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Industrial Hygiene Survey Report

Jaff Brothers Woodworks, Inc.
Long Island City, New York

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EXECUTIVE SUMMARY

In response to a request from the National Labor-Management Committee for the Custom Woodworking Industry to assist them in characterizing wood dust and other occupational hazards that may be present in the custom woodworking industry, National Institute for Occupational Safety and Health (NIOSH) representatives conducted an industrial hygiene survey at the Jaff Brothers Woodworks, Inc., Long Island City, New York facility on February 12 and 13, 1991.

Jaff Brothers Woodworks, Inc., is an architectural woodwork manufacturer that produces custom wood office interiors for commercial and institutional establishments. In the manufacture of these custom wood office interiors, employees perform a wide variety of woodworking, assembly, and finishing operations typical of the custom woodworking industry.

During the industrial hygiene survey, a total of 40 personal and general area air samples were collected for total dust, dust size, organic vapors, formaldehyde, and noise. Also, direct-reading total dust measurements were made during several woodworking operations, relative humidity was measured throughout the facility, and ventilation measurements were made at several ventilated production operations.

The survey results indicated that overall, most employee exposures to airborne dust, organic vapors, and formaldehyde were well controlled with local exhaust ventilation and were below applicable NIOSH, American Conference of Governmental Industrial Hygienists (ACGIH), and Occupational Safety and Health Administration (OSHA) evaluation criteria. However, hand sanding operations were not controlled with ventilation and resulted in employee exposures to total dust exceeding the NIOSH and ACGIH criteria for wood dust of 1.0 mg/m^3 (work practices were observed to be important in predicting total dust exposures). Also, the woodworking machinery was relatively noisy and resulted in an employee noise exposure that exceeded the NIOSH and ACGIH criteria for noise of 85 dBA. Additionally, four woodworking machines were found to have defects in their local exhaust ventilation systems, adversely affecting dust control, and the negative pressure of the production areas relative to the outdoors indicated that the make-up air provided was insufficient for the exhaust (this was exemplified by the backflow of air through the spray booth when its exhaust fans were not operating).

Recommendations were provided to reduce employee exposures and included: (1) establishing a respiratory protection program; (2) ensuring the use of good work practices; (3) continuing the hazard communication program; (4) establishing a hearing conservation program; (5) repairing ventilation defects found in four woodworking machines; (6) operating the spray booth exhaust fans during the workshift; and (7) evaluating the make-up air requirements for the production areas.

INTRODUCTION

In June 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request from the National Labor-Management Committee for the Custom Woodworking Industry (NLMC/CWI) to assist them in characterizing exposures to wood dust and other occupational hazards that may be present in the custom woodworking industry. In response to this request, NIOSH representatives conducted walk-through surveys at four custom woodworking facilities in August 1990. These walk-through surveys were conducted to familiarize NIOSH representatives with the custom woodworking industry and to obtain sufficient information to plan an industrial hygiene characterization. From the information obtained during these walk-through surveys, industrial hygiene surveys were planned to be conducted at two of the facilities previously visited. These two facilities were selected as being representative of the NLMC/CWI membership based on the relative amount of millwork and the diversity of the operations performed at them. One of the two facilities selected was Jaff Brothers Woodworks, Inc., located in Long Island City, New York.

As part of this effort, NIOSH representatives conducted a walk-through survey at the Jaff Brothers facility on August 30, 1990, and later, conducted an industrial hygiene survey there on February 12 and 13, 1991. The activities, findings, and recommendations resulting from the industrial hygiene survey are presented in this report.

BACKGROUND

Jaff Brothers Woodworks, Inc., is an architectural woodwork manufacturer that produces custom wood office interiors for commercial and institutional establishments. The overall design and dimension specifications for these custom wood office interiors are usually provided by an architect. Depending on the particular order, some functional or operational specifications may be provided by the manufacturer. Since the final product is a custom wood office interior, hardwoods are most commonly used in the manufacturing process. However, composite wood products such as particle board and plywood are also used as necessary. On occasion, veneers of very rare or exotic hardwoods may be required.

The manufacture of a custom wood office interior begins with the preparation of drawings for production of the interior components based on information provided by an architect. These drawings are then used by the production employees to manufacture the desired custom wood office interior. To prepare the wood components of the custom office interior, a wide variety of woodworking operations are utilized, such as sawing, shaping, jointing, routing, boring, drilling, planing, and sanding. Several other specialized woodworking operations may also be required, such as those needed for dovetails, edges, hinges, veneers, and moldings. The individual wood components are then assembled using nails, staples, screws, and glue as is appropriate. The assembled wood components are then finished with a wide variety of stains and lacquers as required. These stains and lacquers may be applied either by hand or spray. Once completed, the custom office interior components are packaged to prevent damage in transit and shipped to the site for installation.

Production began at the 32,000 ft^2 Jaff Brothers facility in 1929. The manufacturing portion of this facility has five production areas: milling, assembly, spray finishing, finishing, and veneer. There are also office, shipping and receiving, and storage areas to support the production areas of the facility. (A diagram of the Jaff Brothers facility is provided in Figure 1.) At the time of the industrial hygiene survey in February 1991, there were approximately 30 production employees working a 40-hour workweek on a daily 7:45 a.m. to 4:15 p.m. workshift (including a 30-minute lunch break). The production employees are represented for bargaining purposes by the United Brotherhood of Carpenters and Joiners of America (UBCJA) Local 1164.

METHODS

During the walk-through survey of the Jaff Brothers facility on August 30, 1990, it was determined that potential exposures were present to wood dust (predominantly hardwood dust), organic vapors (from the stains and lacquer finishes), formaldehyde (from the adhesive used in producing veneers), and noise (predominately in the milling area). This information was used to develop the sampling strategy for the industrial hygiene survey conducted on February 12 and 13, 1991, to characterize occupational exposures.

Therefore, during the industrial hygiene survey of the Jaff Brothers facility, 34 personal air samples were collected for total dust, dust size, organic vapors, formaldehyde, and noise. Also, six general area air samples for organic vapors and formaldehyde were collected. In addition, direct-reading total dust measurements were made during several woodworking operations, relative humidity was measured throughout the facility, and ventilation measurements were made at several ventilated production operations.

A total of 13 personal air samples for total dust were collected using 37 millimeter (mm) diameter, 0.5 micrometer (um) pore size polyvinyl chloride (PVC) membrane filters in two-section cassettes connected to SKC Model 224-PCXR7 sampling pumps calibrated at flow rates ranging from 1.92 to 2.16 liters per minute (lpm). Employees with the highest potential dust exposures were selected and the samples were collected in their breathing zone for as much of the 8-hour workshift as was practicable. The sampling pumps were removed from the employees during their lunch break and replaced when they returned to work. After sampling was completed, the filter cassettes were sealed in preparation for analysis. Gravimetric analysis of the PVC filter samples for total dust was performed using NIOSH Method 0500 (1).

Direct-reading total dust measurements were obtained at eight different woodworking operations using a ppm, Inc., Model 1050 Handheld Aerosol Monitor (HAM). These were instantaneous measurements obtained from the breathing zone of employees while performing specific woodworking operations up to 15 minutes in duration. This sampling procedure provides information regarding short-term (or peak) exposures that may be higher than the corresponding exposure for the same woodworking operation when averaged over the full 8-hour workshift. For comparison, a background (ambient) measurement using the HAM was also obtained from a location in the milling area not close to any active woodworking machinery. The exposure data was recorded and stored using a Gulton, Inc., Rustrak Ranger Datalogger. For subsequent analysis of the direct-reading total dust data, the datalogger was downloaded into a personal computer.

A total of six personal air samples for dust size were collected using SKC Model 225-50 Personal Cascade Impactors connected to SKC Model 224-PCXR7 sampling pumps calibrated at flow rates ranging from 1.93 to 2.05 lpm. For each personal dust size sample, four impactor stages were used, each having a decreasing particle cutpoint diameter (Dp). These were: stage 1 (Dp = 21 um); stage 4 (Dp = 6.0 um); stage 7 (Dp = 0.9 um); and stage F (Dp = 0.0 um). (The particle cutpoint diameter corresponds to the average particle diameter which is retained by a stage, with smaller particles passing through. Stage F is the final impactor stage and essentially collects the particles not deposited on the preceding impactor stage.) This four-stage configuration was selected to allow an estimation of respirable dust concentration. Each impactor stage contained a spray-coated collection substrate to reduce the likelihood of particle bounce. Employees with the highest potential dust exposures were selected and the samples were collected in their breathing zone for as much of the 8-hour workshift as practicable. The sampling pumps were removed during their lunch break and replaced when they returned to work. After sampling was completed, the personal cascade impactors were sealed in preparation for analysis. The collection substrates for each of the impactor stages were gravimetrically analyzed for dust using NIOSH Method 0500 (1).

A total of six air samples for organic vapors were collected using 150 milligram (mg) coconut shell charcoal tubes connected to SKC Model 224-PCXR7 sampling pumps calibrated at flow rates ranging from 0.019 to 0.022 lpm. The organic vapor samples were collected over as much of the 8-hour workshift as practicable. To prevent sample loss, the charcoal tubes were changed approximately halfway through the workshift, resulting in two charcoal tubes per sample during the workshift. Four of these were personal air samples and were collected in the breathing zone of employees with the highest potential for organic vapor exposures. The sampling pumps were removed from the employees during their lunch break and replaced when they returned to work. The other two were general area air samples and were collected at locations close to organic vapor sources in the finishing and spray finishing areas. After sampling was completed, the charcoal tubes were sealed in preparation for analysis.

The organic vapors selected for analysis were acetone, methyl isobutyl ketone (MIBK), VM&P naphtha, toluene, and xylenes. These five organic compounds were selected to be representative of the organic vapor exposures based on information obtained from the material safety data sheets (MSDS's) for the white lacquer undercoat and clear lacquer top coat used exclusively for wood finishing during the industrial hygiene survey. The criteria used to make these selections were percentage (by weight), volatility, and toxicity (environmental criteria). The organic vapor samples were analyzed for acetone and MIBK by gas chromatography (GC) with flame ionization detection (FID) using NIOSH Method 1300; for VM&P naphtha by GC/FID using NIOSH Method 1550; and for toluene and xylene by GC/FID using NIOSH Method 1501 (1).

A total of five air samples for formaldehyde were collected using Air Quality Research Model PF-20 Formaldehyde Monitors. These formaldehyde monitors operated by the diffusion of the formaldehyde vapor from the air, through a porous membrane, and onto a sorbent. (Because these monitors operate by diffusion, they are commonly known as passive monitors.) The sampling rate for these monitors was 0.016 lpm. The formaldehyde samples were collected over as much of the 8-hour workshift as was practicable. One of these was a personal air sample and was collected in the breathing zone of an employee with the highest potential for formaldehyde exposure. The formaldehyde monitor was removed from the employee during his lunch break and replaced upon his return to work. The other four were general area air samples and were collected at locations close to formaldehyde sources in the veneer area. After sampling was completed, the formaldehyde monitors were sealed in preparation for analysis. The monitors were analyzed for formaldehyde by visible light spectrophotometry using NIOSH Method 3500 with modifications (1).

Relative humidity measurements were obtained in the production areas throughout the facility using a Belfort Instrument Company Model 566-3 Psychron. For each measurement, dry bulb and wet bulb readings were recorded and relative humidity determined from a psychometric table supplied with the instrument. Relative humidity is an important parameter to measure because, if too high, it may adversely effect some sorbent-type air sampling methods and, if too low, can increase the electrostatic charge and overall "dustiness" of a hygroscopic particulate such as wood dust.

A total of 10 personal noise samples were collected using Metrosonics, Inc., Model db-301 Metrologgers (dosimeters) calibrated prior to each use. The noise dosimeters were programmed to determine compliance with Occupational Safety and Health Administration (OSHA) requirements (2). Employees with the highest potential noise exposures were selected and the samples were collected in their hearing zone for as much of the 8-hour workday as was practicable. The noise dosimeters were removed from the employees during their lunch break and replaced when they returned to work. At the end of the sample period, the noise exposure data from each dosimeter was downloaded and stored in a Metrosonics, Inc., Model db-651 Metroreader. For subsequent analysis of the noise exposure data, the Metroreader was downloaded into a personal computer.

Local exhaust ventilation measurements were obtained at nine different machines representative of the various woodworking operations present at the Jaff Brothers facility. Air velocity measurements were made at exhaust openings using an Alnor Compuflow Model 8565 Thermoanemometer. Duct air flows were determined using the pitot traverse method (3) with a Dwyer Pitot Tube and an Alnor Compuflow Model 8530D-I Electromanometer. General ventilation measurements of flow patterns were also obtained in the production areas of the facility using a Drager smoke tube kit.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH representatives employ environmental evaluation criteria for assessment of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is important to note, however, that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects, even if the occupational exposures are controlled at the limits set by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus the overall exposure may be increased above measured airborne concentrations. Evaluation criteria typically change over time as new information on the toxic effects of an agent become available.

The primary sources of environmental criteria for the workplace are the following: NIOSH Criteria Documents and Recommended Exposure Limits (RELs), the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and the OSHA Permissible Exposure Limits (PELs). These values are usually based on a time-weighted average (TWA) exposure, which refers to the average airborne concentration of a substance over the entire 8- to 10-hour workday. Concentrations are usually expressed in parts per million (ppm) or milligrams per cubic meter (mg/m^3). In addition, for some substances there are short-term exposure limits (STELs) or ceiling limits which are intended to supplement the TWA limits where there are recognized toxic effects from short-term exposures.

The OSHA standards are required to take into account the feasibility of reducing exposures in various industries where the agents are used; whereas, the NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and NIOSH recommendations for reducing exposures, it should be noted that employers are legally required to meet the requirements of OSHA PELs and other OSHA standards.

For wood dust, the current NIOSH REL is a TWA of 1.0 mg/m^3 (4). When recommending their REL, NIOSH noted that wood dust should be considered a potential occupational carcinogen and that exposures should be reduced to the lowest feasible level, not to exceed the REL of 1.0 mg/m^3. The NIOSH REL does not distinguish between wood types (hard and soft wood). The ACGIH TLV for hard wood dust is a TWA of 1.0 mg/m^3 and their TLV for soft wood dust is a TWA of 5.0 mg/m^3. The ACGIH has also recommended a STEL for soft wood dust of 10 mg/m^3 averaged over a 15-minute period which should not be exceeded at any time during the workday even if the 8-hour TWA exposure value is within the TLV. Exposures above the TLV up to the STEL should occur no more than four times per day (5). The OSHA PEL for hard and soft wood dust is a TWA of 5.0

mg/m^3; their 15-minute STEL for hard and soft wood dust is 10 mg/m^3. OSHA has also established a separate PEL for western red cedar which is a TWA of 2.5 mg/m^3 (6). The adverse health effects that have been associated with exposure to wood dust upon which these evaluation criteria are based include dermatitis, allergenic respiratory effects, mucosal and nonallergenic respiratory effects, and cancer.

The organic vapors selected for analysis, acetone, MIBK, VM&P naphtha, toluene and xylenes, all have separate evaluation criteria. For acetone, the NIOSH REL is a TWA of 250 ppm (4); the ACGIH TLV and OSHA PEL are a TWA of 750 ppm (5,6). For MIBK, the NIOSH REL, ACGIH TLV, and OSHA PEL are a TWA of 50 ppm (4,5,6). For VM&P naphtha, the NIOSH REL is a TWA of 80 ppm (4); the ACGIH TLV and OSHA PEL are 300 ppm (5,6). (For VM&P naphtha, these evaluation criteria ppm values are based on an average molecular weight of 110.) For both toluene and xylene, the NIOSH REL, ACGIH TLV, and OSHA PEL are 100 ppm (4,5,6). The adverse health effects that have been associated with exposure to either individual or mixtures of these organic vapors upon which these evaluation criteria are based include headache, dizziness, nausea, eye, skin and respiratory irritation, and narcosis.

For formaldehyde, the NIOSH REL is a TWA of 0.016 ppm (4); the ACGIH TLV and OSHA PEL are a TWA of 1.0 ppm (5,6). When recommending their REL, NIOSH noted that formaldehyde should be considered a potential occupational carcinogen and that exposures should be reduced to the lowest feasible level; when recommending theirs, the ACGIH noted that formaldehyde should be considered a suspected human carcinogen. The adverse health effects that have been associated with exposure to formaldehyde upon which these evaluation criteria are based include eye, nose and throat irritation, mucosal and respiratory irritation, dermatitis, nausea, and cancer.

For continuous or intermittent noise, the NIOSH REL and ACGIH TLV are a TWA of 85 dBA (7,5); the OSHA PEL is a TWA of 90 dBA with an action level of 85 dBA (2). The adverse health effects that have been associated with exposure to noise upon which these evaluation criteria are based include both temporary and permanent loss of hearing.

RESULTS AND DISCUSSION

During the February 12 and 13, 1991, industrial hygiene survey at the Jaff Brothers facility, 13 personal air samples were collected for total dust on employees involved in a variety of milling, assembly, and finishing activities. In the milling and assembly areas, the exposure was primarily to hard wood dust. In the finishing area, the exposure was to a mixture of lacquer and wood dust. (For the wood and lacquer dust mixture, the wood dust evaluation criteria will be used for comparison in this report.) The results indicated airborne total dust exposures ranging from 0.58 to 2.09 mg/m^3 (Table 1). Four of the 13 employees sampled had exposures above the NIOSH REL and ACGIH TLV (for hard wood) of 1.0 mg/m^3. These four employees were performing hand sanding operations for at least a portion of the workshift. The employee with the highest total dust exposure (2.09 mg/m^3) worked in the assembly area and performed manual hand sanding during the workshift. The other three employees were predominately using orbital sanders; one worked in the finishing area and had an exposure of 1.41 mg/m^3, and two worked in the assembly area and had exposures of 1.38 and 1.05 mg/m^3 (the latter was using an orbital sander with a dust bag control). None of the milling area employees sampled had total dust exposures that exceeded the NIOSH REL and ACGIH TLV of 1.0 mg/m^3. None of the 13 employees sampled had total dust exposures in excess of the OSHA PEL of 5.0 mg/m^3.

