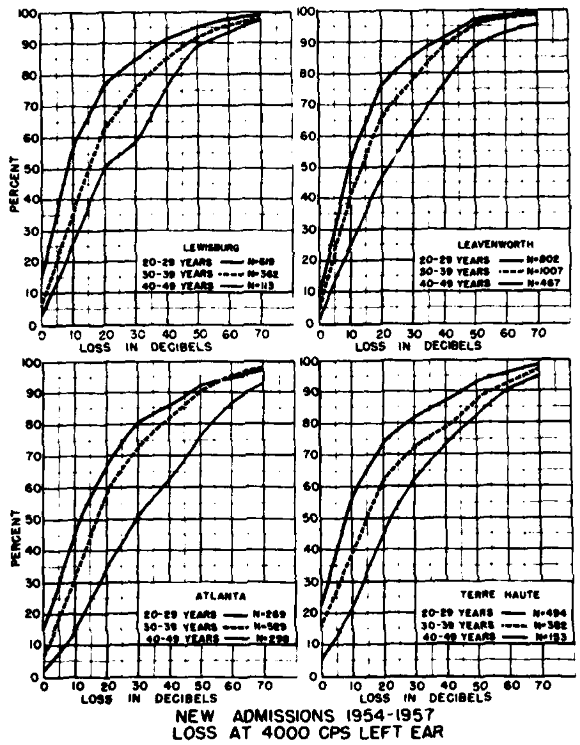

FIGURE 2

or not combining data of two or more institutions is a reasonable procedure.

With one minor exception which will be pointed out later, we have not combined data from the study groups of different institutions. However, the data on new admissions from the four institutions have been combined for use for control purposes. Specifically, we have taken the combined data for the four institutions at the 50% points as the median value for all new admissions in a given age bracket. For the comparisons which follow, we are concerned not only

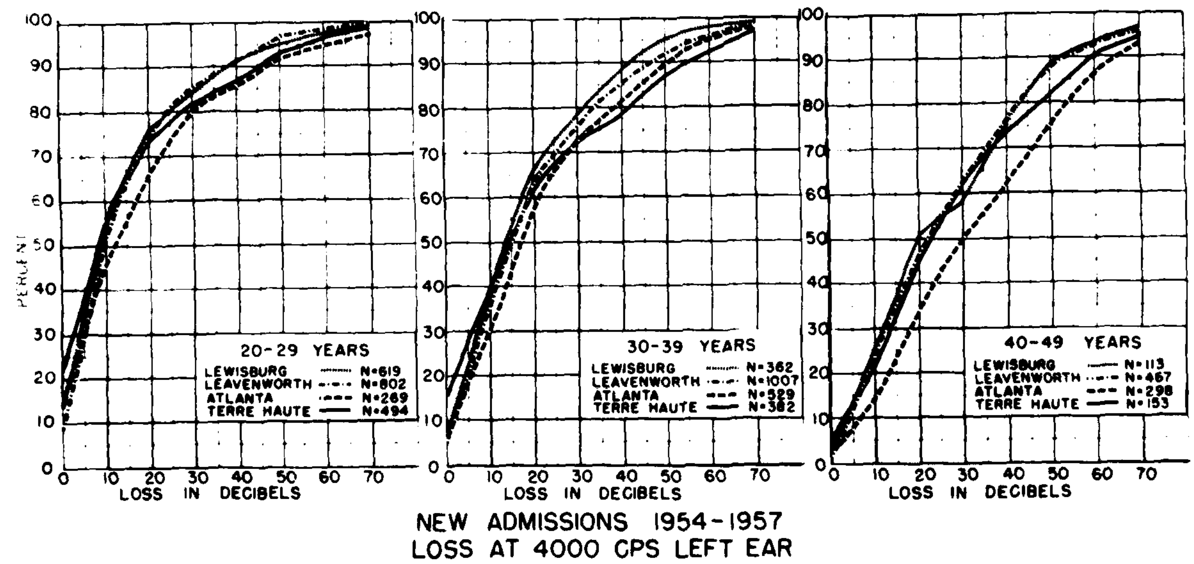

FIGURE 3

with 4,000 cycles in the left ear, but with six frequencies in each of two ears. Even with a combining of the new admission data, we have 12 sets of curves for each of the age categories as shown by the figures 4 and 5 which follow. Figure 4 shows the losses by age in the left ear for 500, 1,000, 2,000, 3,000, 4,000, and 6,000 cps for 6,053 men whose hearing was analyzed.

Figure 5 gives the same data for the right ear. The numbers of men in each age bracket tested are as follows:

20–29 years	2, 184
30–39 years	2, 280
40–49 years	1, 031
50 and older	558

Figure 6 shows the median hearing loss by age for each ear in the different age categories. The consistent difference between left and right ears is readily apparent. The curves in this figure are the ones which will be employed in this paper for comparison purposes where hearing losses from noise exposures are presented.

Various other populations of comparable size have been studied in the past by other investigators. One was in the National Health Survey conducted by the U.S. Public Health Service in 1935 and 1936. The most recent published data of this sort were contained in the report of the studies conducted at the 1954 Wisconsin State Fair. In figure 7, median losses in both