During the industrial hygiene survey, it was observed that several production area employees (including those performing hand sanding operations) wore single-use, disposable dust masks. These dust masks cannot form a tight seal between the face and the mask and, therefore, provide only limited protection against inhaling airborne dust.

Direct-reading total dust measurements were collected at a background (ambient) site in the milling area and in the breathing zone of milling and assembly area employees performing eight different woodworking operations ranging from 1.5 to 13.5 minutes in duration. The woodworking operations measured were sawing 1x4-inch hardwood, 1-inch plywood, and 1.5-inch particle board (with Formica surfaces) using two finish saws (nos. 10 and 12); cutting grooves into 1-inch plywood using a shaper (no. 18); sanding short and long strips of 1x2-inch hardwood using the small belt sander (no. 29); sanding 2x8-foot panels using the large belt sander (no. 28); and manual hand sanding by an employee in the assembly area (Figure 1). The activities performed by the employees included selecting, measuring, preparing, and machining the wood piece. For the purposes of reporting, these tasks were grouped into the categories of between machining (selecting, measuring, and preparing) and during machining.

The results from the direct-reading total dust measurements indicated that the background (ambient) concentration of total dust in the milling area was 0.3 mg/m^3 and that the total dust concentrations from the breathing zone of employees performing the individual woodworking operations ranged from 0.3 to 4.0 mg/m^3 (Table 2). None of these results exceeded the ACGIH (soft wood) or OSHA 15-minute STEL for wood dust of 10 mg/m^3. However, the employees performing operations which used a shaper (no. 18), the small belt sander (no. 29), and manual hand sanding, generated concentrations above 1.0 mg/m^3. Graphs of the direct-reading total dust exposure concentrations for the background (ambient) measurement and for the employees performing each of the woodworking operations are presented in Figures 2 through 10. (On Figures 3 through 10, the time spent performing the machining task is depicted as a double bar (=) above the exposure tracing.) As shown in Figures 3 through 10, airborne total dust concentrations in the employees' breathing zone generally increased as machining time increased.

While making the direct-reading measurements in the breathing zone of employees performing woodworking operations, it was observed that the location of the employee in relation to the dust source was a significant factor in predicting airborne dust concentrations. Where the dust was propelled away from the employee, the dust concentrations in the breathing zone were lower. When the employee was positioned near or actually in a dust plume, the dust concentrations in the breathing zone were higher.

Six personal cascade impactor air samples for dust size were collected on employees in the milling, assembly, and finishing areas. As previously described, in the milling and assembly areas, the dust was primarily hard wood and, in the finishing area, was a mixture of lacquer and wood. The results indicated that the majority of the airborne dust in all areas was relatively large in size (Table 3). Percentages of dust (by mass) collected below 6.0 um diameter in size ranged from 4.1% for a finishing area employee to 31.7% for an assembly area employee. Percentages of dust (by mass) collected below 0.9 um diameter in size also ranged from 4.1% for a finishing area employee to 31.7% for an assembly area employee. Of the employees performing sanding operations, the finishing employee had the lowest percentage of small-sized dust collected. In addition, these results indicate that the three employees performing sanding operations (two from the assembly area and one from the finishing area) had higher collected dust concentrations (ranging from 1.77 to 5.76 mg/m^3) than did the three milling area employees (collected dust concentrations ranging from 0.79 to 1.35 mg/m^3). (These airborne dust results cannot be directly compared to any of the total dust evaluation criteria previously described due to differences in sampling requirements.)

The size of airborne dust can be used to predict how the dust will be deposited in the respiratory system when inhaled. Generally, approximately 99 percent of all particles greater than 10 um in diameter are removed in the nasal chamber and have little probability of reaching the lungs. Therefore, particles less than 10 um in diameter may reach the lungs and are considered potentially "respirable". The percentage of these potentially respirable particles actually reaching the lungs increases with decreasing particle size down to about 1.0 um in diameter. In reference to the personal cascade impactor results (Table 3), approximately 83 percent of particles less than 6.0 um in diameter are respirable and could be deposited in the lungs (5). Below 1.0 um in diameter, approximately 97 percent of inhaled particles are able to be deposited in the lungs or exhaled (8,9).

Four personal and two general area air samples were collected for organic vapors. The personal samples were collected on employees in the spray finishing, assembly, and veneer areas. The general area air samples were collected on the mixing table in the spray finishing area and near the waste drum in the finishing area. The results indicated very low or non-detectable exposures to the five organic vapors selected for analysis (Table 4). Exposures to acetone ranged from <1.35 to 5.60 ppm. (A concentration value preceded by the < symbol indicates the sample results were below the analytical limit of detection (LOD).) Exposures to VM&P naphtha ranged from <0.24 to 15.36 ppm; those for toluene ranged from <0.29 to 8.11 ppm. None of the six organic vapor air samples collected contained detectable quantities of MIBK or xylenes. None of these organic vapor exposures were close to the corresponding NIOSH REL, ACGIH TLV, or OSHA PEL for acetone, MIBK, VM&P naphtha, toluene, and xylenes.

One personal and four general area air samples were collected for formaldehyde in the veneer area where the formaldehyde-containing adhesive is used. One personal air sample was collected on the veneerer; the four general area air samples were collected at locations near the mixing station, above the glue spreader, and at the left and right ends of the hot press. The veneer operation requiring the use of the adhesive was performed over a 4-hour period (approximately one-half of the workshift). None of the five air samples contained detectable quantities of formaldehyde, corresponding to a concentration of <0.08 ppm (Table 5). These results are below the ACGIH TLV and OSHA PEL for formaldehyde of 1.0 ppm. However, the sampling rate of the passive monitors used was too low to determine if the NIOSH REL for formaldehyde of 0.016 ppm was exceeded over an 8-hour workshift.

Twenty-seven environmental psychrometer measurements were made throughout the facility over both days of the industrial hygiene survey (Table 6). On February 12, 1991, psychrometer measurements were made in the milling, assembly, spray finishing, finishing, and veneer areas three times: mid-morning, about noon, and mid-afternoon. Relative humidities on that day ranged from 12 to 19 percent. Since air sampling was not conducted in the veneer area on February 13, psychrometer measurements were made in the remaining four areas three times as previously described. Relative humidities on the second day of the survey ranged from 16 to 26 percent. These relative humidities would be too low to have any adverse effect on the sorbent media air sampling methods utilized for organic vapors and formaldehyde and would not be high enough to appreciably decrease the "dustiness" of the airborne wood particles.

Ten personal samples were collected for noise on employees working in the milling, assembly, and spray finishing areas. However, exposure data from four of the noise dosimeters were lost during the downloading sequence at the end of the workshift. Therefore, TWA noise exposures are available for only six of the ten employees sampled. The results indicated exposures to noise ranging from 81.8 to 86.4 dBA (Table 7). The employee with the highest noise exposure (86.4 dBA) worked in the milling area. This was the only TWA noise exposure that exceeded the NIOSH PEL, ACGIH TLV, and OSHA action level for continuous or intermittent noise of 85 dBA. However, three other employees working in the spray finishing, assembly, and milling areas had noise exposures above 84 dBA (84.3, 84.4, and 84.9 dBA respectively). It is possible that on other workdays, these employees may also have noise exposures above 85 dBA. None of the exposures exceeded the OSHA PEL for continuous or intermittent noise of 90 dBA. It was noted during the industrial hygiene survey that the majority of employees were wearing earplugs.

Local exhaust measurements were made at nine different woodworking machines in the milling area: the small belt sander (no. 29), the large belt sander (no. 28), three finish saws (nos. 10, 11, and 12), a shaper (no. 19), a jointer (no. 21), a swing saw (no. 3), and a router (no. 23). The results from these measurements indicated that the local exhaust system flow rates for six of these machines were within ACGIH industrial ventilation recommended guidelines (Table 8) (3). Three, however, were below the minimum recommended for the adequate conveying of particulates. The small belt sander (no. 29) had an actual flow rate of 379 cubic feet per minute (cfm); about two-thirds the recommended flow rate of 550 cfm. A jointer (no. 21) had an actual flow rate of 423 cfm; about one-half the recommended flow rate of 785 cfm. A swing saw (no. 3) had an actual flow rate of 214 cfm; less than one-half the recommended flow rate of 500 cfm.

Observations regarding the local exhaust ventilation made during the industrial hygiene survey indicated that a finish saw (no. 8) had a duct clean-out cover missing. Also, the planer (no. 25), the rip saw (no. 15), and a band saw (no. 16), had open areas in the exhaust enclosure beneath the work table (Figure 1). Problems such as these adversely affect the dust control provided by the local exhaust ventilation systems at these woodworking machines.

Observations regarding the general ventilation of the Jaff Brothers facility indicated that the production areas were under a relative negative pressure with reference to the outdoors. Characteristic of this relative negative pressure, when the exhaust fans for the spray booth in the spray finishing area were turned off (as they were for most of the industrial hygiene survey), a backflow into the adjoining areas of the facility occurred preventing the containment of the organic vapors from the wood finishes being used in the spray finishing area.

CONCLUSIONS

Overall, airborne dust exposures during woodworking operations at the Jaff Brothers facility were well controlled through the use of local exhaust ventilation. However, hand sanding operations in the assembly and finishing areas were not controlled through the use of local exhaust ventilation and resulted in employee TWA exposures to total dust exceeding the NIOSH REL and ACGIH TLV (for hard wood) of 1.0 mg/m^3. Employee work practices also had a direct effect on their relative dust exposures, particularly regarding the position of the employee relative to the dust plume generated during the woodworking operations. Poorer work practices increased dust exposures; better work practices decreased dust exposures.

Employee TWA exposures to organic vapors (from the finishing stains and lacquers) and formaldehyde (from the veneer adhesive) were very low or non-detectable. These exposures could increase with either an increase in finishing activity or a change in finishing products which may contain more toxic or more volatile compounds.

The woodworking machinery was relatively noisy and resulted in an employee TWA exposure that exceeded the NIOSH REL, ACGIH TLV, and OSHA action level for continuous or intermittent noise of 85 dBA. These noise exposures could increase with more activity requiring greater use of woodworking machinery.

Four woodworking machines, a finish saw (no.8), the planer (no. 25), the rip saw (no. 15), and a band saw (no. 16) were found to have defects in their local exhaust ventilation systems that adversely effected dust control.

The negative pressure of the production areas relative to the outdoors indicated that the make-up air supply was insufficient for the exhaust. This was exemplified by the backflow of air through the spray booth in the spray finishing area when the exhaust fans for the spray booth were not operating.

RECOMMENDATIONS

Based on the results from this industrial hygiene survey, the following recommendations should be considered to reduce employee exposures:

1. Establish a respiratory protection program meeting OSHA requirements and provide NIOSH-approved dust respirators for the employees performing hand sanding operations until engineering controls can be installed to reduce their TWA total dust exposures to below 1.0 mg/m^3 (10,11). These engineering controls could include a downdraft or sanding table (for small parts) or commercially-available vacuum hand sanders. The OSHA respiratory protection program requirements are provided in Appendix A.

2. Ensure that employees use good work practices to minimize dust exposures during all woodworking operations, particularly hand sanding. Employees should be instructed to avoid having their face in the dust plume generated by woodworking machinery and, where local exhaust ventilation is provided, direct the dust plume toward the ventilation inlet.

3. Continue to obtain material safety data sheets from the suppliers for all products (particularly finishing products) used in the facility as part of the ongoing, OSHA-required hazard communication program (12). This will provide the appropriate alert to changes in supplied products that could require additional industrial hygiene sampling.

4. Establish a hearing conservation program meeting OSHA requirements and continue to provide appropriate hearing protection for the employees routinely using woodworking machinery (2). The OSHA occupational noise exposure requirements are provided in Appendix B.

5. Repair the defects noted in the local exhaust ventilation systems for the finish saw (no. 8), planer (no. 25), rip saw (no. 15), and band saw (no. 16), and routinely maintain the local exhaust ventilation systems for all ventilated woodworking machinery to ensure their proper operation.

6. Operate the exhaust fans for the spray booth in the spray finishing area at all times during the workshift to prevent the backflow of air into the adjoining production areas until the ventilation system can be balanced.

7. Evaluate the make-up air supply for the production areas of the facility and increase to the required amount so a proper balance is achieved.

REFERENCES

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Table 1

Total Dust Air Sampling Results

Jaff Brothers Woodworks, Inc.
Long Island City, New York

Date	Area	Job Description	Time	Total Time (min)	Flow Rate (lpm)	Volume (m^3)	Total Dust Concentration (mg/m^3)	Comments
2/12/91	Finishing	Hand Finisher	0758 - 1142 1217 - 1608	455	1.93	0.88	1.41	Operated Orbital Sander
2/12/91	Milling	Machine Operator	0803 - 1144 1224 - 1608	445	2.03	0.90	0.58	Operated Jointer, Band Saw, Rip Saw, Planer
2/12/91	Milling	Machine Operator	0812 - 1146 1224 - 1607	443	2.05	0.90	0.76	Operated Table Saw
2/12/91	Assembly	Assembler	0818 - 1147 1218 - 1608	439	2.04	0.90	*	Operated Orbital Sander
2/12/91	Assembly	Assembler	0825 - 1144 1219 - 1606	426	2.08	0.89	0.71	
2/12/91	Assembly	Assembler	0834 - 1143 1220 - 1605	414	1.81	0.75	1.05	Operated Orbital Sander (with dust bag)
2/13/91	Milling	Machine Operator	0757 - 1142 1221 - 1611	455	2.00	0.91	0.43	
2/13/91	Milling	Machine Operator	0800 - 1143 1215 - 1612	460	2.11	0.97	0.68	Operated Finish Saw
2/13/91	Milling	Machine Operator	0802 - 1144 1220 - 1612	454	2.16	0.98	0.74	Operated Belt Sander
2/13/91	Assembly	Assembler	0804 - 1146 1219 - 1614	457	2.10	0.96	2.09	
2/13/91	Assembly	Assembler	0810 - 1142 1216 - 1603	439	2.09	0.92	0.73	
2/13/91	Assembly	Assembler	0812 - 1143 1219 - 1602	434	1.92	0.83	1.38	Operated Orbital Sander
2/13/91	Milling	Machine Operator	0818 - 1143 1221 - 1556	420	1.94	0.82	0.59	Operated Finish Saw
Evaluation Criteria:					NIOSH ACGIH ACGIH OSHA	REL TLV TLV PEL	1.0** 1.0+ 5.0++ 5.0	

*Invalid Sample (damaged filter)
**Potential Occupational Carcinogen
+Hard Wood
++Soft Wood

Table 2

Direct-Reading Total Dust Air Sampling Results

Jaff Brothers Woodworks, Inc.
Long Island City, New York

Date	Machine No./ Location*	Machine Type	Operation Description	Sampling Period: Total Time (min)	Sampling Period: Machine Time (%)	Total Dust Concentration (mg/m^3): Between Machining	Total Dust Concentration (mg/m^3): During Machining	Reference Figure No.
2/12/91	A	—	Background (ambient)	336	-	-	0.3	2
2/13/91	10	Finish Saw	1"x 4" (4" cuts)	11.2	4	0.5	0.4	3
2/13/91	10	Finish Saw	1" Plywood (2' & 4' cuts)	1.5	3	0.5	0.5	4
2/13/91	12	Finish Saw	1.5" Particle Board	13.5	12	0.3	0.3	5
2/13/91	18	Shaper	1" Plywood 1'x 2' Panels	7.6	42	1.5	2.0	6
2/13/91	29	Small Belt Sander	1"x 2" (2' & 3' lengths)	5.1	68	1.8	2.4	7
2/13/91	29	Small Belt Sander	1" x 2" (8' lengths)	11.6	54	1.8	4.0	8
2/13/91	28	Large Belt Sander	2' x 8' Panel	6.3	71	0.3	0.3	9
2/13/91	H	Hand Sanding	1" Wide Edge	10.1	94	1.0	1.5	10
Evaluation Criteria:						ACGIH	STEL	10**
						OSHA	STEL	10

*Refer to Figure 1
**Soft Wood

Table 3

Dust Size Air Sampling Results

Jaff Brothers Woodworks, Inc.
Long Island City, New York

Date	Area	Job Description	Time	Total Time (min)	Flow Rate (lpm)	Volume (m³)	Impactor Stage Number	Stage Cutpoint (Dp (um))	Dust Concentration (mg/m³)	Dust Weight % < Dp	Comments
2/12/91	Milling	Machine Operator	0805 - 1146 1219 - 1609	451	2.04	0.92	1	21	0.37	56.0	Operated Jointer, Planer, Rip Saw
							4	6.0	0.36	13.1	
							7	0.9	0.00	13.1	
							F	0.0	0.11	0.0	
									(0.84)*		
2/12/91	Assembly	Assembler	0820 - 1147 1223 - 1606	430	1.93	0.83	1	21	1.77	60.0	
							4	6.0	1.25	31.7	
							7	0.9	0.00	31.7	
							F	0.0	1.40	0.0	
									(4.42)		
2/12/91	Milling	Machine Operator	0825 - 1146 1221 - 1608	428	2.03	0.87	1	21	0.64	52.5	Operated Shaper
							4	6.0	0.47	17.8	
							7	0.9	0.00	17.8	
							F	0.0	0.24	0.0	
									(1.35)		
2/13/91	Milling	Machine Operator	0752 - 1146 1223 - 1611	462	1.98	0.92	1	21	0.23	71.2	Operated Planer
							4	6.0	0.51	6.8	
							7	0.9	0.00	6.8	
							F	0.0	0.05	0.0	
									(0.79)		
2/13/91	Assembly	Assembler	0750 - 1145 1215 - 1610	470	2.05	0.96	1	21	3.27	43.2	
							4	6.0	1.63	15.0	
							7	0.9	0.12	12.8	
							F	0.0	0.74	0.0	
									(5.76)		
2/13/91	Finishing	Hand Finisher	0743 - 1146 1217 - 1610	476	2.04	0.97	1	21	0.89	50.0	Operated Orbital Sander
							4	6.0	0.81	4.1	
							7	0.9	0.00	4.1	
							F	0.0	0.07	0.0	
									(1.77)		