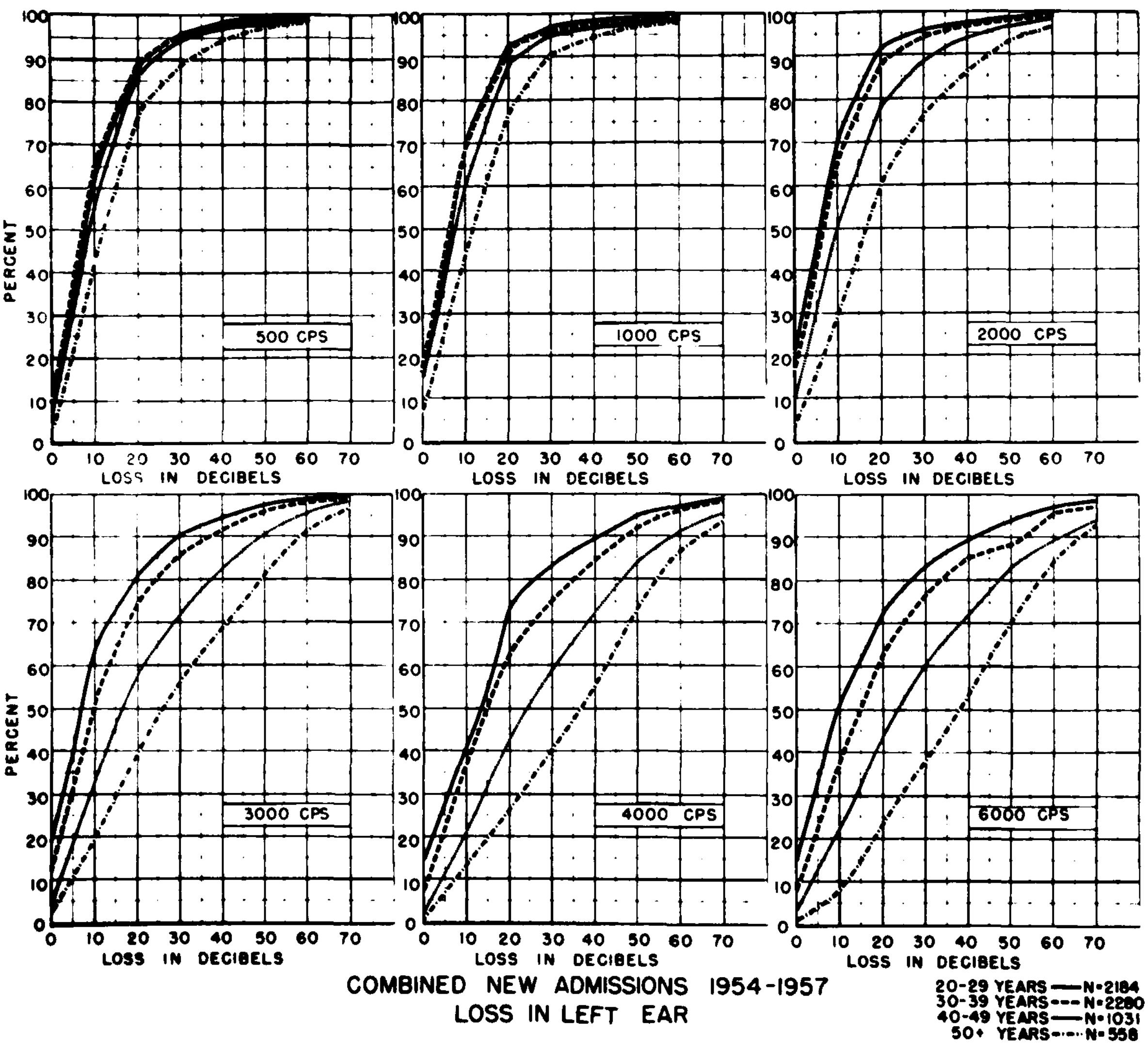

FIGURE 4

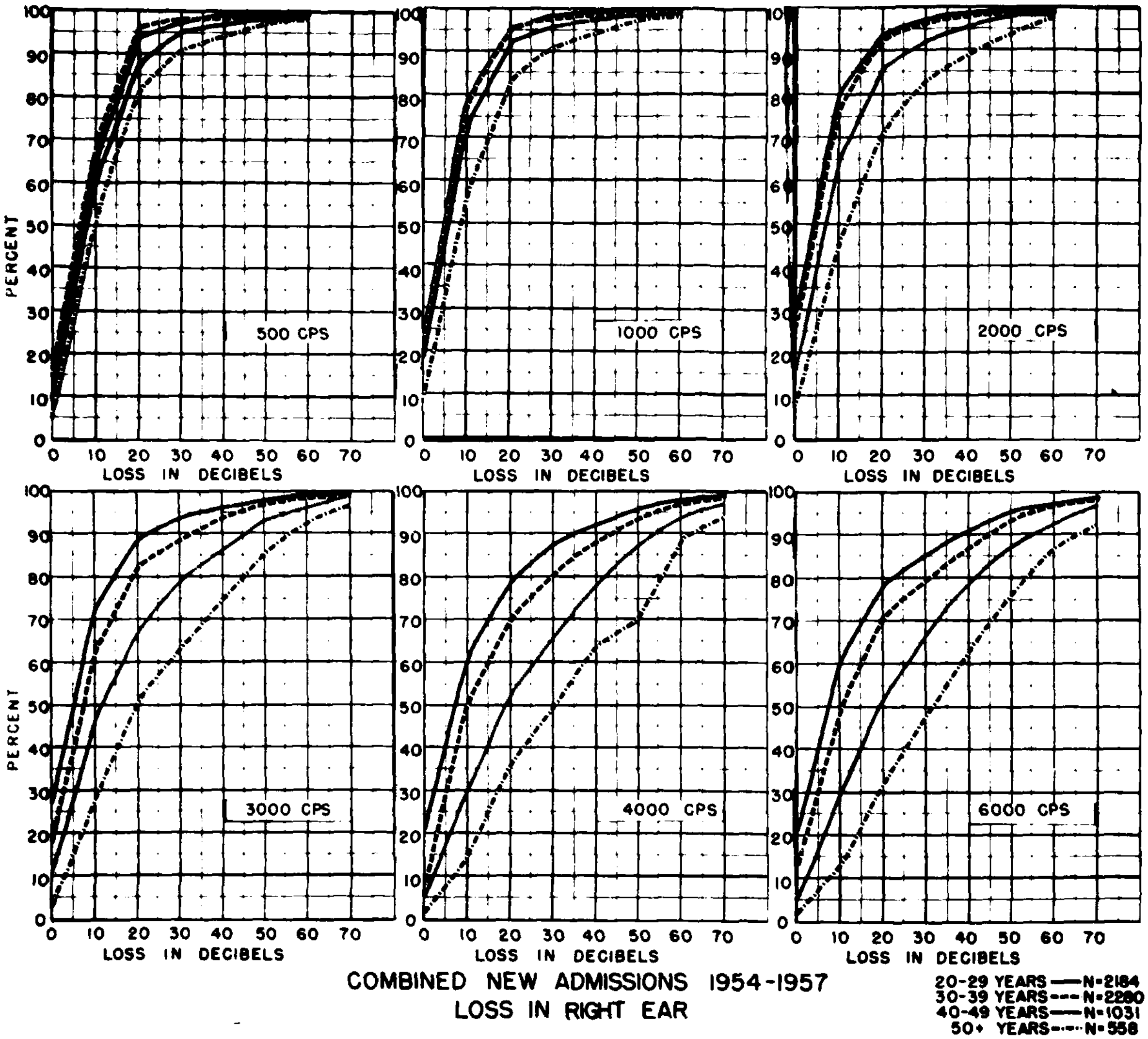

FIGURE 5

ears for the 30–39 age group of our study are compared with those groups in the Wisconsin and National Health Survey studies. It will be observed that there are appreciable differences, with the prison population having the best hearing and the Wisconsin group the worst. This figure emphasizes that large variations can be found between different segments of the population. Figure 8, taken from the Wisconsin report, shows the influence of occupation upon hearing, as indicated by the lines representing office, farm and factory workers 30–39 years of age. To this figure we have added data from our study for the same age group, as shown by the curve labeled "New Admissions." One can observe that men admitted to Federal penitentiaries have hearing fairly comparable to that of the Wisconsin officeworkers. Officials of the Bureau of Prisons agree with our theory that a large proportion of the men admitted to the penitentiaries have probably not held steady employment for long periods and consequently have had comparatively little noise exposure.

The remainder of this paper deals with data obtained from serial audiometric studies on workers in various industries. Although we have considerable information on workers with longer periods of exposure, the data presented here are limited to a maximum of one year of employment in a specific noise environment.

Since a number of different industries were included in these studies, a great variety of noise environments were encountered. The range of total sound pressure levels extended from 70 decibels or less to 110 decibels or more. A wide range of sound frequency distributions were encountered and many types of sounds from intermittent impacts to continuous constant level sounds were found. It is generally believed that the