*Total Dust Concentration of Sample Shown in Parentheses

Table 4

Organic Vapor Air Sampling Results

Jaff Brothers Woodworks, Inc.
Long Island City, New York

Date	Area	Job Description/ Location	Time	Total Time (min)	Flow Rate (lpm)	Volume (liters)	Organic Vapor Concentrations (ppm)				
							Acetone	MIBK	Naphtha	Toluene	Xylenes
2/12/91	Spray Finishing	Spray Finisher	0753 - 1143 1216 - 1607	461	0.020	9.28	<1.36	<0.79	11.04	3.73	<0.75
2/12/91	Assembly	Assembler	0818 - 1146 1226 - 1610	430	0.019	8.29	5.60	<0.30	2.96	1.28	<0.84
2/12/91	Veneer	Veneerer	0838 - 1147 1228 - 1614	415	0.022	9.23	<1.37	<0.26	<0.24	<0.29	<0.25
2/12/91	Spray Finishing	On Mixing Table	0846 - 1149 1258 - 1549	354	0.021	7.54	5.59	<0.97	15.36	8.11	<0.92
2/13/91	Spray Finishing	Spray Finisher	0739 - 1141 1216 - 1605	471	0.020	9.36	<1.35	<0.78	7.85	2.84	<0.74
2/13/91	Finishing	Near Waste Drum	0741 - 1128 1205 - 1656	518	0.020	10.54	4.00	<0.70	13.10	7.07	<0.66
Evaluation Criteria:					NIOSH	REL	250	50	80	100	100
					ACGIH	TLV	750	50	300	100	100
					OSHA	PEL	750	50	300	100	100

Table 5

Formaldehyde Air Sampling Results

Jaff Brothers Woodworks, Inc.
Long Island City, New York

Date	Area	Job Description/ Location	Time	Total Time (min)	Sample Rate (lpm)	Volume (liters)	Formaldehyde Concentration (ppm)
2/12/91	Veneer	Veneerer	0838 - 1545	427	0.016	6.83	<0.08
2/12/91	Veneer	Near Mixing Station	0852 - 1545	413	0.016	6.61	<0.08
2/12/91	Veneer	Above Glue Spreader	0852 - 1544	412	0.016	6.59	<0.08
2/12/91	Veneer	Right End of Hot Press	0852 - 1543	411	0.016	6.58	<0.08
2/12/91	Veneer	Left End of Hot Press	0852 - 1543	411	0.016	6.58	<0.08
Evaluation Criteria:					NIOSH	REL	0.016*
					ACGIH	TLV	1**
					OSHA	PEL	1

* Potential Occupational Carcinogen
** Suspected Human Carcinogen

Table 6

Environmental Psychrometer Measurements

Jaff Brothers Woodworks, Inc.
Long Island City, New York

Date	Area	Time	Dry Bulb Temperature (°C)	Wet Bulb Temperature (°C)	Relative Humidity (%)
2/12/91	Milling	0945	18.0	7.0	14
2/12/91	Assembly	0948	18.5	7.0	12
2/12/91	Spray Finishing	0950	18.0	7.5	17
2/12/91	Finishing	0952	17.0	6.5	14
2/12/91	Veneer	0954	18.0	7.0	14
2/12/91	Milling	1237	21.5	9.0	13
2/12/91	Assembly	1238	20.0	8.0	12
2/12/91	Spray Finishing	1241	20.5	8.5	13
2/12/91	Finishing	1240	21.5	9.0	13
2/12/91	Veneer	1245	16.0	6.5	19
2/12/91	Milling	1500	20.0	8.5	15
2/12/91	Assembly	1503	21.0	8.5	12
2/12/91	Spray Finishing	1506	19.0	7.5	13
2/12/91	Finishing	1505	20.0	8.0	12
2/12/91	Veneer	1508	17.5	7.0	16
2/13/91	Milling	0910	19.0	9.5	26
2/13/91	Assembly	0912	21.0	9.5	17
2/13/91	Spray Finishing	0915	17.0	7.5	21
2/13/91	Finishing	0917	19.5	8.5	17
2/13/91	Milling	1225	19.5	9.5	23
2/13/91	Assembly	1227	20.0	9.5	21
2/13/91	Spray Finishing	1230	18.5	9.0	25
2/13/91	Finishing	1232	20.5	9.0	16
2/13/91	Milling	1505	19.5	8.5	17
2/13/91	Assembly	1507	20.5	9.0	16
2/13/91	Spray Finishing	1510	21.5	10.0	18
2/13/91	Finishing	1509	20.0	9.0	18

Table 7

Noise Dosimeter Sampling Results

Jaff Brothers Woodworks, Inc.
Long Island City, New York

Date	Area	Job Description	Time	Sample Rate	Period Length	Periods Completed	Maximum Period Average (dBA)	TWA (dBA)
2/12/91	Milling	Machine Operator	0832 - 1142 1232 - 1609	4/sec	1 min.	407	91	81.8
2/12/91	Milling	Machine Operator	0806 - 1146 1231 - 1610	4/sec	1 min.	*	*	*
2/12/91	Milling	Machine Operator	0803 - 1145 1230 - 1609	4/sec	1 min.	*	*	*
2/12/91	Milling	Machine Operator	0832 - 1144 1233 - 1609	4/sec	1 min.	*	*	*
2/12/91	Assembly	Assembler	0843 - 1146 1231 - 1608	4/sec	1 min.	*	*	*
2/13/91	Milling	Machine Operator	0757 - 1146 1221 - 1612	4/sec	1 min	460	97	84.9
2/13/91	Assembly	Assembler	0806 - 1143 1218 - 1612	4/sec	1 min.	451	98	84.4
2/13/91	Milling	Machine Operator	0752 - 1143 1223 - 1612	4/sec	1 min.	460	100	86.4
2/13/91	Assembly	Assembler	0805 - 1143 1218 - 1614	4/sec	1 min.	454	99	83.4
2/13/91	Spray Finishing	Hand Finisher	0739 - 1142 1216 - 1606	4/sec	1 min.	473	101	84.3
Evaluation Criteria:						NIOSH	REL	85
						ACGIH	TLV	85
						OSHA	PEL	90**

*Invalid Sample (data lost during down-loading)
**OSHA Action Level is 85 dBA

Table 8

Local Exhaust Ventilation Measurements

Jaff Brothers Woodworks, Inc.
Long Island City, New York

Date	Machine No./ Location*	Machine Type	Measured Flow Rate (cfm)	ACGIH Recommended Flow Rate (cfm)
2/12/91	29	Small Belt Sander	379	550
2/12/91	28	Large Belt Sander	2388/1842**	—
2/12/91	10	Finish Saw	636	350 to 440
2/12/91	11	Finish Saw	554	350 to 440
2/13/91	19	Shaper	584	440 to 1400
2/13/91	12	Finish Saw	1442	350 to 440
2/13/91	21	Jointer	423	785
2/13/91	3	Swing Saw	214	500
2/13/91	23	Router	1186	350 to 800

* Refer to Figure 1
** Flow Rates in Ducts 1 and 2

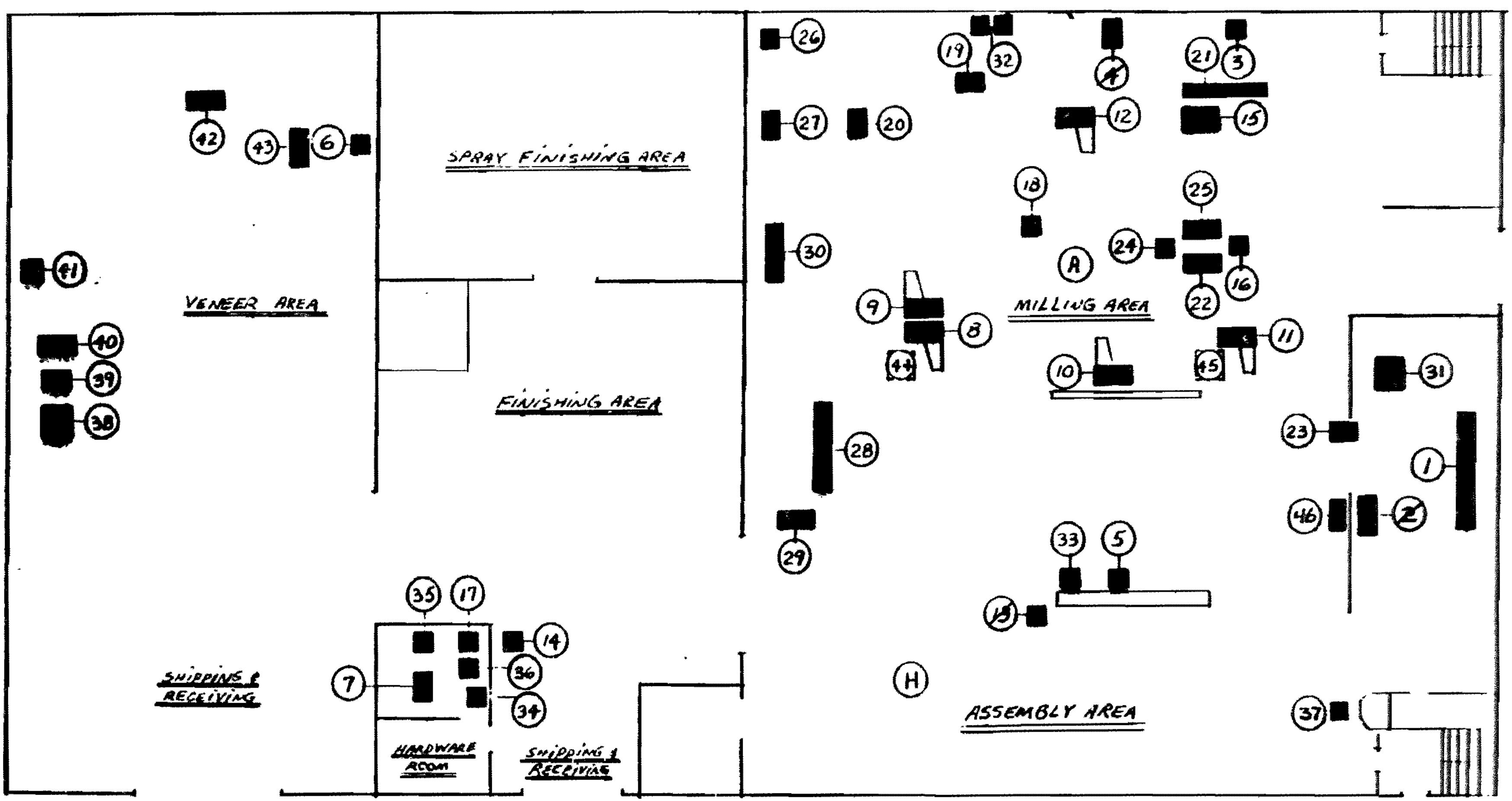


Figure 1: Jaft Brothers Woodworks, Inc., Facility Diagram.

Figure 1 Legend

Machine No./Machine Type		Machine No./Machine Type	
1	Edger	24	Borer
2	Not in Service	25	Planer
3	Swing Saw	26	Dove Tailer
4	Not in Service	27	Dove Tailer
5	Swing Saw	28	Large Belt Sander
6	Cut-off Saw	29	Small Belt Sander
7	Cut-off Saw	30	Moulding Sander
8	Finish Saw	31	Drum Sander
9	Finish Saw	32	Grinder
10	Finish Saw	33	Grinder
11	Finish Saw	34	Grinder
12	Finish Saw	35	Grinder
13	Not in Service	36	Drill Press
14	Finish Saw	37	Drill Press
15	Rip Saw	38	Veneer Press
16	Band Saw	39	Rising Table
17	Band Saw	40	Glue Spreader
18	Shaper	41	Glue Mixer
19	Shaper/Feeder	42	Glue Veneer Taper
20	Shaper/Feeder	43	Veneer Trimmer
21	Jointer	44	Blower
22	Jointer	45	Blower
23	Router	46	Hinge Router

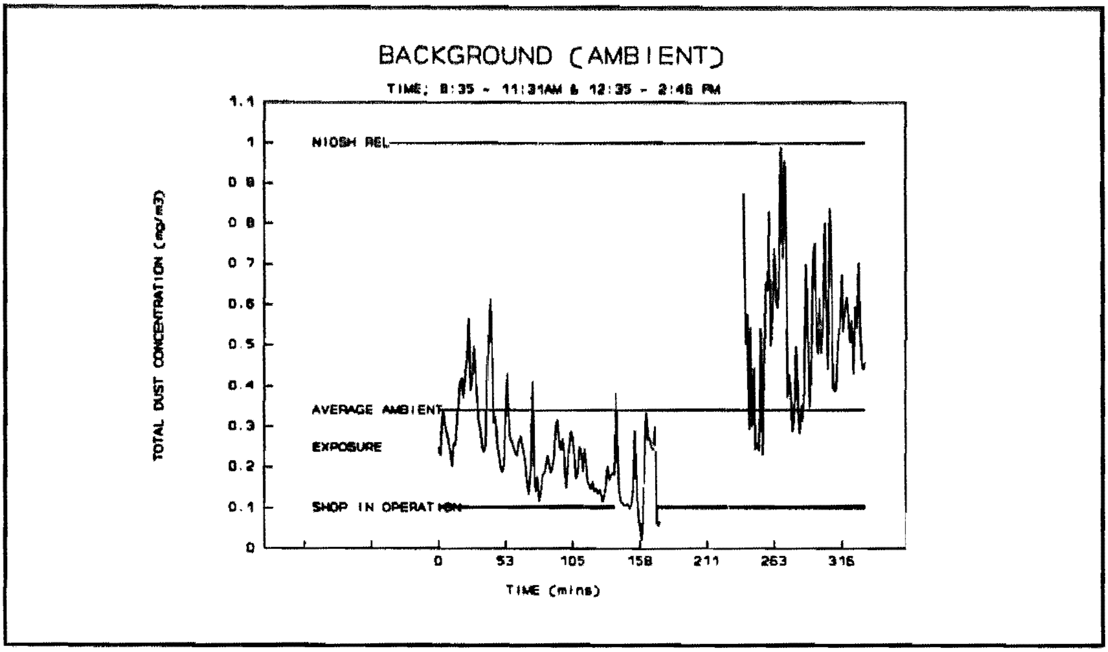


Figure 2: Background (Ambient) Total Dust Concentration In The Milling Area.

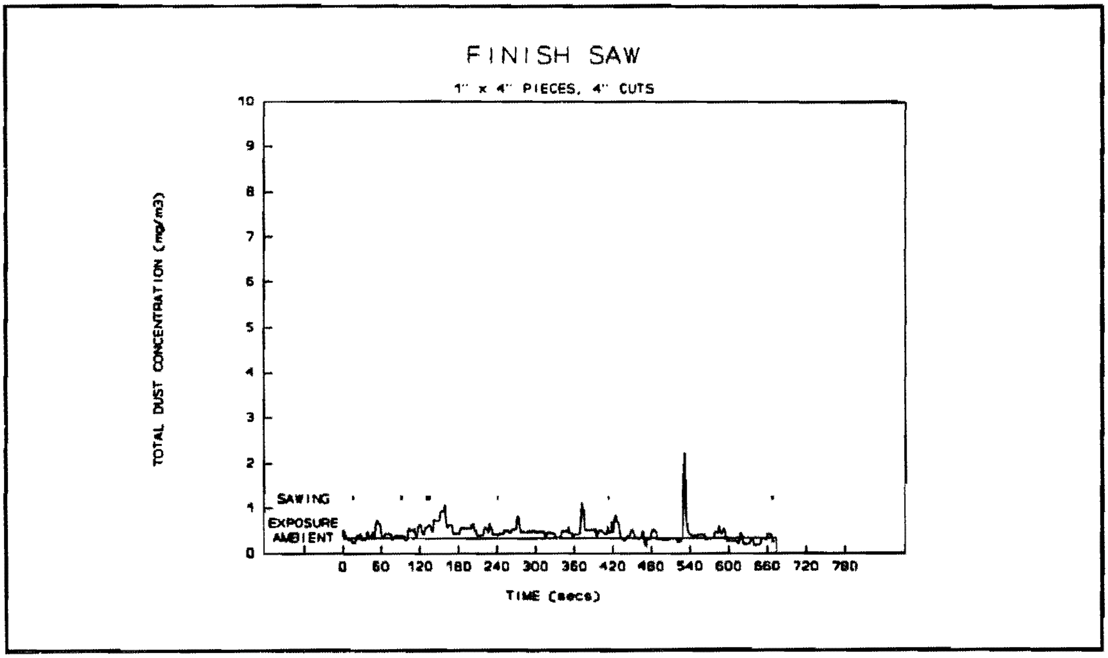


Figure 3: Finish Saw (No. 10), 4" Cuts on 1" by 4" Pieces.

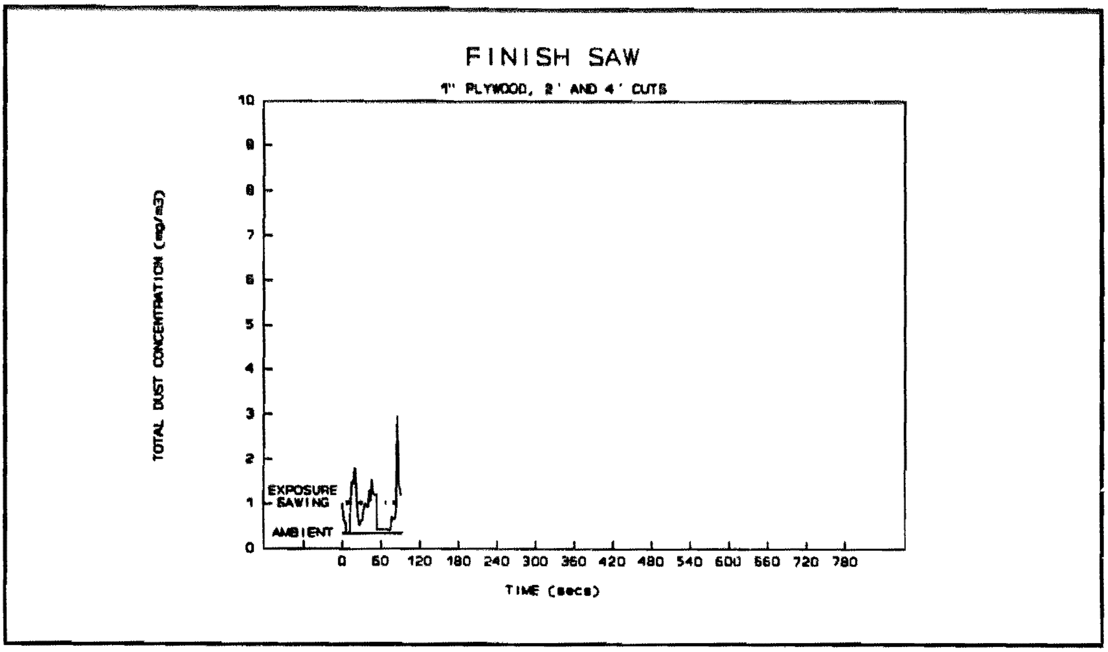


Figure 4: Finish Saw (No. 10), 2' and 4' Cuts on 1" Plywood.