nature of the sound as well as the overall sound pressure level must be taken into consideration in assessing potential effects of noise on the ear. In this preliminary examination of our data, however, it was felt that noise environments should be separated only into a few simple classifications. Consequently, they were divided first into either steady state or intermittent impact classes. Steady state noises were grouped in the six following ranges:

100–104 db.
95–99 db.
90–94 db
85–89 db.
80–84 db.
Less than 80 db.

Impact noise environments were divided into three groups:

100 db.
95 db.
82–92 db.

In this first examination of findings, each department has been placed in one of the nine foregoing categories in accordance with our judgment as to the single figure which might best indicate the average noise exposure over a working day.

Some of the data obtained on testing the hearing of groups of workers after three months and after one year of employment in the weave room of the cotton mill are seen in figure 9. This department is in the 100–104 steady state category. The larger curves show the median hearing loss in the left ear of 47 workers at the end of one-quarter of a year employment in this department and the median loss in the left ear of 32 workers in this department after one year of employment. Also shown is the median hearing loss of all inmates between 30 and 39 years of age admitted to the four institutions. The median age of men studied in this department was 34 years. The solid line represents the median hearing loss of 60 workers at the time of assignment to this department but before actually beginning work. Note that their loss was greater than that of the control group shown by the heavy dotted line. In classifying inmates for work in the prison industries, consideration is given to previous experience in given jobs. Bureau of Prison officials