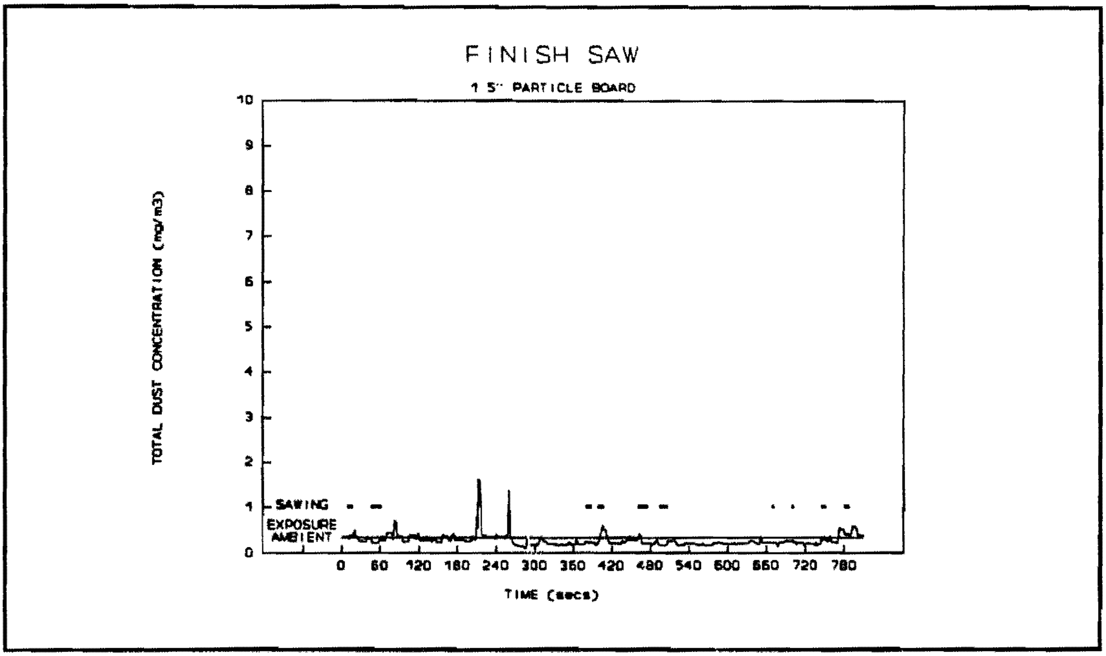


Figure 5: Finish Saw (No. 12), 4' and 8' Cuts on 1.5" Particle Board (With Formica Surfaces on the Top and Bottom).

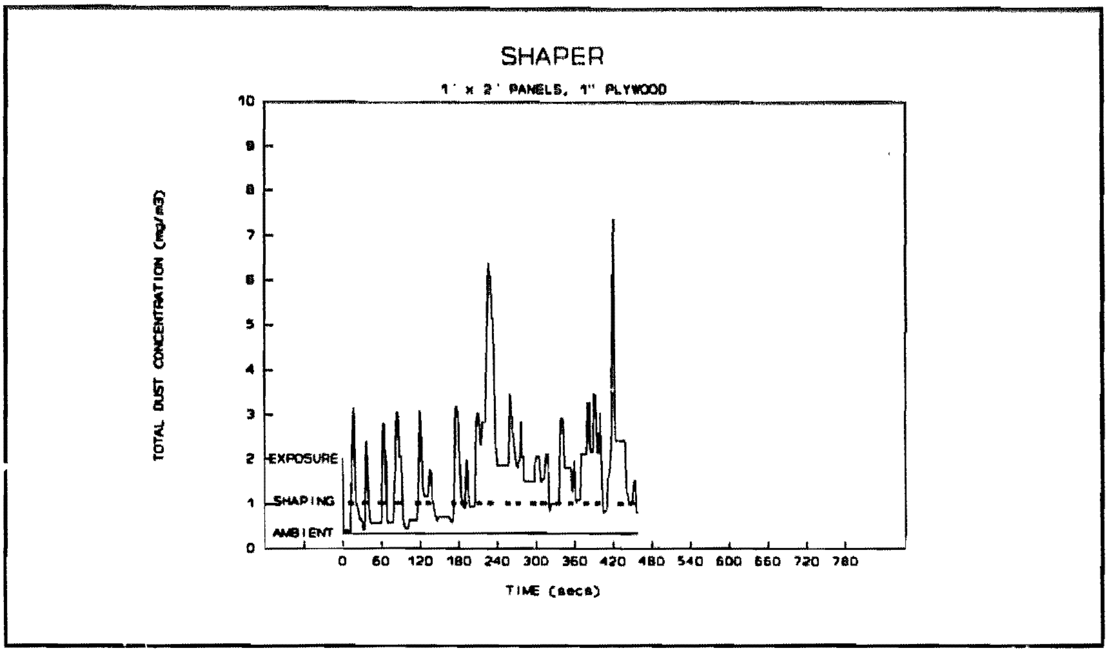


Figure 6: Shaper (No. 18) Cutting Grooves on Two Sides of 1" Plywood.

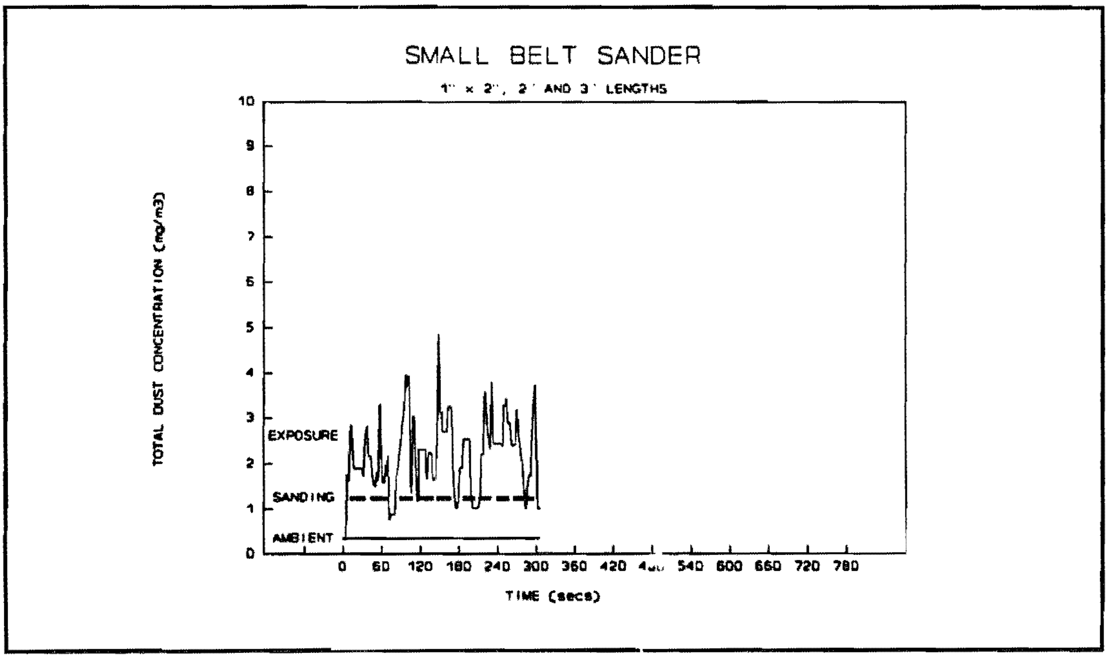


Figure 7: Small Belt Sander (No. 29) Sanding 1" and 2" Edges That are 2' and 3' Long.

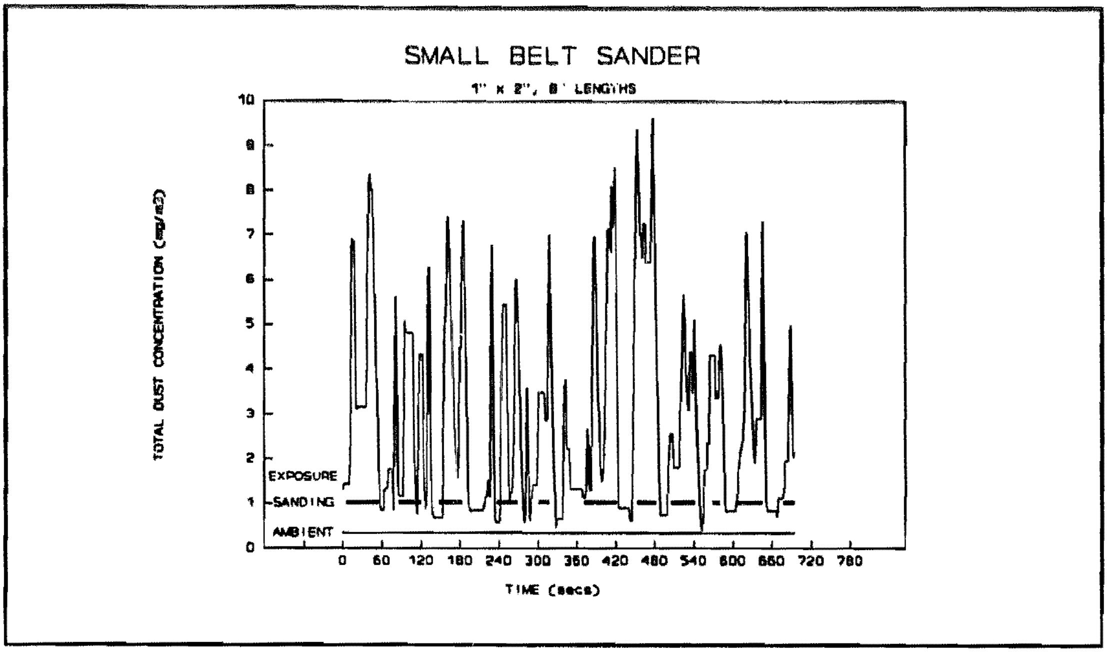


Figure 8: Small Belt Sander (No. 29) Sanding 1" and 2" Edges That are 8' Long.

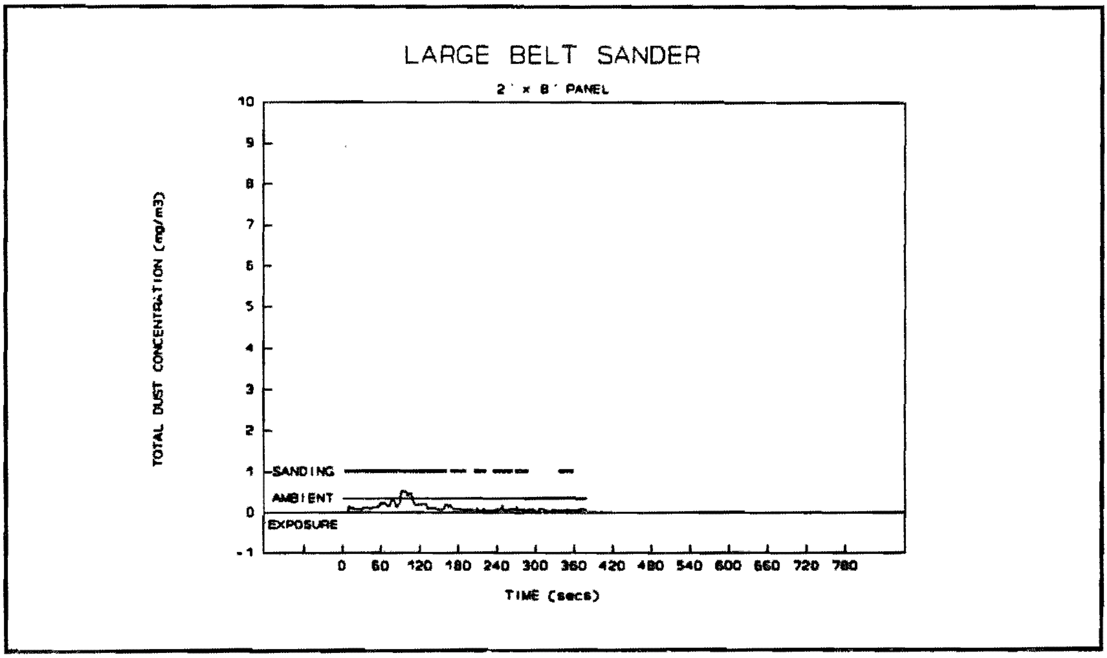


Figure 9: Large Belt Sander (No. 28) Sanding a 2' by 8' Panel.

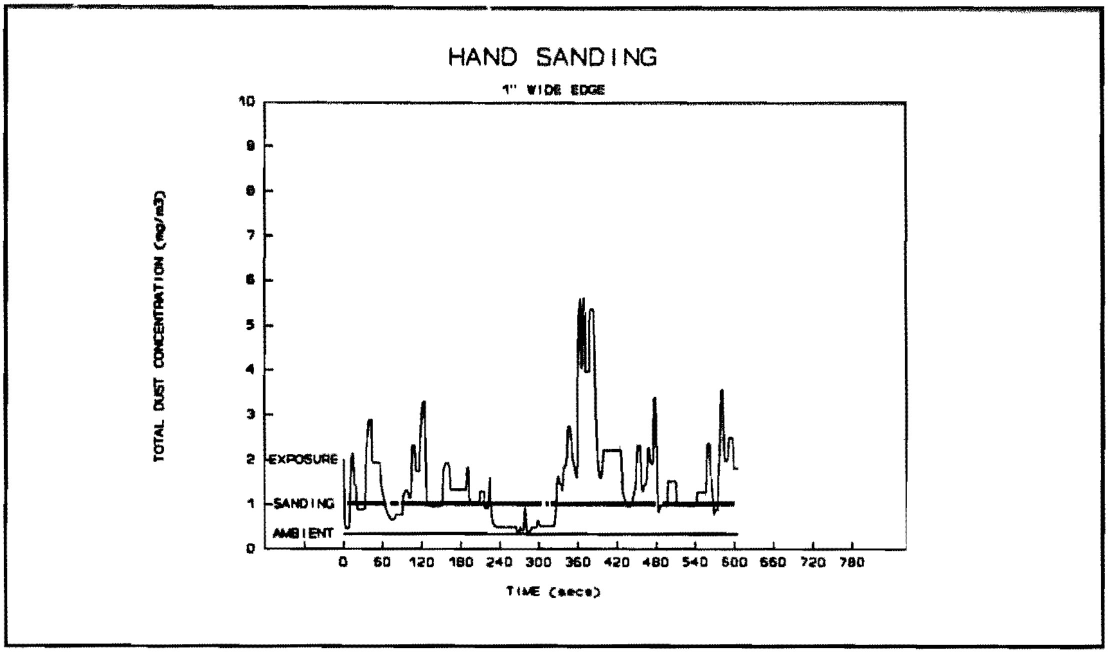


Figure 10: Manual Hand Sanding a 1" Wide Edge.

Appendix A

OSHA Respiratory Protection Standard (29 CFR 1910.134)

OCCUPATIONAL SAFETY AND HEALTH STANDARDS
SUBPART I — PERSONAL PROTECTIVE EQUIPMENT

(Code of Federal Regulations, Title 29, Chapter XVII, Part 1910, Subpart I: 36 FR 10466, May 29, 1971; amended at 36 FR 15105, August 13, 1971; 37 FR 22231, October 18, 1972; republished at 39 FR 23502, June 27, 1974; standard provision revoked at 43 FR 49726, October 24, 1978; amended at 49 FR 5322, February 10, 1984)

Subpart I—Personal Protective Equipment

§ 1910.132 General requirements.

(a) *Application*. Protective equipment, including personal protective equipment for eyes, face, head, and extremities, protective clothing, respiratory devices, and protective shields and barriers, shall be provided, used, and maintained in a sanitary and reliable condition wherever it is necessary by reason of hazards of processes or environment, chemical hazards, radiological hazards, or mechanical irritants encountered in a manner capable of causing injury or impairment in the function of any part of the body through absorption, inhalation or physical contact.

(b) *Employee-owned equipment*. Where employees provide their own protective equipment, the employer shall be responsible to assure its adequacy, including proper maintenance, and sanitation of such equipment.

(c) *Design*. All personal protective equipment shall be of safe design and construction for the work to be performed.

§ 1910.133 Eye and face protection.

(a) *General*. (1) Protective eye and face equipment shall be required where there is a reasonable probability of injury that can be prevented by such equipment. In such cases, employers shall make conveniently available a type of protector suitable for the work to be performed, and employees shall use such protectors. No unprotected person shall knowingly be subjected to a hazardous environmental condition. Suitable eye protectors shall be provided where machines or operations present the hazard of flying objects, glare, liquids, injurious radiation, or a combination of these hazards.

(2) Protectors shall meet the following minimum requirements:

(i) They shall provide adequate protection against the particular hazards for which they are designed.

(ii) They shall be reasonably comfortable when worn under the designated conditions.

(iii) They shall fit snugly and shall not unduly interfere with the movements of the wearer.

(iv) They shall be durable.

(v) They shall be capable of being disinfected.

(vi) They shall be easily cleanable.

(vii) Protectors should be kept clean and in good repair.

(3) Persons whose vision requires the use of corrective lenses in spectacles, and who are required by this standard to wear eye protection, shall wear goggles or spectacles of one of the following types:

(i) Spectacles whose protective lenses provide optical correction.

(ii) Goggles that can be worn over corrective spectacles without disturbing the adjustment of the spectacles.