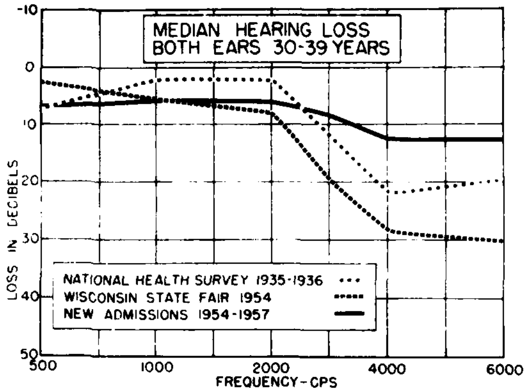

FIGURE 7

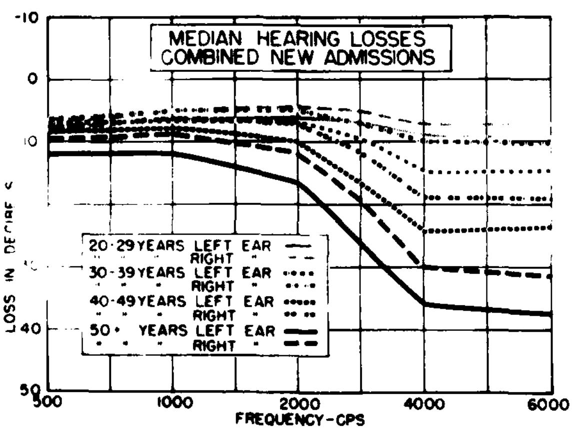

FIGURE 6

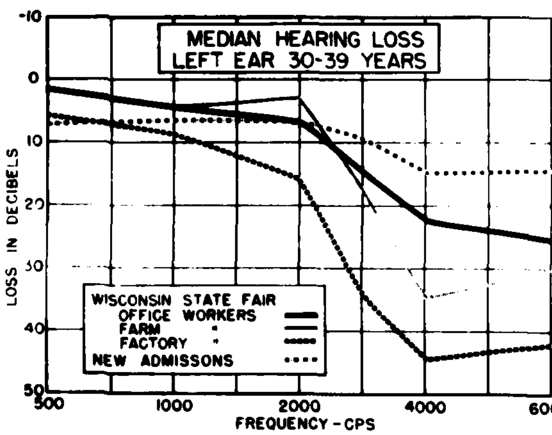

FIGURE 8

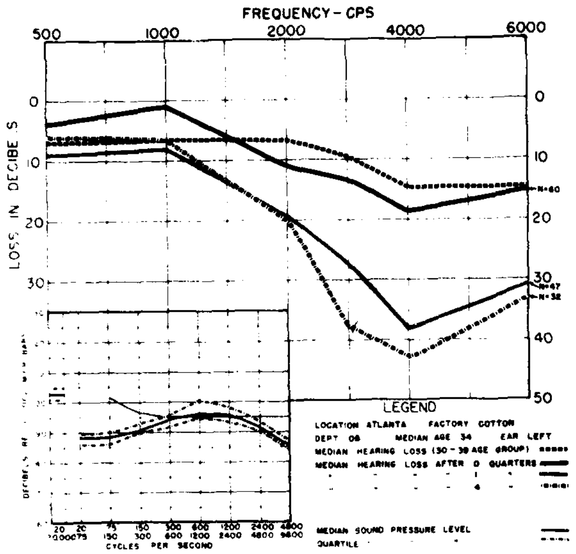

FIGURE 9

have advised us that many of the men assigned to the cotton mill have had previous experience in the textile industry. In other words, these men could have already suffered some hearing loss because of previous employment. Although not presented in this paper, our data indicate that the average hearing loss of men to be assigned to noisy jobs is greater than that of men to be assigned to quiet jobs and that the noisier the impending job the poorer the initial hearing. This is attributed also to consideration of previous work experience in connection with job assignments.

As may be noted, a very considerable amount of hearing loss apparently develops even after only 3 months of exposure. In this instance, the loss after 3 months seems to be almost as great as after 12 months. It should be emphasized at this point, however, that these losses and the others presented in this paper represent temporary and permanent losses combined. Additional studies, to be undertaken soon, may determine how much of this loss is permanent and how much is merely a temporary threshold shift. It has long been known that weavers have a noise-induced hearing loss. We believe therefore that an appreciable portion of the losses shown in this figure is permanent.

The noise to which these men were exposed was measured and analyzed in different locations within the department on a number of occasions. There were 587 looms in this department and the noise environment was essentially the same throughout. The solid line in the lower portion of figure 9 indicates the median values obtained from all of the octave band analyses performed in this department over a 4-year period. The lines above and below it show the upper and lower quartiles of the data thus obtained. The short horizontal lines to the extreme left show the total sound pressure levels. It will be noted that the median value is 103 decibels.

The remaining curve, which appears on all of the figures which follow, is the well-known damage-risk criteria curve contained in the WADC Technical Report "Handbook of Acoustic Noise Control, Volume 2, Noise and Man," by Rosenblith, Stevens, and the staff of Bolt, Beranek & Newman. For those unfamiliar with that report, we would emphasize that its authors did not present those criteria as precise figures. When the criteria were proposed 5 years ago, it was stated that the contour should not be "* * * taken too literally since deviations of the order of 1 or 2 db in either direction could probably be disregarded. Contours such as these should be interpreted as zones with some uncertainty attending the measurement of the exposure stimulus, and biologic variability modifying the probability of damage. We feel, however, that contours 10 db lower would involve negligible risks indeed, while contours 10 db higher would result in significant increases in hearing loss." Other criteria which have been proposed in the interim do not differ markedly from these, which, significantly, were considered to be safe in terms of 8-hour daily exposures for a working lifetime, for noise that has a reasonably continuous time character with no substantial sharp energy peaks. Also these criteria were proposed, we believe, primarily to prevent appreciable loss in the speech frequencies, that is, those which lie below 3,000 cps.

In view of these criteria, the fact that the median values in figure 9 do not exceed the damage risk curve by more than 1 db at any point is of considerable interest.

Figure 10 contains similar data obtained on testing the hearing of workers employed in the weave room of the woolen mill. The character of the noise exposure as determined by the octave band analyses was quite similar to that found

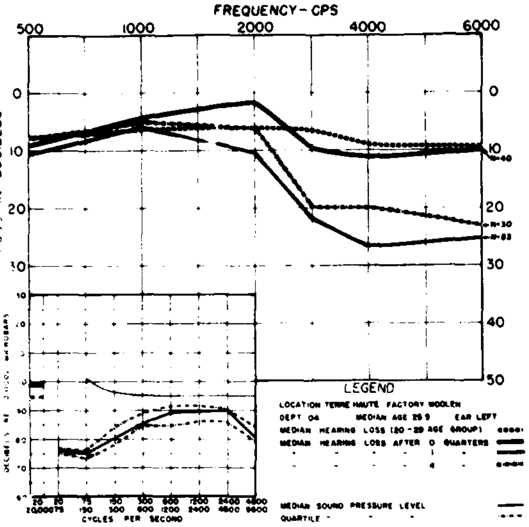

FIGURE 10

in the cotton mill. The overall level was somewhat lower, however, the median value being 98 db or approximately 5 db less. This department had only 42 looms compared with 587 in the cotton mill. A slight peak was observed here in the 2,400–4,800 octave band areas. In the cotton mill the peak values were found at 600–1,200 and 1,200–2,400. The hearing loss of workers in this department is apparently considerable although less than for the workers in the cotton weave room, particularly at 4,000 cycles. The group of men tested after one quarter of employment shows a slightly greater loss than the ones tested after four quarters. It should be pointed out that not all of the men tested are to be found in each of the groups. This becomes apparent when one notes there were 40 men in the preplacement group, 53 after one quarter, and 30 after four quarters. Note that the median octave band analysis is at least 5 db below the criteria curve at all points.

The data in figure 11 were obtained on workers in the cotton mill employed in departments other than weaving. Most of these men were engaged in spinning and carding. The median overall sound pressure level to which this group was exposed was about 96 db, only 2 db less than the overall for the weave operation in the woolen mill and 7 db less than the weave operation in the cotton mill. The noise is seen to be concentrated more in the lower frequencies, particularly in the three octaves included between 150 and 1,200 cps. The noise is the steady state type. Examination of the hearing loss curves indicates a much smaller median loss, less than 10 db, in the higher frequencies. The numbers of men tested were 90 in the preplacement group, 83 after one quarter and 46 after four quarters.

The next three figures are for operations in the woolen mill, exclusive of weaving. The first of these, figure 12, is for men employed in dyeing, picking, and finishing. Median overall sound pressure levels in these departments is seen to be 90 db with most of the noise, which was of steady type, concentrated in frequencies less than 600 cps. Examination of the audiometric data shows only slight evidence, if any, of hearing loss after 1 year of exposure. Figure 13 includes workers in carding, spinning and maintenance. The overall noise level to which they were exposed was approximately 88 db with most of the sound concentrated between 150 and 1,200 cps. The audiometric data gave no indications of loss of even a temporary nature. Figure 14 refers to the workers with still lower noise exposures. The overall sound pressure level to which they were exposed was less than 85 db. No signs of any hearing loss are observable in this group either.

Figure 15 combines the data from the three previous groups, in other words, all workers in the woolen mill outside of weaving operations. The median overall sound pressure level to which these workers were exposed was 88 db. These groups when combined show no signs of any hearing loss after one year of exposure. The numbers of men tested here were 136 preplacement, 143 after one quarter and 43 after 1 year.

Data obtained in wooden furniture manufacturing in the vicinity of planers and saws is plotted in figure 16. The median overall sound pressure level is seen to be 100 db with the octave band analyses showing an essentially flat response except at the two ends. Unfortunately, the number of men employed at these operations was so small that very little data of statistical value were obtainable. The median hearing loss for 11 men having one year of employment in this environment is shown. Data on enough men were not available for the preparation of curves for other intervals of exposure. Only limited conclusions should be drawn from the results on 11 men. We shall merely point

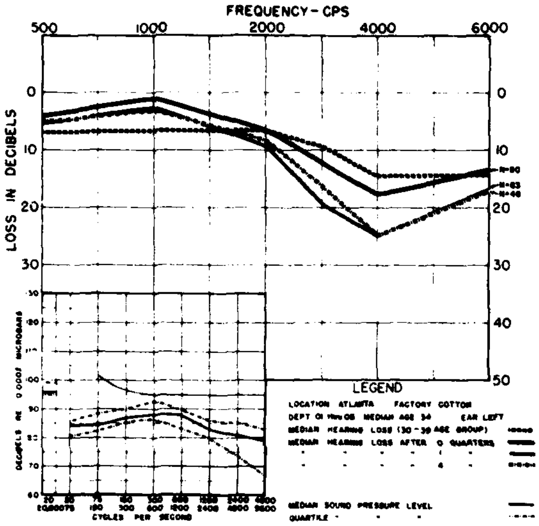

FIGURE 11

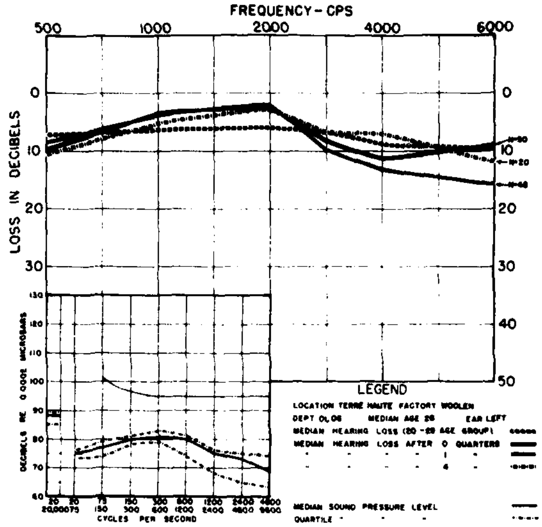

FIGURE 13

out that the median hearing loss values obtained for this group resemble those obtained in weaving operations where the total sound pressure level was approximately the same.

The next two figures give the data obtained from workers employed in shoe manufacturing. Figure 17 shows data for men employed in the bottoming department and treeing and packing department. The median overall sound pressure level for these operations was approximately 94 db. Examination of the octave band analyses shows a slight peak in the 600–1,200-cps octave band with much of the remaining energy in the two adjacent octave bands. Examination of the median hearing loss curves for workers in these departments shows nothing indicative of a hearing loss during the first year of employment. There were 17 men in the preplacement group, 26 with one quarter of exposure, and 29 with four quarters.

Figure 18 includes the lasting, making, cutting, sole leather and welting departments. The sound pattern is very similar to that shown in the previous figure with the overall sound pres-