(iii) Goggles that incorporate corrective lenses mounted behind the protective lenses.

(4) Every protector shall be distinctly marked to facilitate identification only of the manufacturer.

(5) When limitations or precautions are indicated by the manufacturer, they shall be transmitted to the user and care taken to see that such limitations and precautions are strictly observed.

(6) Design, construction, testing, and use of devices for eye and face protection shall be in accordance with American National Standard for Occupational and Educational Eye and Face Protection, Z87.1-1968.

§ 1910.134 Respiratory protection.

(a) *Permissible practice*. (1) In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination. This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used pursuant to the following requirements.

(2) Respirators shall be provided by the employer when such equipment is necessary to protect the health of the employee. The employer shall provide the respirators which are applicable and suitable for the purpose intended. The employer shall be responsible for the establishment and maintenance of a respiratory protective program which shall include the requirements outlined in paragraph (b) of this section.

(3) The employee shall use the provided respiratory protection in accordance with instructions and training received.

(b) *Requirements for a minimal acceptable program*. (1) Written standard operating procedures governing the selection and use of respirators shall be established.

(2) Respirators shall be selected on the basis of hazards to which the worker is exposed.

(3) The user shall be instructed and trained in the proper use of respirators and their limitations.

(4) [Removed]

[1910.134(b)(4) deleted by 49 FR 5322, February 10, 1984]

(5) Respirators shall be regularly cleaned and disinfected. Those used by more than

one worker shall be thoroughly cleaned and disinfected after each use
[1910.134(b)(5) amended by 49 FR 5322, February 10, 1984]

(6) Respirators shall be stored in a convenient, clean, and sanitary location.

(7) Respirators used routinely shall be inspected during cleaning. Worn or deteriorated parts shall be replaced. Respirators for emergency use such as self-contained devices shall be thoroughly inspected at least once a month and after each use.

(8) Appropriate surveillance of work area conditions and degree of employee exposure or stress shall be maintained.

(9) There shall be regular inspection and evaluation to determine the continued effectiveness of the program.

(10) Persons should not be assigned to tasks requiring use of respirators unless it has been determined that they are physically able to perform the work and use the equipment. The local physician shall determine what health and physical conditions are pertinent. The respirator user's medical status should be reviewed periodically (for instance, annually).

(11) Approved or accepted respirators shall be used when they are available. The respirator furnished shall provide adequate respiratory protection against the particular hazard for which it is designed in accordance with standards established by competent authorities. The U.S. Department of Interior, Bureau of Mines, and the U.S. Department of Agriculture are recognized as such authorities. Although respirators listed by the U.S. Department of Agriculture continue to be acceptable for protection against specified pesticides, the U.S. Department of the Interior, Bureau of Mines, is the agency now responsible for testing and approving pesticide respirators.

(c) *Selection of respirators.* Proper selection of respirators shall be made according to the guidance of American National Standard Practices for Respiratory Protection Z88.2–1969.

(d) *Air quality.* (1) Compressed air, compressed oxygen, liquid air, and liquid oxygen used for respiration shall be of high purity. Oxygen shall meet the requirements of the United States Pharmacopoeia for medical or breathing oxygen. Breathing air shall meet at least the requirements of the specification for Grade D breathing air as described in Compressed Gas Association Commodity Specification G–7.1–1966. Compressed oxygen shall not be used in supplied-air respirators or in open circuit self-contained breathing apparatus that have previously used compressed air. Oxygen must never be used with air line respirators.

(2) Breathing air may be supplied to respirators from cylinders or air compressors.

(i) Cylinders shall be tested and maintained as prescribed in the Shipping Container Specification Regulations of the Department of Transportation (49 CFR Part 178).

(ii) The compressor for supplying air shall be equipped with necessary safety and standby devices. A breathing air-type compressor shall be used. Compressors shall be constructed and situated so as to avoid entry of contaminated air into the system and suitable in-line air purifying sorbent beds and filters installed to further assure breathing air quality. A receiver of sufficient capacity to enable the respirator wearer to escape from a contaminated atmosphere in event of compressor failure, and alarms to indicate compressor failure and overheating shall be installed in the system. If an oil-lubricated compressor is used, it shall have a high-temperature or carbon monoxide alarm, or both. If only a high-temperature alarm is used, the air from the compressor shall be frequently tested for carbon monoxide to insure that it meets the specifications in subparagraph (1) of this paragraph.

(3) Air line couplings shall be incompatible with outlets for other gas systems to prevent inadvertent servicing of air line respirators with nonrespirable gases or oxygen.

(4) Breathing gas containers shall be marked in accordance with American National Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained, Z48.1–1954; Federal Specification BB–A–1034a, June 21, 1968, Air, Compressed for Breathing Purposes; or Interim Federal Specification GG–B–00675b, April 27, 1965, Breathing Apparatus, Self-Contained.

(e) *Use of respirators.* (1) Standard procedures shall be developed for respirator use. These should include all information and guidance necessary for their proper selection, use, and care. Possible emergency and routine uses of respirators should be anticipated and planned for.

(2) The correct respirator shall be specified for each job. The respirator type is usually specified in the work procedures by a qualified individual supervising the respiratory protective program. The individual issuing them shall be adequately instructed to insure that the correct respirator is issued.
[1910.134(e)(2) amended by 49 FR 5322, February 10, 1984]

(3) Written procedures shall be prepared covering safe use of respirators in dangerous atmospheres that might be encountered in normal operations or in emergencies. Personnel shall be familiar with these procedures and the available respirators.

(i) In areas where the wearer, with failure of the respirator, could be overcome by a toxic or oxygen-deficient atmosphere, at least one additional man shall be present. Communications (visual, voice, or signal line) shall be maintained between both or all individuals present. Planning shall be such that one individual will be unaffected by any likely incident and have the proper rescue equipment to be able to assist the other(s) in case of emergency.

(ii) When self-contained breathing apparatus or hose masks with blowers are used in atmospheres immediately dangerous to life or health, standby men must be present with suitable rescue equipment.

(iii) Persons using air line respirators in atmospheres immediately hazardous to life or health shall be equipped with safety harnesses and safety lines for lifting or removing persons from hazardous atmospheres or other and equivalent provisions for the rescue of persons from hazardous atmospheres shall be used. A standby man or men with suitable self-contained breathing apparatus shall be at the nearest fresh air base for emergency rescue.

(4) Respiratory protection is no better than the respirator in use, even though it is worn conscientiously. Frequent random inspections shall be conducted by a qualified individual to assure that respirators are properly selected, used, cleaned, and maintained.

(5) For safe use of any respirator, it is essential that the user be properly instructed in its selection, use, and maintenance. Both supervisors and workers shall be so instructed by competent persons. Training shall provide the men an opportunity to handle the respirator, have it fitted properly, test its face-piece-to-face seal, wear it in normal air for a long familiarity period, and, finally, to wear it in a test atmosphere.

(i) Every respirator wearer shall receive fitting instructions including demonstrations and practice in how the respirator should be worn, how to adjust it, and how to determine if it fits properly. Respirators shall not be worn when conditions prevent a good face seal. Such conditions may be a growth of beard, sideburns, a skull cap that projects under the facepiece, or temple pieces on glasses. Also, the absence of one or both dentures can seriously affect the fit of a facepiece. The worker's diligence in observing these factors shall be evaluated by periodic check. To assure proper protection, the facepiece fit shall be checked by the wearer each time he puts on the respirator. This may be done by following the manufacturer's facepiece fitting instructions.

(ii) Providing respiratory protection for individuals wearing corrective glasses is a serious problem. A proper seal cannot be established if the temple bars of eye glasses extend through the sealing edge of the full facepiece. As a temporary measure, glasses with short temple bars or without temple bars may be taped to the wearer's head. Wearing of contact lenses in contaminated atmospheres with a respirator shall not be allowed. Systems have been developed for mounting corrective lenses inside full facepieces. When a workman must wear corrective lenses as part of the facepiece, the facepiece and lenses shall be fitted by qualified individuals to provide good vision, comfort, and a gas-tight seal.

(iii) If corrective spectacles or goggles are required, they shall be worn so as not to affect the fit of the facepiece. Proper selection of equipment will minimize or avoid this problem.

(f) *Maintenance and care of respirators.* (1) A program for maintenance and care of respirators shall be adjusted to the type of plant, working conditions, and hazards involved, and shall include the following basic services:

(i) Inspection for defects (including a leak check),

(ii) Cleaning and disinfecting,

(iii) Repair,

(iv) Storage

Equipment shall be properly maintained to retain its original effectiveness.

(2) (i) All respirators shall be inspected routinely before and after each use. A respirator that is not routinely used but is kept ready for emergency use shall be inspected after each use and at least monthly to assure that it is in satisfactory working condition.

(ii) Self-contained breathing apparatus shall be inspected monthly. Air and oxygen cylinders shall be fully charged according to the manufacturer's instructions. It shall be determined that the regulator and warning devices function properly.

(iii) Respirator inspection shall include a check of the tightness of connections and the condition of the facepiece, headbands, valves, connecting tube, and canisters. Rubber or elastomer parts shall be inspected for pliability and signs of deterioration. Stretching and manipulating rubber or elastomer parts with a massaging action will keep them pliable and flexible and prevent them from taking a set during storage.

(iv) A record shall be kept of inspection dates and findings for respirators maintained for emergency use.

(3) Routinely used respirators shall be collected, cleaned, and disinfected as frequently as necessary to insure that proper protection is provided for the wearer. Respirators maintained for emergency use shall be cleaned and disinfected after each use

[1910.134(f)(3) amended by 49 FR 5322, February 10, 1984]

(4) Replacement or repairs shall be done only by experienced persons with parts designed for the respirator. No attempt shall be made to replace components or to make adjustment or repairs beyond the manufacturer's recommendations. Reducing or admission valves or regulators shall be returned to the manufacturer or to a trained technician for adjustment or repair.

(5) (i) After inspection, cleaning, and necessary repair, respirators shall be stored to protect against dust, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals. Respirators placed at stations and work areas for emergency use should be quickly accessible at all times and should be stored in compartments built for the purpose. The compartments should be clearly marked. Routinely used respirators, such as dust respirators, may be placed in plastic bags. Respirators should not be stored in such places as lockers or tool boxes unless they are in carrying cases or cartons.

(ii) Respirators should be packed or stored so that the facepiece and exhalation valve will rest in a normal position and function will not be impaired by the elastomer setting in an abnormal position.

(iii) Instructions for proper storage of emergency respirators, such as gas masks and self-contained breathing apparatus, are found in "use and care" instructions usually mounted inside the carrying case lid.

(g) *Identification of gas mask canisters.* (1) The primary means of identifying a gas mask canister shall be by means of properly worded labels. The secondary means of identifying a gas mask canister shall be by a color code.

(2) All who issue or use gas masks falling within the scope of this section shall see that all gas mask canisters purchased or used by them are properly labeled and colored in accordance with these requirements before they are placed in service and that the labels and colors are properly maintained at all times thereafter until the canisters have completely served their purpose.

(3) On each canister shall appear in bold letters the following:

(i)—

Canister for ....

(Name for atmospheric contaminant)

or

Type N Gas Mask Canister

(ii) In addition, essentially the following wording shall appear beneath the appropriate phrase on the canister label: "For respiratory protection in atmospheres containing not more than ...... percent by volume of ...."

(Name of atmospheric contaminant)

(iii) [Revoked]

(4) Canisters having a special high-efficiency filter for protection against radionuclides and other highly toxic particulates shall be labeled with a statement of the type and degree of protection afforded by the filter. The label shall be affixed to the neck end of, or to the gray stripe which is around and near the top of, the canister. The degree of protection shall be marked as the percent of penetration of the canister by a 0.3-micron-diameter dioctyl phthalate (DOP) smoke at a flow rate of 85 liters per minute.

(5) Each canister shall have a label warning that gas masks should be used only in atmospheres containing sufficient oxygen to support life (at least 16 percent by volume), since gas mask canisters are only designed to neutralize or remove contaminants from the air.

(6) Each gas mask canister shall be painted a distinctive color or combination of colors indicated in Table I-1. All colors used shall be such that they are clearly identifiable by the user and clearly distinguishable from one another. The color coating used shall offer a high degree of resistance to chipping, scaling, peeling, blistering, fading, and the effects of the ordinary atmospheres to which they may be exposed under normal conditions of storage and use. Appropriately colored pressure sensitive tape may be used for the stripes.

[Section 1910.134(g)(3)(iii) revoked at 43 FR 49726, October 24, 1978, effective November 24, 1978]

TABLE I-1

Atmospheric contaminants to be protected against	Colors assigned*
Acid gases	White.
Hydrocyanic acid gas	White with ½-inch green stripe completely around the canister near the bottom.
Chlorine gas	White with ½-inch yellow stripe completely around the canister near the bottom.
Organic vapors	Black.
Ammonia gas	Green.
Acid gases and ammonia gas	Green with ½-inch white stripe completely around the canister near the bottom.
Carbon monoxide	Blue.
Acid gases and organic vapors	Yellow.
Hydrocyanic acid gas and chloropicrin vapor	Yellow with ½-inch blue stripe completely around the canister near the bottom.
Acid gases, organic vapors, and ammonia gases.	Brown.
Radioactive materials, excepting tritium and noble gases.	Purple (Magenta).
Particulates (dusts, fumes, mists, fogs, or smokes) in combination with any of the above gases or vapors.	Canister color for contaminant, as designated above, with ½-inch gray stripe completely around the canister near the top.
All of the above atmospheric contaminants	Red with ½-inch gray stripe completely around the canister near the top.

*Gray shall not be assigned as the main color for a canister designed to remove acids or vapors.

NOTE: Orange shall be used as a complete body, or stripe color to represent gases not included in this table. The user will need to refer to the canister label to determine the degree of protection the canister will afford.

Appendix B

OSHA Occupational Noise Exposure Standard (29 CFR 1910.95)

cases where harmful chemicals may be splashed on parts of the body.

(viii) Operators with sores, burns, or other skin lesions requiring medical treatment shall not be allowed to work at their regular operations until so authorized by a physician. Any small skin abrasions, cuts, rash, or open sores which are found or reported shall be treated by a properly designated person so that chances of exposures to the chemicals are removed. Workers exposed to chromic acids shall have a periodic examination made of the nostrils and other parts of the body, to detect incipient ulceration.

(ix) Sufficient washing facilities, including soap, individual towels, and hot water, shall be provided for all persons required to use or handle any liquids which may burn, irritate, or otherwise be harmful to the skin, on the basis of at least one basin (or its equivalent) with a hot water faucet for every 10 employees. See § 1910.141(d).

(x) Locker space or equivalent clothing storage facilities shall be provided to prevent contamination of street clothing.

(xi) First aid facilities specific to the hazards of the operations conducted shall be readily available.

(10) *Special precautions for cyanide.* Dikes or other arrangements shall be provided to prevent the possibility of intermixing of cyanide and acid in the event of tank rupture.

(11) *Inspection, maintenance, and installation.*

(i) Floors and platforms around tanks shall be prevented from becoming slippery both by original type of construction and by frequent flushing. They shall be firm, sound, and of the design and construction to minimize the possibility of tripping.

(ii) Before cleaning the interior of any tank, the contents shall be drained off, and the cleanout doors shall be opened where provided. All pockets in tanks or pits, where it is possible for hazardous vapors to collect, shall be ventilated and cleared of such vapors.

(iii) Tanks which have been drained to permit employees to enter for the purposes of cleaning, inspection, or maintenance may contain atmospheres which are hazardous to life or health, through the presence of flammable or toxic air contaminants, or through the absence of sufficient oxygen. Before employees shall be permitted to enter any such tank, appropriate tests of the atmosphere shall be made to determine if the limits set by subparagraph (2)(iii) of this paragraph are exceeded, or if the oxygen concentration is less than 19.5 percent.

(iv) If the tests made in accordance with subdivision (iii) of this subparagraph indicate that the atmosphere in the tank is unsafe, before any employee is permitted to enter the tank, the tank shall be ventilated until the hazardous atmosphere is removed, and ventilation shall be continued so as to prevent the occurrence of a hazardous atmosphere as long as an employee is in the tank.

(v) If, in emergencies, such as rescue work, it is necessary to enter a tank which may contain a hazardous atmosphere, suitable respirators, such as self-contained breathing apparatus; hose mask with blower, if there is a possibility of oxygen deficiency; or a gas mask, selected and operated in accordance with subparagraph (9)(vi) of this paragraph, shall be used. If a contaminant in the tank can cause dermatitis, or be absorbed through the skin, the employee entering the tank shall also wear protective clothing. At least one trained standby employee, with suitable respirator, shall be present in the nearest uncontaminated area. The standby employee must be able to communicate with the employee in the tank and be able to haul him out of the tank with a lifeline if necessary.

(vi) Maintenance work requiring welding or open flame, where toxic metal fumes such as cadmium, chromium, or lead may be evolved, shall be done only with sufficient local exhaust ventilation to prevent the creation of a health hazard, or be done with respirators selected and used in accordance with subparagraph (9)(vi) of this paragraph. Welding, or the use of open flames near any solvent cleaning equipment shall be permitted only after such equipment has first been thoroughly cleared of solvents and vapors.

(12) *Vapor degreasing tanks.* (i) In any vapor degreasing tank equipped with a condenser or vapor level thermostat, the condenser or thermostat shall keep the level of vapors below the top edge of the tank by a distance at least equal to one-half the tank width, or at least 36 inches, whichever is shorter.

(ii) Where gas is used as a fuel for heating vapor degreasing tanks, the combustion chamber shall be of tight construction, except for such openings as the exhaust flue, and those that are necessary for supplying air for combustion. Flues shall be of corrosion-resistant construction and shall extend to the outer air. If mechanical exhaust is used on this flue, a draft diverter shall be used. Special precautions must be taken to prevent solvent fumes from entering the combustion air of this or any other heater when chlorinated or fluorinated hydrocarbon solvents (for example, trichloroethylene, Freon) are used.

(iii) Heating elements shall be so designed and maintained that their surface temperature will not cause the solvent or mixture to decompose, break down, or be converted into an excessive quantity of vapor.

(iv) Tanks or machines of more than 4 square feet of vapor area, used for solvent cleaning or vapor degreasing, shall be equipped with suitable cleanout or sludge doors located near the bottom of each tank or still. These doors shall be so designed and gasketed that there will be no leakage of solvent when they are closed.

(13) *Scope.* (i) This paragraph (d) applies to all operations involving the immersion of materials in liquids, or in the vapors of such liquids, for the purpose of cleaning or altering their surfaces, or adding or imparting a finish thereto, or changing the character of the materials, and their subsequent removal from the liquids or vapors, draining, and drying. Such operations include washing, electroplating, anodizing, pickling, quenching, dyeing, dipping, tanning, dressing, bleaching, degreasing, alkaline cleaning, stripping, rinsing, digesting, and other similar operations, but do not include molten materials handling operations or surface coating operations.

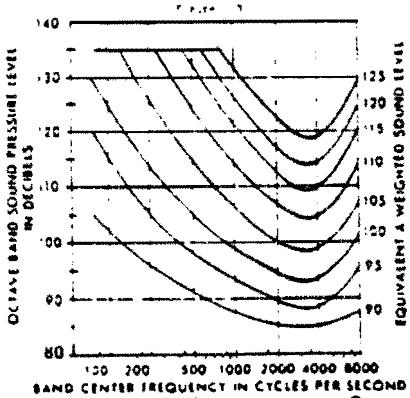
(ii) "Molten materials handling operations" means all operations, other than welding, burning, and soldering operations, involving the use, melting, smelting, or pouring of metals, alloys, salts, or other similar substances in the molten state. Such operations also include heat treating baths, descaling baths die casting stereotyping, galvanizing, tinning, and similar operations.

(iii) "*Surface coating operations*" means all operations involving the application of protective, decorative, adhesive, or strengthening coating or impregnation to one or more surfaces, or into the interstices of any object or material, by means of spraying, spreading, flowing, brushing, roll coating, pouring, cementing, or similar means; and any subsequent draining or drying operations, excluding open-tank operations.

[Sections 1910.94(c)(5)(i)(b) and (c)(5)(iii) revoked at 43 FR 49726, October 24, 1978, effective November 24, 1978]

§ 1910.95 Occupational noise exposure.

(a) Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table G-16 when measured on the A scale of a standard sound level meter at slow response. When noise levels are determined by octave band analysis, the equivalent A-weighted sound level may be determined as follows:



Equivalent sound level contours. Octave band sound pressure levels may be converted to the equivalent A-weighted sound level by plotting them on this graph and noting the A-weighted sound level corresponding to the point of highest penetration into the sound level contours. This equivalent A-weighted sound level, which may differ from the actual A-weighted sound level of the noise, is used to determine exposure limits from Table G-16.

[Sec. 1910.95 amended at 39 FR 19468, June 3, 1974]

(b)(1) When employees are subjected to sound exceeding those listed in Table

G-16, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of Table G-16, personal protective equipment shall be provided and used to reduce sound levels within the levels of the table.

(2) If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous.

TABLE G-16—PERMISSIBLE NOISE EXPOSURES [1]

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

[1] When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: $C_1/T_1 + C_2/T_2 \ldots C_n/T_n$ exceeds unity, then, the mixed exposure should be considered to exceed the limit value. C_n indicates the total time of exposure at a specified noise level, and T_n indicates the total time of exposure permitted at that level.

Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

[Sec. 1910.95 Table G-16 amended at 39 FR 19468, June 3, 1974]

[Section 1910.95(c)—(s) and Appendices A—I amended by 46 FR 4161, January 16, 1981]

(c) *Hearing conservation program.* (1) The employer shall administer a continuing, effective hearing conservation program, as described in paragraphs (c) through (o) of this section, whenever employee noise exposures equal or exceed an 8-hour time-weighted average sound level (TWA) of 85 decibels measured on the A scale (slow response) or, equivalently, a dose of fifty percent. For purposes of the hearing conservation program, employee noise exposures shall be computed in accordance with Appendix A and Table G-16a, and without regard to any attenuation provided by the use of personal protective equipment.

(2) For purposes of paragraphs (c) through (n) of this section, an 8-hour time-weighted average of 85 decibels or a dose of fifty percent shall also be referred to as the action level.

(d) *Monitoring.* (1) When information indicates that any employee's exposure may equal or exceed an 8-hour time-weighted average of 85 decibels, the employer shall develop and implement a monitoring program.

(i) The sampling strategy shall be designed to identify employees for inclusion in the hearing conservation program and to enable the proper selection of hearing protectors.

(ii) Where circumstances such as high worker mobility, significant variations in sound level, or a significant component of impulse noise make area monitoring generally inappropriate, the employer shall use representative personal sampling to comply with the monitoring requirements of this paragraph unless the employer can show that area sampling produces equivalent results.

(2)(i) All continuous, intermittent and impulsive sound levels from 80 decibels to 130 decibels shall be integrated into the noise measurements.

(ii) Instruments used to measure employee noise exposure shall be calibrated to ensure measurement accuracy.

(3) Monitoring shall be repeated whenever a change in production, process, equipment or controls increases noise exposures to the extent that:

[illegible] 'onal employees may be ex- [illegible] bove the action level; or [illegible] tenuation provided by [illegible] tors being used by em- [illegible] be rendered inadequate [illegible] requirements of paragrapl [illegible] his section.

(e) *Employee notification.* The employer shall notify each employee exposed at or above an 8-hour time-weighted average of 85 decibels of the results of the monitoring.

(f) *Observation of monitoring.* The employer shall provide affected employees or their representatives with an opportunity to observe any noise measurements conducted pursuant to this section.

(g) *Audiometric testing program.* (1) The employer shall establish and maintain an audiometric testing program as provided in this paragraph by making audiometric testing available to all employees whose exposures equal or exceed an 8-hour time-weighted average of 85 decibels.

(2) The program shall be provided at no cost to employees.

(3) Audiometric tests shall be performed by a licensed or certified audiologist, otolaryngologist, or other physician, or by a technician who is certified by the Council of Accreditation in Occupational Hearing Conservation, or who has satisfactorily demonstrated competence in administering audiometric examinations, obtaining valid audiograms, and properly using, maintaining and checking calibration and proper functioning of the audiometers being used. A technician who operates microprocessor audiometers does not need to be certified. A technician who performs audiometric tests must be responsible to an audiologist, otolaryngologist or physician.

(4) All audiograms obtained pursuant to this section shall meet the requirements of Appendix C: *Audiometric Measuring Instruments.*

(5) *Baseline audiogram.* (i) Within 6 months of an employee's first exposure at or above the action level, the employer shall establish a valid baseline audiogram against which subsequent audiograms can be compared.

(ii) *Mobile test van exception.* Where mobile test vans are used to meet the audiometric testing obligation, the employer shall obtain a valid baseline audiogram within 1 year of an employee's first exposure at or above the action level. Where baseline audiograms are obtained more than 6 months after the employee's first exposure at or above the action level, employees shall wearing hearing protectors for any period exceeding six months after first exposure until the baseline audiogram is obtained.

(iii) Testing to establish a baseline audiogram shall be preceded by at least 14 hours without exposure to workplace noise. Hearing protectors may be used as a substitute for the requirement that baseline audiograms be preceded by 14 hours without exposure to workplace noise.

(iv) The employer shall notify employees of the need to avoid high levels of non-occupational noise exposure during the 14-hour period immediately preceding the audiometric examination.

(6) *Annual audiogram.* At least annually after obtaining the baseline audiogram, the employer shall obtain a new audiogram for each employee exposed at or above an 8-hour time-weighted average of 85 decibels.

(7) *Evaluation of audiogram.* (i) Each employee's annual audiogram shall be compared to that employee's baseline audiogram to determine if the audiogram is valid and if a standard

threshold shift as defined in paragraph (g)(10) of this section has occurred. This comparison may be done by a technician.

(ii) If the annual audiogram shows that an employee has suffered a standard threshold shift, the employer may obtain a retest within 30 days and consider the results of the retest as the annual audiogram.

(iii) The audiologist, otolaryngologist, or physician shall review problem audiograms and shall determine whether there is a need for further evaluation. The employer shall provide to the person performing this evaluation the following information:

(A) A copy of the requirements for hearing conservation as set forth in paragraphs (c) through (n) of this section;

(B) The baseline audiogram and most recent audiogram of the employee to be evaluated;

(C) Measurements of background sound pressure levels in the audiometric test room as required in Appendix D: Audiometric Test Rooms.

(D) Records of audiometer calibrations required by paragraph (h)(5) of this section.

(8) *Follow-up procedures.* (i) If a comparison of the annual audiogram to the baseline audiogram indicates a standard threshold shift as defined in paragraph (g)(10) of this section has occurred, the employee shall be informed of this fact in writing, within 21 days of the determination.

(ii) Unless a physician determines that the standard threshold shift is not work related or aggravated by occupational noise exposure, the employer shall ensure that the following steps are taken when a standard threshold shift occurs:

(A) Employees not using hearing protectors shall be fitted with hearing protectors, trained in their use and care, and required to use them.

(B) Employees already using hearing protectors shall be refitted and retrained in the use of hearing protectors and provided with hearing protectors offering greater attenuation if necessary.

(C) The employee shall be referred for a clinical audiological evaluation or an otological examination, as appropriate, if additional testing is necessary or if the employer suspects that a medical pathology of the ear is caused or aggravated by the wearing of hearing protectors.

(D) The employee is informed of the need for an otological examination if a medical pathology of the ear that is unrelated to the use of hearing protectors is suspected.

(iii) If subsequent audiometric testing of an employee whose exposure to noise is less than an 8-hour TWA of 90 decibels indicates that a standard threshold shift is not persistent, the employer:

(A) Shall inform the employee of the new audiometric interpretation; and

(B) May discontinue the required use of hearing protectors for that employee.

(9) *Revised baseline.* An annual audiogram may be substituted for the baseline audiogram when, in the judgment of the audiologist, otolaryngologist or physician who is evaluating the audiogram:

(i) The standard threshold shift revealed by the audiogram is persistent; or

(ii) The hearing threshold shown in the annual audiogram indicates significant improvement over the baseline audiogram.

(10) *Standard threshold shift.* (i) As used in this section, a standard threshold shift is a change in hearing threshold relative to the baseline audiogram of an average of 10 dB or more at 2000, 3000, and 4000 Hz in either ear.

(ii) In determining whether a standard threshold shift has occurred, allowance may be made for the contribution of aging (presbycusis) to the change in hearing level by correcting the annual audiogram according to the procedure described in Appendix F: *Calculation and Application of Age Correction to Audiograms.*

(h) *Audiometric test requirements.* (1) Audiometric tests shall be pure tone, air conduction, hearing threshold examinations, with test frequencies including as a minimum 500, 1000, 2000, 3000, 4000, and 6000 Hz. Tests at each frequency shall be taken separately for each ear.

(2) Audiometric tests shall be conducted with audiometers (including microprocessor audiometers) that meet the specifications of, and are maintained and used in accordance with, American National Standard Specification for Audiometers, S3.6-1969.

(3) Pulsed-tone and self-recording audiometers, if used, shall meet the requirements specified in Appendix C: *Audiometric Measuring Instruments.*

(4) Audiometric examinations shall be administered in a room meeting the requirements listed in Appendix D: *Audiometric Test Rooms.*

(5) *Audiometer calibration.* (i) The functional operation of the audiometer shall be checked before each day's use by testing a person with known, stable hearing thresholds, and by listening to the audiometer's output to make sure that the output is free from distorted or unwanted sounds. Deviations of 10 decibels or greater require an acoustic calibration.

(ii) Audiometer calibration shall be checked acoustically at least annually in accordance with Appendix E: *Acoustic Calibration of Audiometers.* Test frequencies below 500 Hz and above 6000 Hz may be omitted from this check. Deviations of 15 decibels or greater require an exhaustive calibration.

(iii) An exhaustive calibration shall be performed at least every two years in accordance with sections 4.1.2; 4.1.3.; 4.1.4.3; 4.2; 4.4.1; 4.4.2; 4.4.3; and 4.5 of the American National Standard Specification for Audiometers, S3.6-1969. Test frequencies below 500 Hz and above 6000 Hz may be omitted from this calibration.

(i) *Hearing protectors.* (1) Employers shall make hearing protectors available to all employees exposed to an 8-hour time-weighted average of 85 decibels or greater at no cost to the employees. Hearing protectors shall be replaced as necessary.

(2) Employers shall ensure that hearing protectors are worn:

(i) By an employee who is required by paragraph (b)(1) of this section to wear personal protective equipment; and

(ii) By any employee who is exposed to an 8-hour time-weighted average of 85 decibels or greater, and who:

(A) Has not yet had a baseline audiogram established pursuant to paragraph (g)(5)(ii); or

(B) Has experienced a standard threshold shift.

(3) Employees shall be given the opportunity to select their hearing protectors from a variety of suitable hearing protectors provided by the employer.

(4) The employer shall provide training in the use and care of all hearing protectors provided to employees.

(5) The employer shall ensure proper initial fitting and supervise the

correct use of all hearing protectors.

(j) *Hearing protector attenuation.* (1) The employer shall evaluate hearing protector attenuation for the specific noise environments in which the protector will be used. The employer shall use one of the evaluation methods described in Appendix B: *Methods for Estimating the Adequacy of Hearing Protection Attenuation.*

(2) Hearing protectors must attenuate employee exposure at least to an 8-hour time-weighted average of 90 decibels as required by paragraph (b) of this section.

(3) For employees who have experienced a standard threshold shift, hearing protectors must attenuate employee exposure to an 8-hour time-weighted average of 85 decibels or below.

(4) The adequacy of hearing protector attenuation shall be re-evaluated whenever employee noise exposures increase to the extent that the hearing protectors provided may no longer provide adequate attenuation. The employer shall provide more effective hearing protectors where necessary.

(k) *Training program.* (1) The employer shall institute a training program for all employees who are exposed to noise at or above an 8-hour time-weighted average of 85 decibels, and shall ensure employee participation in such program.

(2) The training program shall be repeated annually for each employee included in the hearing conservation program. Information provided in the training program shall be updated to be consistent with changes in protective equipment and work processes.

(3) The employer shall ensure that each employee is informed of the following:

(i) The effects of noise on hearing;

(ii) The purpose of hearing protectors, the advantages, disadvantages, and attenuation of various types, and instructions on selection, fitting, use, and care; and

(iii) The purpose of audiometric testing, and an explanation of the test procedures.

(l) *Access to information and training materials.* (1) The employer shall make available to affected employees or their representatives copies of this standard and shall also post a copy in the workplace.

(2) The employer shall provide to affected employees any informational materials pertaining to the standard that are supplied to the employer by the Assistant Secretary.

(3) The employer shall provide, upon request, all materials related to the employer's training and education program pertaining to this standard to the Assistant Secretary and the Director.

(m) *Recordkeeping*—(1) *Exposure measurements.* The employer shall maintain an accurate record of all employee exposure measurements required by paragraph (d) of this section.

(2) *Audiometric tests.* (i) The employer shall retain all employee audiometric test records obtained pursuant to paragraph (g) of this section:

(ii) This record shall include:

(A) Name and job classification of the employee;

(B) Date of the audiogram;

(C) The examiner's name;

(D) Date of the last acoustic or exhaustive calibration of the audiometer; and

(E) Employee's most recent noise exposure assessment.

(F) The employer shall maintain accurate records of the measurements of the background sound pressure levels in audiometric test rooms.

(3) *Record retention.* The employer shall retain records required in this paragraph (m) for at least the following periods.

(i) Noise exposure measurement records shall be retained for two years.

(ii) Audiometric test records shall be retained for the duration of the affected employee's employment.

(4) *Access to records.* All records required by this section shall be provided upon request to employees, former employees, representatives designated by the individual employee, and the Assistant Secretary. The provisions of 29 CFR 1910.20 (a)-(e) and (g)-(i) apply to access to records under this section.

(5) *Transfer of records.* If the employer ceases to do business, the employer shall transfer to the successor employer all records required to be maintained by this section, and the successor employer shall retain them for the remainder of the period prescribed in paragraph (m) (3) of this section.

(n) *Appendices.* (1) Appendices A, B, C, D, and E to this section are incorporated as part of this section and the contents of these Appendices are mandatory.

(2) Appendices F and G to this section are informational and are not intended to create any additional obligations not otherwise imposed or to detract from any existing obligations.

(o) *Exemptions.* Paragraphs (c) through (n) of this section shall not apply to employers engaged in oil and gas well drilling and servicing operations.

(p) *Startup date.* Baseline audiograms required by paragraph (g) of this section shall be completed by March 1, 1984.

[1910.95, Appendix A amended by 54 FR 24333, June 7, 1989]

(Approved by the Office of Management and Budget under control number 1218-0048)

[Section 1910.95(c)—(p) revised by 48 FR 9776, March 8, 1983]

[Section 1910.95(q)—(s) deleted by 48 FR 9776, March 8, 1983]

[Editor's note: The Occupational Safety and Health Administration June 28, 1983 (48 FR 29687) corrected the amendatory language which was published at 48 FR 9776, March 8, 1983, to reflect the agency's intention to delete paragraphs (q)—(s). The correction was done earlier by editor.]

[Appendices A—I revised by 48 FR 9776, March 8, 1983]

Appendix A: Noise Exposure Computation

This Appendix is Mandatory

I. Computation of Employee Noise Exposure

(1) Noise dose is computed using Table G-16a as follows:

(i) When the sound level, L, is constant over the entire work shift, the noise dose, D, in percent, is given by: $D = 100\ C/T$ where C is the total length of the work day, in hours, and T is the reference duration corresponding to the measured sound level, L, as given in Table G-16a or by the formula shown as a footnote to that table.

(ii) When the workshift noise exposure is composed of two or more periods of noise at different levels, the total noise dose over the work day is given by:

$$D = 100\ (C_1/T_1 + C_2/T_2 + \ldots + C_n/T_n),$$

where C_n indicates the total time of exposure at a specific noise level, and T_n indicates the reference duration for that level as given by Table G-16a.

(2) The eight-hour time-weighted average sound level (TWA), in decibels, may be computed from the dose, in percent, by means of the formula: $TWA = 16.61\ \log_{10}\ (D/100) + 90$. For an eight-hour workshift with the noise level constant over the entire shift, the TWA is equal to the measured sound level.