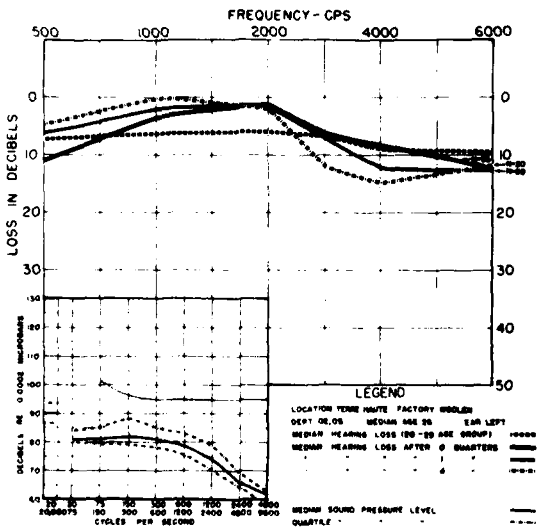

FIGURE 12

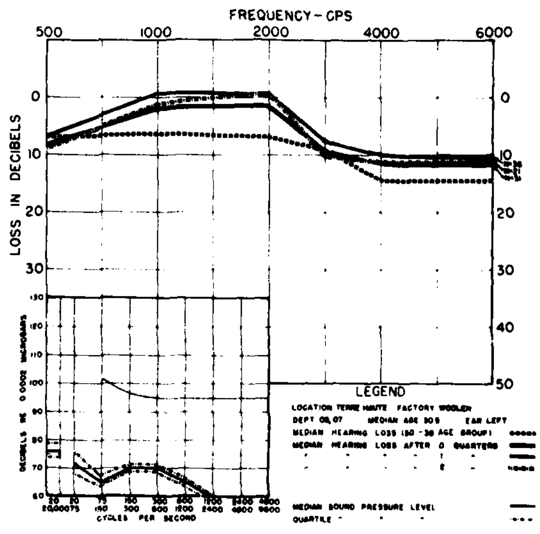

FIGURE 14

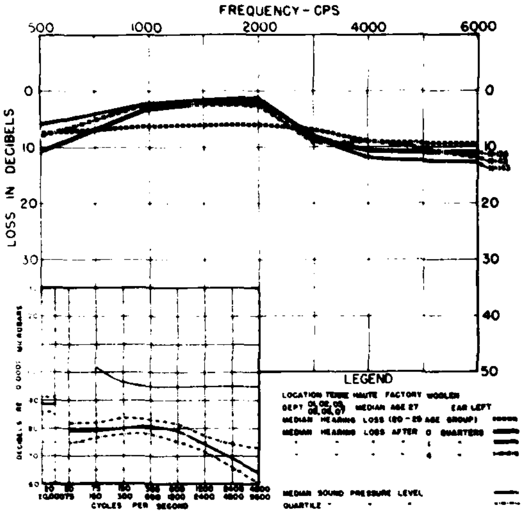

FIGURE 15

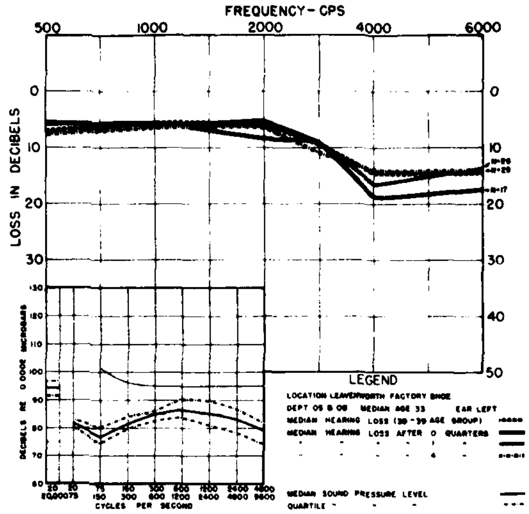

FIGURE 17

sure level of 93 db being only slightly less. The audiometric data reveal a slight dip at 4,000 cycles after 12 months of exposure, but there is no evidence of loss elsewhere. Seventy-six men were included in this group with 12 months of exposure. With a group this size showing this dip at 4,000 cps, however, study of the effects of this environment over a longer period of time is indicated. Sixty-seven men with one quarter of exposure were tested and there were 40 in this preplacement group.

Figure 19 shows data obtained in connection with certain brush manufacturing operations. The median total sound pressure level in this case was just under 90 db. It will be noted that most of the energy was in the lower frequencies. The numbers of men tested in this area were 22 in the preplacement group, 28 after one quarter, and 34 after four quarters of exposure. No particular signs of hearing loss are to be seen in these groups.

The results in the next three figures were obtained in clothing manufacturing. Figure 20 is for the Lewisburg factory. The overall noise