(3) A table relating dose and TWA is given in Section II.

TABLE G-16a

A-weighted sound level, L (decibel)	Reference duration, T (hour)
80	32
81	27.9
82	24.3
83	21.1
84	18.4
85	16
86	13.9
87	12.1
88	10.6
89	9.2
90	8
91	7.0
92	6.1
93	5.3
94	4.6
95	4
96	3.5
97	3.0
98	2.6
99	2.3
100	2
101	1.7
102	1.5
103	1.3
104	1.1
105	1
106	0.87
107	0.76
108	0.66
109	0.57
110	0.5
111	0.44
112	0.38
113	0.33
114	0.29
115	0.25
116	0.22
117	0.19
118	0.16
119	0.14
120	0.125
121	0.11
122	0.095
123	0.082
124	0.072
125	0.063
126	0.054
127	0.047
128	0.041
129	0.036
130	0.031

In the above table the reference duration, T, is computed by

$$T = \frac{8}{2^{(L-90)/5}}$$

where L is the measured A-weighted sound level.

II. Conversion Between "Dose" and "8-Hour Time-Weighted Average" Sound Level

Compliance with paragraphs (c)-(r) of this regulation is determined by the amount of exposure to noise in the workplace. The amount of such exposure is usually measured with an audiodosimeter which gives a readout in terms of "dose." In order to better understand the requirements of the amendment, dosimeter readings can be converted to an "8-hour time-weighted average sound level." (TWA).

In order to convert the reading of a dosimeter into TWA, see Table A-1, below. This table applies to dosimeters that are set by the manufacturer to calculate dose or percent exposure according to the relationships in Table G-16a. So, for example, a dose of 91 percent over an eight hour day results in a TWA of 89.3 dB, and, a dose of 50 percent corresponds to a TWA of 85 dB.

If the dose as read on the dosimeter is less than or greater than the values found in Table A-1, the TWA may be calculated by using the formula: $TWA = 16.61 \log_{10} (D/100) + 90$ where TWA = 8-hour time-weighted average sound level and D = accumulated dose in percent exposure.

TABLE A-1—CONVERSION FROM "PERCENT NOISE EXPOSURE" OR "DOSE" TO "8-HOUR TIME-WEIGHTED AVERAGE SOUND LEVEL" (TWA)

Dose or percent noise exposure	TWA
10	73.4
15	76.3
20	78.4
25	80.0
30	81.3
35	82.4
40	83.4
45	84.2
50	85.0
55	85.7
60	86.3
65	86.9
70	87.4
75	87.9
80	88.4
81	88.5
82	88.6
83	88.7
84	88.7
85	88.8
86	88.9
87	89.0
88	89.1
89	89.2
90	89.2
91	89.3
92	89.4
93	89.5
94	89.6
95	89.6
96	89.7
97	89.8
98	89.9
99	89.9
100	90.0
101	90.1
102	90.1
103	90.2
104	90.3

TABLE A-1—CONVERSION FROM "PERCENT NOISE EXPOSURE" OR "DOSE" TO "8-HOUR TIME-WEIGHTED AVERAGE SOUND LEVEL" (TWA)—Continued

Dose or percent noise exposure	TWA
105	90.4
106	90.4
107	90.5
108	90.6
109	90.6
110	90.7
111	90.8
112	90.8
113	90.9
114	90.9
115	91.1
116	91.1
117	91.1
118	91.2
119	91.3
120	91.3
125	91.6
130	91.9
135	92.2
140	92.4
145	92.7
150	92.9
155	93.2
160	93.4
165	93.6
170	93.8
175	94.0
180	94.2
185	94.4
190	94.6
195	94.8
200	95.0
210	95.4
220	95.7
230	96.0
240	96.3
250	96.6
260	96.9
270	97.2
280	97.4
290	97.7
300	97.9
310	98.2
320	98.4
330	98.6
340	98.8
350	99.0
360	99.2
370	99.4
380	99.6
390	99.8
400	100.0
410	100.2
420	100.4
430	100.5
440	100.7
450	100.8
460	101.0
470	101.2
480	101.3
490	101.5
500	101.6
510	101.8
520	101.9
530	102.0
540	102.2
550	102.3
560	102.4
570	102.6
580	102.7
590	102.8
600	102.9
610	103.0

TABLE A-1—CONVERSION FROM "PERCENT NOISE EXPOSURE" OR "DOSE" TO "8-HOUR TIME-WEIGHTED AVERAGE SOUND LEVEL" (TWA)—Continued

Dose or percent noise exposure	TWA
620	103.2
630	103.3
640	103.4
650	103.5
660	103.6
670	103.7
680	103.8
690	103.9
700	104.0
710	104.1
720	104.2
730	104.3
740	104.4
750	104.5
760	104.6
770	104.7
780	104.8
790	104.9
800	105.0
810	105.1
820	105.2
830	105.3
840	105.4
850	105.4
860	105.5
870	105.6
880	105.7
890	105.8
900	105.8
910	105.9
920	106.0
930	106.1
940	106.2
950	106.2
960	106.3
970	106.4
980	106.5
990	106.5
999	106.6

APPENDIX B: METHODS FOR ESTIMATING THE ADEQUACY OF HEARING PROTECTOR ATTENUATION

This Appendix is Mandatory

For employees who have experienced a significant threshold shift, hearing protector attenuation must be sufficient to reduce employee exposure to a TWA of 85 dB. Employers must select one of the following methods by which to estimate the adequacy of hearing protector attenuation.

The most convenient method is the Noise Reduction Rating (NRR) developed by the Environmental Protection Agency (EPA). According to EPA regulation, the NRR must be shown on the hearing protector package. The NRR is then related to an individual worker's noise environment in order to assess the adequacy of the attenuation of a given hearing protector. This Appendix describes four methods of using the NRR to determine whether a particular hearing protector provides adequate protection within a given exposure environment. Selection among the four procedures is dependent upon the employer's noise measuring instruments.

Instead of using the NRR, employers may evaluate the adequacy of hearing protector attenuation by using one of the three methods developed by the National Institute for Occupational Safety and Health (NIOSH), which are described in the "List of Personal Hearing Protectors and Attenuation Data," HEW Publication No 76-120, 1975, pages 21-37. These methods are known as NIOSH methods #1, #2 and #3. The NRR described below is a simplification of NIOSH method #2. The most complex method is NIOSH method #1, which is probably the most accurate method since it uses the largest amount of spectral information from the individual employee's noise environment. As in the case of the NRR method described below, if one of the NIOSH methods is used, the selected method must be applied to an individual's noise environment to assess the adequacy of the attenuation. Employers should be careful to take a sufficient number of measurements in order to achieve a representative sample for each time segment.

NOTE: The employer must remember that calculated attenuation values reflect realistic values only to the extent that the protectors are properly fitted and worn.

When using the NRR to assess hearing protector adequacy, one of the following methods must be used:

(i) When using a dosimeter that is capable of C-weighted measurements:

(A) Obtain the employee's C-weighted dose for the entire workshift, and convert to TWA (see Appendix A, II).

(B) Subtract the NRR from the C-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

(ii) When using a dosimeter that is not capable of C-weighted measurements, the following method may be used:

(A) Convert the A-weighted dose to TWA (see Appendix A).

(B) Subtract 7 dB from the NRR.

(C) Subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

(iii) When using a sound level meter set to the A-weighting network:

(A) Obtain the employee's A-weighted TWA.

(B) Subtract 7 dB from the NRR, and subtract the remainder from the A-weighted TWA to obtain the estimated A-weighted TWA under the ear protector.

(iv) When using a sound level meter set on the C-weighting network:

(A) Obtain a representative sample of the C-weighted sound levels in the employee's environment.

(B) Subtract the NRR from the C-weighted average sound level to obtain the estimated A-weighted TWA under the ear protector.

(v) When using area monitoring procedures and a sound level meter set to the A-weighing network.

(A) Obtain a representative sound level for the area in question.

(B) Subtract 7 dB from the NRR and subtract the remainder from the A-weighted sound level for that area.

(vi) When using area monitoring procedures and a sound level meter set to the C-weighting network:

(A) Obtain a representative sound level for the area in question.

(B) Subtract the NRR from the C-weighted sound level for that area.

APPENDIX C: AUDIOMETRIC MEASURING INSTRUMENTS

This Appendix is Mandatory

1. In the event that pulsed-tone audiometers are used, they shall have a tone on-time of at least 200 milliseconds.

2. Self-recording audiometers shall comply with the following requirements:

(A) The chart upon which the audiogram is traced shall have lines at positions corresponding to all multiples of 10 dB hearing level within the intensity range spanned by the audiometer. The lines shall be equally spaced and shall be separated by at least ¼ inch. Additional increments are optional. The audiogram pen tracings shall not exceed 2 dB in width.

(B) It shall be possible to set the stylus manually at the 10-dB increment lines for calibration purposes.

(C) The slewing rate for the audiometer attenuator shall not be more than 6 dB/sec except that an initial slewing rate greater than 6 dB/sec is permitted at the beginning of each new test frequency, but only until the second subject response.

(D) The audiometer shall remain at each required test frequency for 30 seconds (± 3 seconds). The audiogram shall be clearly marked at each change of frequency and the actual frequency change of the audiometer shall not deviate from the frequency boundaries marked on the audiogram by more than ± 3 seconds.

(E) It must be possible at each test frequency to place a horizontal line segment parallel to the time axis on the audiogram, such that the audiometric tracing crosses the line segment at least six times at that test frequency. At each test frequency the threshold shall be the average of the midpoints of the tracing excursions.

APPENDIX D: AUDIOMETRIC TEST ROOMS

This Appendix is Mandatory

Rooms used for audiometric testing shall not have background sound pressure levels exceeding those in Table D-1 when measured by equipment conforming at least to the Type 2 requirements of American National Standard Specification for Sound Level Meters, S1.4-1971 (R1976), and to the Class II requirements of American National Standard Specification for Octave, Half-Octave, and Third-Octave Band Filter Sets, S1.11-1971 (R1976).

Table D-1—Maximum Allowable Octave-Band Sound Pressure Levels for Audiometric Test Rooms

Octave-band center frequency (Hz)	500	1000	2000	4000	8000
Sound pressure level (dB)	40	40	47	57	62

Appendix E: Acoustic Calibration of Audiometers

This Appendix is Mandatory

Audiometer calibration shall be checked acoustically, at least annually, according to the procedures described in this Appendix. The equipment necessary to perform these measurements is a sound level meter, octave-band filter set, and a National Bureau of Standards 9A coupler. In making these measurements, the accuracy of the calibrating equipment shall be sufficient to determine that the audiometer is within the tolerances permitted by American Standard Specification for Audiometers, S3.6-1969.

(1) Sound Pressure Output Check

A. Place the earphone coupler over the microphone of the sound level meter and place the earphone on the coupler.

B. Set the audiometer's hearing threshold level (HTL) dial to 70 dB.

C. Measure the sound pressure level of the tones at each test frequency from 500 Hz through 6000 Hz for each earphone.

D. At each frequency the readout on the sound level meter should correspond to the levels in Table E-1 or Table E-2, as appropriate, for the type of earphone, in the column entitled "sound level meter reading."

(2) Linearity Check

A. With the earphone in place, set the frequency to 1000 Hz and the HTL dial on the audiometer to 70 dB.

B. Measure the sound levels in the coupler at each 10-dB decrement from 70 dB to 10 dB, noting the sound level meter reading at each setting.

C. For each 10-dB decrement on the audiometer the sound level meter should indicate a corresponding 10 dB decrease.

D. This measurement may be made electrically with a voltmeter connected to the earphone terminals.

(3) Tolerances

When any of the measured sound levels deviate from the levels in Table E-1 or Table E-2 by ± 3 dB at any test frequency between 500 and 3000 Hz, 4 dB at 4000 Hz, or 5 dB at 6000 Hz, an exhaustive calibration is advised. An exhaustive calibration is required if the deviations are greater than 15 dB or greater at any test frequency.

Table E-1—Reference Threshold Levels for Telephonics—TDH-39 Earphones

Frequency, Hz	Reference threshold level for TDH-39 earphones, dB	Sound level meter reading, dB
500	11.5	81.5
1000	7	77
2000	9	79
3000	10	80
4000	9.5	79.5
6000	15.5	85.5

Table E-2—Reference Threshold Levels for Telephonics—TDH-49 Earphones

Frequency, Hz	Reference threshold level for TDH-49 earphones, dB	Sound level meter reading, dB
500	13.5	83.5
1000	7.5	77.5
2000	11	81.0
3000	9.5	79.5
4000	10.5	80.5
6000	13.5	83.5

Appendix F: Calculations and Application of Age Corrections to Audiograms

This Appendix Is Non-Mandatory

In determining whether a standard threshold shift has occurred, allowance may be made for the contribution of aging to the change in hearing level by adjusting the most recent audiogram. If the employer chooses to adjust the audiogram, the employer shall follow the procedure described below. This procedure and the age correction tables were developed by the National Institute for Occupational Safety and Health in the criteria document entitled "Criteria for a Recommended Standard . . . Occupational Exposure to Noise," ((HSM)-11001).

For each audiometric test frequency:

(i) Determine from Tables F-1 or F-2 the age correction values for the employee by:

(A) Finding the age at which the most recent audiogram was taken and recording the corresponding values of age corrections at 1000 Hz through 6000 Hz;

(B) Finding the age at which the baseline audiogram was taken and recording the corresponding values of age corrections at 1000 Hz through 6000 Hz.

(ii) Subtract the values found in step (i)(B) from the value found in step (i)(A).

[Appendix F/B(ii) corrected by 48 FR 29687, June 23, 1983]

(iii) The differences calculated in step (ii) represented that portion of the change in hearing that may be due to aging.

Example: Employee is a 32-year-old male. The audiometric history for his right ear is shown in decibels below.

Employee's age	Audiometric test frequency (Hz)				
	1000	2000	3000	4000	6000
26	10	5	5	10	5
*27	0	0	0	5	5
28	0	0	0	10	5
29	5	0	5	15	5
30	0	5	10	20	10
31	5	10	20	15	15
*32	5	10	10	25	20

The audiogram at age 27 is considered the baseline since it shows the best hearing threshold levels. Asterisks have been used to identify the baseline and most recent audiogram. A threshold shift of 20 dB exists at 4000 Hz between the audiograms taken at ages 27 and 32.

(The threshold shift is computed by subtracting the hearing threshold at age 27, which was 5, from the hearing threshold at age 32, which is 25). A retest audiogram has confirmed this shift. The contribution of aging to this change in hearing may be estimated in the following manner:

Go to Table F-1 and find the age correction values (in dB) for 4000 Hz at age 27 and age 32.

	Frequency (Hz)				
	1000	2000	3000	4000	6000
Age 32	6	5	7	10	14
Age 27	5	4	6	7	11
Difference	1	1	1	3	3

The difference represents the amount of hearing loss that may be attributed to aging in the time period between the baseline audiogram and the most recent audiogram. In this example, the difference at 4000 Hz is 3 dB. This value is subtracted from the hearing level at 4000 Hz, which in the most recent audiogram is 25, yielding 22 after adjustment. Then the hearing threshold in the baseline audiogram at 4000 Hz (5) is subtracted from the adjusted annual audiogram hearing threshold at 4000 Hz (22). Thus the age-corrected threshold shift would be 17 dB (as opposed to a threshold shift of 20 dB without age correction).

TABLE F-1—AGE CORRECTION VALUES IN DECIBELS FOR MALES

Years	Audiometric Test Frequencies (Hz)				
	1000	2000	3000	4000	6000
20 or younger	5	3	4	5	8
21	5	3	4	5	8
22	5	3	4	5	8
23	5	3	4	6	9
24	5	3	5	6	9
25	5	3	5	7	10
26	5	4	5	7	10
27	5	4	6	7	11
28	6	4	6	8	11
29	6	4	6	8	12
30	6	4	6	9	12
31	6	4	7	9	13
32	6	5	7	10	14
33	6	5	7	10	14
34	6	5	8	11	15
35	7	5	8	11	15
36	7	5	9	12	16
37	7	6	9	12	17
38	7	6	9	13	17
39	7	6	10	14	18
40	7	6	10	14	18
41	7	6	10	14	20
42	8	7	11	16	20
43	8	7	12	16	21
44	8	7	12	17	22
45	8	7	13	18	23
46	8	8	13	19	24
47	8	8	14	19	24
48	9	8	14	20	25
49	9	9	15	21	26
50	9	9	16	22	27
51	9	9	16	23	28
52	9	10	17	24	29
53	9	10	18	25	30
54	10	10	18	26	31
55	10	11	19	27	32
56	10	11	20	28	34
57	10	11	21	29	35
58	10	12	22	31	36
59	11	12	22	32	37
60 or older	11	13	23	33	38

TABLE F-2—AGE CORRECTION VALUES IN DECIBELS FOR FEMALES

Years	Audiometric Test Frequencies (Hz)				
	1000	2000	3000	4000	6000
20 or younger	7	4	3	3	6
21	7	4	4	3	6
22	7	4	4	4	6
23	7	5	4	4	7
24	7	5	4	4	7
25	8	5	4	4	7
26	8	5	5	4	8
27	8	5	5	5	8
28	8	5	5	5	8
29	8	5	5	5	9
30	8	6	5	5	9
31	8	6	6	5	9
32	9	6	6	6	10
33	9	6	6	6	10
34	9	6	6	6	10
35	9	6	7	7	11
36	9	7	7	7	11
37	9	7	7	7	12
38	10	7	7	7	12
39	10	7	8	8	12
40	10	7	8	8	13
41	10	8	8	8	13
42	10	8	9	9	13
43	11	8	9	9	14
44	11	8	9	9	14
45	11	8	10	10	15
46	11	9	10	10	15
47	11	9	10	11	16
48	12	9	11	11	16
49	12	9	11	11	16
50	12	10	11	12	17
51	12	10	12	12	17
52	12	10	12	13	18
53	13	10	13	13	18
54	13	11	13	14	19
55	13	11	14	14	19
56	13	11	14	15	20
57	13	11	15	15	20
58	14	12	15	16	21
59	14	12	16	16	21
60 or older	14	12	16	17	22

APPENDIX G: MONITORING NOISE LEVELS NON-MANDATORY INFORMATIONAL APPENDIX

This appendix provides information to help employers comply with the noise monitoring obligations that are part of the hearing conservation amendment.