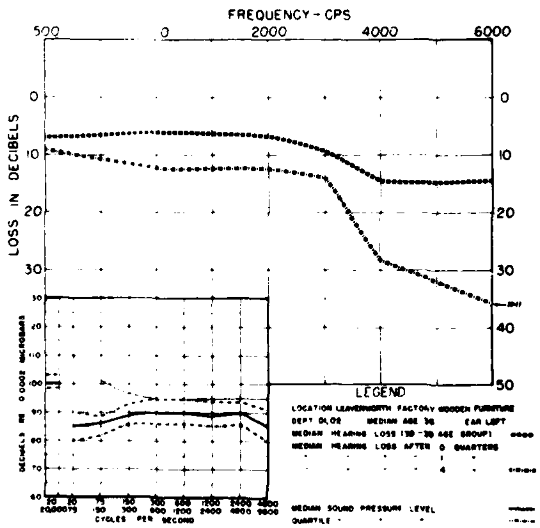

FIGURE 16

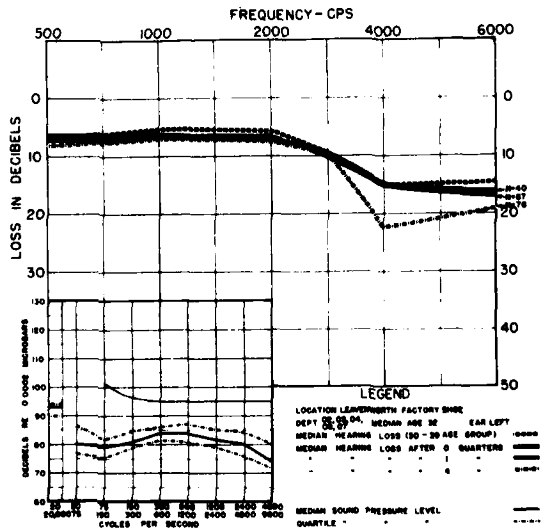

FIGURE 18

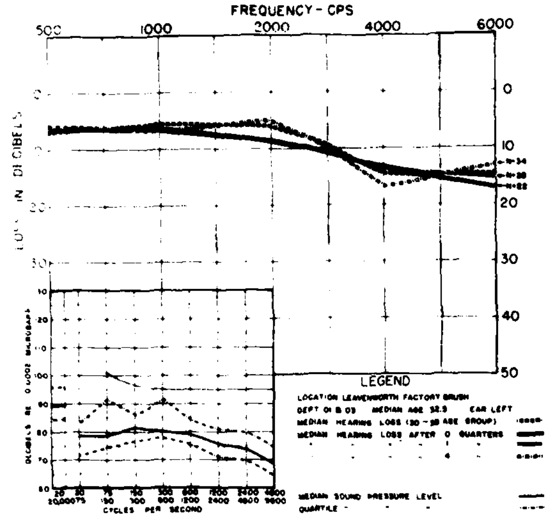

FIGURE 19

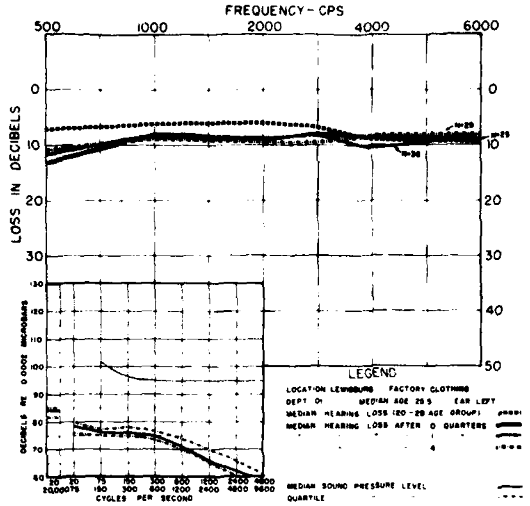

FIGURE 20

level here was 84 db with the energy peak being in the frequencies below 75 cps. The median age of the men in these operations was 25.5 years. The hearing of the study groups here was virtually identical with that of the new admissions of 20–29 years. The numbers tested were 25 in the preplacement group, 36 after one quarter, and 29 after one year.

Figure 21 presents data for a similar factory at Leavenworth. The noise level and pattern is identical with that obtained at Lewisburg. Again, the hearing of the workers closely paralleled that of new admissions of the same age group. The difference here from figure 21 is that the medium age of the Leavenworth workers was 38.5 years. The dotted line shown for comparison purposes, therefore, is the 30–39 year new admission group. The numbers of workers tested here were 17 in the preplacement group, 22 after one quarter and 27 after four quarters

Figure 22 is the only one in which we have combined data on workers from two different institutions. Here we have combined the data shown in the two previous figures. The numbers tested were 42 in the preplacement groups, 64 after one quarter and 63 after 1 year. The median age of the combined groups of workers was 29 years. It will be observed that their hearing fits between that of the new admission groups of 20–29 years and 30–39 years of age.

The remainder of the figures deal with noise exposures of the intermittent, impact type. All of them involve operations in the manufacture of metal furniture, including steel shelving. The measurement of impact noises is difficult to accomplish. The assignment of a single decibel value which accurately depicts the weighted average exposure is even more difficult, particularly in a plant like the metal furniture factory at Lewisburg, since the types of products, as well as rates of production, may vary considerably from month to month. Despite the fact that the weighted average exposures assigned are under 100 db, workers in these operations were frequently subjected to instantaneous peaks in excess of 125 db.

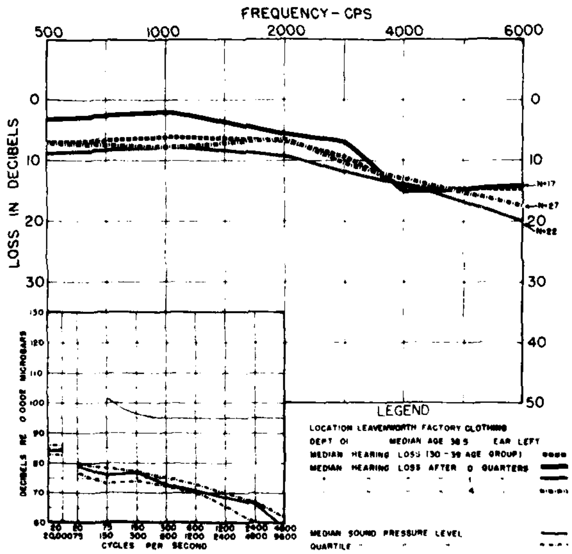

FIGURE 21

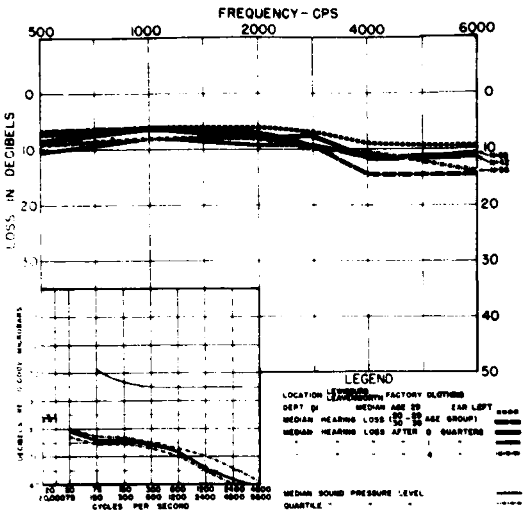

FIGURE 22

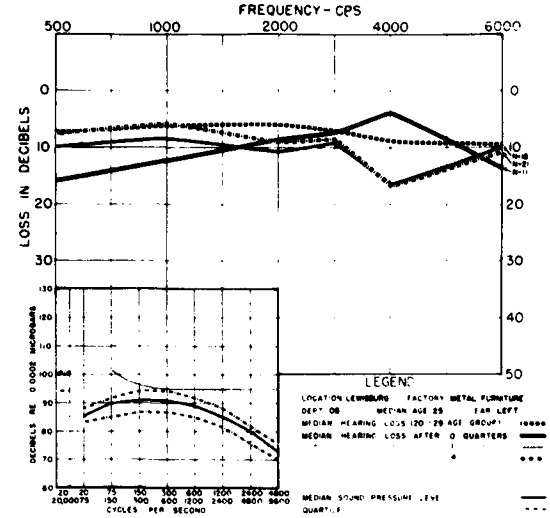

FIGURE 24

The operations are carried out on eight floors, each 60 feet by 200 feet, located in three buildings. Two floors are equipped with punch presses, shears, brakes, and lathes. Two floors have metal finishing, buffing, grinding, and maintenance. One floor is devoted to welding operations, including a spot-welding assembly line. This factory usually consumes between 600 and 800 tons of steel per month.

As stated earlier, we have attempted to divide estimated overall exposures in these operations into three general groups. Figure 23 shows results obtained in workers in assembly and warehouse work. The median overall noise level for these workers is shown as 86 db. It is readily apparent that no signs of hearing loss appeared among workers during their first year in these areas. The numbers tested were 18 in the preplacement group, 39 with one quarter of work, and 31 with four quarters.

Figure 24 presents data from the shelving department. The median overall noise level assigned here was slightly under 95 db. There is some sign of a hearing loss at 4,000 cps in the

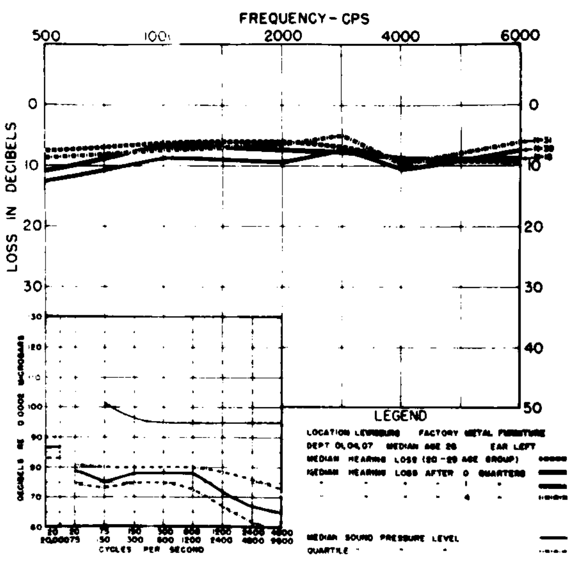

FIGURE 23

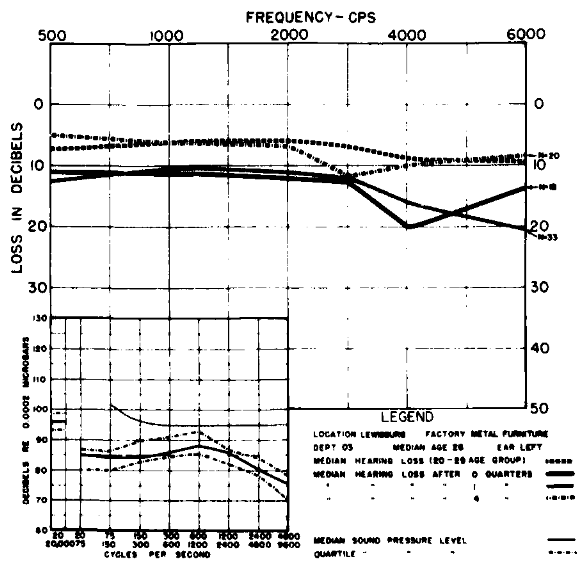

FIGURE 25

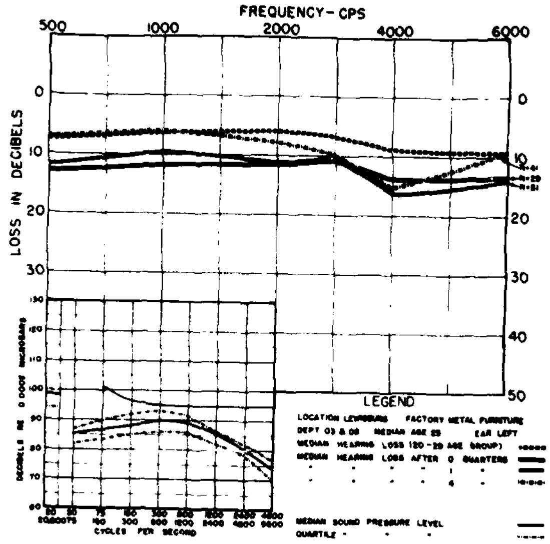

FIGURE 26

workers here. The numbers tested were small, however, there being only 18 after one quarter and 21 after one year. The preplacement group contained only 11 men, which may explain the erratic shape of the solid line.

The data in figure 25 are from the press department. The overall noise level here is not too different from that encountered in the shelving department. We assigned it a value of 96 db. The octave band analyses indicate a fairly definite peak in the 600–1,200-cps octave. The shelving department noise was more concentrated in the 150 to 600 range. The audiometric data for press department workers are inconsistent. The 18 men in the preplacement group and 33 tested after one quarter of exposure showed hearing consistently worse, at all frequencies, than the new admissions in the 20–29 age group. Twenty men with a year of exposure did not show this loss.

Since the numbers of men in both the shelving and press departments were small and since both were exposed to intermittent impact noise of approximately 95 decibels we have combined the data for them in figure 26. While this reveals a slight apparent loss, particularly at 4,000 cps, we do not believe that definite conclusions are indicated here.

A detailed report of the overall findings is now being prepared. Hearing data for other work intervals should help us to draw some more definite conclusions, particularly if corrections for temporary threshold shift can be made.