WHAT IS THE PURPOSE OF NOISE MONITORING?

This revised amendment requires that employees be placed in a hearing conservation program if they are exposed to average noise levels of 85 dB or greater during an 8 hour workday. In order to determine if exposures are at or above this level, it may be necessary to measure or monitor the actual noise levels in the workplace and to estimate the noise exposure or "dose" received by employees during the workday.

WHEN IS IT NECESSARY TO IMPLEMENT A NOISE MONITORING PROGRAM?

It is not necessary for every employer to measure workplace noise. Noise monitoring or measuring must be conducted only when exposures are at or above 85 dB. Factors which suggest that noise exposures in the workplace may be at this level include employee complaints about the loudness of noise, indications that employees are losing their hearing, or noisy conditions which make normal conversation difficult. The employer should also consider any information available regarding noise emitted from specific machines. In addition, actual workplace noise measurements can suggest whether or not a monitoring program should be initiated.

HOW IS NOISE MEASURED?

Basically, there are two different instruments to measure noise exposures: the sound level meter and the dosimeter. A sound level meter is a device that measures the intensity of sound at a given moment. Since sound level meters provide a measure of sound intensity at only one point in time, it is generally necessary to take a number of measurements at different times during the day to estimate noise exposure over a workday. If noise levels fluctuate, the amount of time noise remains at each of the various measured levels must be determined.

To estimate employee noise exposures with a sound level meter it is also generally necessary to take several measurements at different locations within the workplace. After appropriate sound level meter readings are obtained, people sometimes draw "maps" of the sound levels within different areas of the workplace. By using a sound level "map" and information on employee locations throughout the day, estimates of individual exposure levels can be developed. This measurement method is generally referred to as *area* noise monitoring.

A dosimeter is like a sound level meter except that it stores sound level measurements and integrates these measurements over time, providing an average noise exposure reading for a given period of time, such as an 8-hour workday. With a dosimeter, a microphone is attached to the employee's clothing and the exposure measurement is simply read at the end of the desired time period. A reader may be used to read-out the dosimeter's measurements. Since the dosimeter is worn by the employee, it measures noise levels in those locations in which the employee travels. A sound level meter can also be positioned within the immediate vicinity of the exposed worker to obtain an individual exposure estimate. Such procedures are generally referred to as *personal* noise monitoring.

Area monitoring can be used to estimate noise exposure when the noise levels are relatively constant and employees are not mobile. In workplaces where employees move about in different areas or where the noise intensity tends to fluctuate over time, noise exposure is generally more accurately estimated by the personal monitoring approach.

In situations where personal monitoring is appropriate, proper positioning of the microphone is necessary to obtain accurate measurements. With a dosimeter, the microphone is generally located on the shoulder and remains in that position for the entire workday. With a sound level meter, the microphone is stationed near the employee's head, and the instrument is usually held by an individual who follows the employee as he or she moves about.

Manufacturer's instructions, contained in dosimeter and sound level meter operating manuals, should be followed for calibration and maintenance. To ensure accurate results, it is considered good professional practice to calibrate instruments before and after each use.

How often is it necessary to monitor noise levels?

The amendment requires that when there are significant changes in machinery or production processes that may result in increased noise levels, remonitoring must be conducted to determine whether additional employees need to be included in the hearing conservation program. Many companies choose to remonitor periodically (once every year or two) to ensure that all exposed employees are included in their hearing conservation programs.

Where can equipment and technical advice be obtained?

Noise monitoring equipment may be either purchased or rented. Sound level meters cost about $500 to $1,000, while dosimeters range in price from about $750 to $1,500. Smaller companies may find it more economical to rent equipment rather than to purchase it. Names of equipment suppliers may be found in the telephone book (Yellow Pages) under headings such as: "Safety Equipment," "Industrial Hygiene," or "Engineers-Acoustical." In addition to providing information on obtaining noise monitoring equipment, many companies and individuals included under such listings can provide professional advice on how to conduct a valid noise monitoring program. Some audiological testing firms and industrial hygiene firms also provide noise monitoring services. Universities with audiology, industrial hygiene, or acoustical engineering departments may also provide information or may be able to help employers meet their obligations under this amendment.

Free, on-site assistance may be obtained from OSHA-supported state and private consultation organizations. These safety and health consultative entities generally give priority to the needs of small businesses. See the attached directory for a listing of organizations to contact for aid.

OSHA Onsite Consultation Project Directory

State	Office and address	Contact
Alabama	Alabama Consultation Program, P O Box 6005, University Alabama 35486	(205) 348-7136, Mr William Weems, Director
Alaska	State of Alaska, Department of Labor Occupational Safety & Health 3301 Eagle St Pouch 7-022 Anchorage, Alaska 99510	(907) 276-5013 Mr Stan Godsoe, Project Manager (Air Mail)
American Samoa	Service not yet available	
Arizona	Consultation and Training Arizona Division of Occupational Safety and Health P O Box 19070 1624 W Adams, Phoenix, AZ 85005	(602) 255-5795 Mr Thomas Ramsley, Manager
Arkansas	OSHA Consultation Arkansas Department of Labor, 1022 High St., Little Rock Ark 72202	(501) 371-2992, Mr George Smith Project Director
California	CAL/OSHA Consultation Service, 2nd Floor 525 Golden Gate Avenue, San Francisco, CA 94102	(415) 557-2870 Mr Emmett Jones, Chief
Colorado	Occupational Safety & Health Section, Colorado State University, Institute of Rural Environmental Health, 110 Veterinary Science Building, Fort Collins, CO 80523	(303) 491-6151 Dr Roy M Buchan Project Director
Connecticut	Division of Occupational Safety & Health, Connecticut Department of Labor, 200 Folly Brook Boulevard, Wethersfield, Conn 06109	(203) 566-4550, Mr Leo Ales, Director
Delaware	Delaware Department of Labor Division of Industrial Affairs, 820 North French Street, 6th Floor, Wilmington, DE 19801	(302) 571-3908, Mr Bruno Salvadori, Director.
District of Columbia	Occupational Safety & Health Division, District of Columbia, Department Employment Services, Office of Labor Standards 2900 Newton Street NE Washington DC 20018	(202) 832-1230 Mr Lorenzo M White, Acting Associate Director
Florida	Department of Labor & Employment Security, Bureau of Industrial Safety and Health, LaFayette Building, Room 204 2551 Executive Center Circle West, Tallahassee, FL 32301	(904) 488-3044 Mr John C Glenn, Administrator
Georgia	Economic Development Division, Technology and Development Laboratory, Engineering Experiment Station, Georgia Institute of Technology, Atlanta GA 30332	(404) 894-3806 Mr William C. Howard, Assistant to Director, Mr James Burson Project Manager
Guam	Department of Labor, Government of Guam, 23548 Guam Main Facility Agana Guam 96921	(671) 772-4291 Joe R San Agustin, Director
Hawaii	Education and Information Branch Division of Occupational Safety and Health Suite 910, 677 Ala Moana, Honolulu, HI 96813	(808) 548-2511 Mr Don Alper, Manager (Air Mail)
Idaho	OSHA Onsite Consultation Program, Boise State University, Community and Environmental Health 1910 University Drive Boise, ID 83725	(208) 385-3929, Dr Eldon Edmundson, Director
Illinois	Division of Industrial Services Dept of Commerce and Community Affairs 310 S Michigan Avenue, 10 Floor, Chicago IL 60601	(800) 972-4140/4216 (Toll-free in State) (312) 793-3270 Mr Stan Czwneru Assistant Director
Iowa	Bureau of Labor 307 E Seventh Street Des Moines, IA 50319	(515) 281-3606 Mr Allen J Meier, Commissioner
Indiana	Bureau of Safety Education and Training Indiana Division of Labor, 1013 State Office Building Indianapolis, IN 46204	(317) 633-5845 Mr Harold Mills, Director
Kansas	Kansas Dept of Human Resources 401 Topeka Ave Topeka KS 66603	(913) 296-4086 Mr Jerry Abbott, Secretary
Kentucky	Education and Training Occupational Safety and Health Kentucky Department of Labor 127 Building 127 South Frankfort KY 40601	(502) 564-6895 Mr Larry Potter, Director

State	Office and address	Contact
Louisiana	No services available as yet (Pending FY 83)	
Maine	Division of Industrial Safety, Maine Dept of Labor, Labor Station 45, State Office Building, Augusta, ME 04333	(207) 289-3331 Mr Lester Wood, Director
Maryland	Consultation Services, Division of Labor & Industry, 501 St Paul Place, Baltimore, Maryland 21202	(301) 659-4210 Ms Ileana O'Brien, Project Manager, 7(c)(1) Agreement
Massachusetts	Division of Industrial Safety, Massachusetts Department of Labor and Industries, 100 Cambridge Street, Boston, MA 02202	(617) 727-3567, Mr Edward Nosworthy, Project Director
Michigan (Health)	Special Programs Section, Division of Occupational Health, Michigan Dept of Public Health, 3500 N Logan, Lansing, MI 48909	(517) 373-1410 Mr Irving Davis, Chief
Michigan (Safety)	Safety Education & Training Division, Bureau of Safety and Regulation, Michigan Department of Labor, 7150 Harris Drive, Box 30015, Lansing, Michigan 48909	(517) 322-1809, Mr Alan Harvie, Chief
Minnesota	Training and Education Unit, Department of Labor and Industry, 5th Floor, 444 Lafayette Road, St. Paul, MN 55101	(612) 296-2973 Mr Timothy Tierney, Project Manager
Mississippi	Division of Occupational Safety and Health, Mississippi State Board of Health, P O Box 1700, Jackson, MS 39205	(601) 987-6315, Mr Henry L. Laird, Director
Missouri	Missouri Department of Labor and Industrial Relations, 722 Jefferson Street, Jefferson City, MO 65101	1-(800) 392-0208, (314) 751-3403, Ms Paula Smith, Mr Jim Brase.
Montana	Montana Bureau of Safety & Health, Division of Workers Compensation, 815 Front Street, Helena, MT 59601	(406) 449-3402, Mr Ed Gatzemeier, Chief
Nebraska	Nebraska Department of Labor, State House Station, State Capitol, P O Box 94600, Lincoln, NB 68509	475-8451 Ext 258, Mr Joseph Carroll, Commissioner
Nevada	Department of Occupational Safety and Health, Nevada Industrial Commission, 515 E. Muller Street, Carson City, NV 89714	(702) 885-5240, Mr. Allen Traenkner, Director
New Hampshire	For information contact	Office of Consultation Programs, Room N3472 200 Constitution Avenue, NW Washington, DC 20210, Phone: (202) 523-8985
New Jersey	New Jersey Department of Labor and Industry Division of Work Place Standards, CN-054, Trenton, NJ 08625	(609) 292-2313, FTS-8-477-2313, Mr William Clark, Assistant Commissioner
New Mexico	OSHA Consultation, Health and Environment Department, Environmental Improvement Division, Occupational Health & Safety Section, 4215 Montgomery Boulevard, NE., Albuquerque, NM 87109	(505) 842-3387, Mr Albert M Stevens, Project Manager
New York	Division of Safety and Health, New York State Department of Labor, 2 World Trade Center, Room 6995, New York, NY 10047	(212) 488-7746/7 Mr Joseph Alleva, Project Manager, DOSH
North Carolina	Consultation Services, North Carolina Department of Labor, 4 West Edenton Street, Raleigh, NC 27601	(919) 733-4885, Mr David Pierce, Director
North Dakota	Division of Environmental Research, Department of Health, Missouri Office Building, 1200 Missouri Avenue, Bismarck, ND 58505	(701) 224-2348, Mr Jay Crawford, Director
Ohio	Department of Industrial Relations Division of Onsite Consultation P O Box 825, 2323 5th Avenue Columbus, OH 43216	(800) 282-1425 (Toll-free in State), (614) 466-7485, Mr Andrew Doehrel, Project Manager
Oklahoma	OSHA Division, Oklahoma Department of Labor, State Capitol, Suite 118, Oklahoma City, OK 73105	(405) 521-2461 Mr Charles W. McGlon, Director
Oregon	Consultative Section, Department of Workers Compensation, Accident Prevention Division, Room 102, Building 1, 2110 Front Street NE., Salem, OR 97310	(503) 378-2890 Mr Jack Buckland, Supervisor
Pennsylvania	For information contact	Office of Consultation Programs, Room N3472 200 Constitution Avenue NW., Washington, DC 20210, Phone: (202) 523-8985
Puerto Rico	Occupational Safety & Health, Puerto Rico Department of Labor and Human Resources, 505 Munoz Rivera Ave., 21st Floor, Hato Rey, Puerto Rico 00919	(809) 754-2134 Mr John Cinque, Assistant Secretary, (Air Mail)
Rhode Island	Division of Occupational Health, Rhode Island Department of Health, The Cannon Building, 206 Health Department Building, Providence, RI 02903	(401) 277-2438, Mr James E Hickey, Chief

OSHA Onsite Consultation Project Directory—Continued

State	Office and address	Contact
South Carolina	Consultation and Monitoring, South Carolina Department of Labor, P.O. Box 11329, Columbia, SC 29211	(803) 758-8921 Mr. Robert Peck, Director 7(c)(1) Project
South Dakota	South Dakota Consultation Program, South Dakota State University, S.T.A.T.E. Engineering Extension, 201 Pugsley Center SDSO, Brookings, SD 57007	(605) 688-4101 Mr. James Cegian, Director
Tennessee	OSHA Consultative Services, Tennessee Department of Labor, 2nd Floor, 501 Union Building, Nashville, TN 37219	(615) 741-2793 Mr. L. H. Craig, Director
Texas	Division of Occupational Safety and State Safety Engineer, Texas Department of Health and Resources, 1100 West 49th Street, Austin, TX 78756	(512) 458-7287 Mr. Walter G. Martin, P.E. Director
Trust Territories..	Service not yet available	
Utah .	Utah Job Safety and Health Consultation Service, Suite 4004, Crane Building, 307 West 200 South, Salt Lake City, UT 84101	(801) 533-7927/8/9 Mr. H. M. Bergeson, Project Director
Vermont	Division of Occupational Safety and Health, Vermont Department of Labor and Industry, 118 State Street, Montpelier, VT 05602	(802) 828-2765 Mr. Robert McLeod, Project Director
Virginia.	Department of Labor and Industry, P.O. Box 12064, 205 N. 4th Street, Richmond, Va 23241	(804) 786-5875 Mr. Robert Beard, Commissioner
Virgin Islands	Division of Occupational Safety and Health, Virgin Islands Department of Labor, Lagoon Street, Room 207, Frederiksted, Virgin Islands 00840	(809) 772-1315 Mr. Louis Llanos, Deputy Director-DOSH
Washington..	Department of Labor and Industry, P.O. Box 207, Olympia, WA 98504	(206) 753-6500 Mr. James Sullivan, Assistant Director
West Virginia	West Virginia Department of Labor, Room 451B, State Capitol, 1800 Washington Street, Charleston, WV 25305	FTS 8-885-7890 Mr. Lawrence Barker, Commissioner
Wisconsin (Health)	Section of Occupational Health, Department of Health and Social Services, P.O. Box 309, Madison, WI 53701	(608) 266-0417 Ms. Patricia Natzke, Acting Chief
Wisconsin (Safety)	Division of Safety and Buildings, Department of Industry, Labor and Human Relations, 1570 E. Moreland Blvd., Waukesha, WI 53186	(414) 544-8686 Mr. Richard Michalsku, Supervisor
Wyoming .	Wyoming Occupational Health and Safety Department, 200 East 8th Avenue, Cheyenne, Wyo 82002	(307) 777-7786 Mr. Donald Owsley, Health and Safety Administrator

Appendix H: Availability of Referenced Documents

Paragraphs (c) through (o) of 29 CFR 1910.95 and the accompanying appendices contain provisions which incorporate publications by reference. Generally, the publications provide criteria for instruments to be used in monitoring and audiometric testing. These criteria are intended to be mandatory when so indicated in the applicable paragraphs of § 1910.95 and appendices.

It should be noted that OSHA does not require that employers purchase a copy of the referenced publications. Employers, however, may desire to obtain a copy of the referenced publications for their own information.

The designation of the paragraph of the standard in which the referenced publications appear, the titles of the publications, and the availability of the publications are as follows:

Paragraph designation	Referenced publication	Available from—
Appendix B	List of Personal Hearing Protectors and Attenuation Data, HEW Pub. No. 76-120, 1975, NTIS-PB267461	National Technical Information Service, Port Royal Road, Springfield, VA 22161
Appendix D	Specification for Sound Level Meters, S1.4-1971 (R1976)	American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018
§ 1910.95(k)(2), appendix E	Specifications for Audiometers, S3.6-1969	American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018
Appendix D	Specification for Octave, Half-Octave and Third-Octave Band Filter Sets, S1.11-1971 (R1976)	Back Numbers Department, Dept. STD, American Institute of Physics, 333 E. 45th St., New York, NY 10017; American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018

The referenced publications (or a microfiche of the publications) are available for review at many universities and public libraries throughout the country. These publications may also be examined at the OSHA Technical Data Center, Room N3439, United States Department of Labor, 200 Constitution Avenue, NW., Washington, DC 20210, (202) 523-9700 or at any OSHA Regional Office (see telephone directories under United States Government—Labor Department).

Appendix I: Definitions

These definitions apply to the following terms as used in paragraphs (c) through (n) of 29 CFR 1910.95.

Action level—An 8-hour time-weighted average of 85 decibels measured on the A-scale, slow response, or equivalently, a dose of fifty percent.

Audiogram—A chart, graph, or table resulting from an audiometric test showing an individual's hearing threshold levels as a function of frequency.

Audiologist—A professional, specializing in the study and rehabilitation of hearing, who is certified by the American Speech-Language-Hearing Association or licensed by a state board of examiners.

Baseline audiogram—The audiogram against which future audiograms are compared.

Criterion sound level—A sound level of 90 decibels.

Decibel (dB)—Unit of measurement of sound level.

Hertz (Hz)—Unit of measurement of frequency, numerically equal to cycles per second.

Medical pathology—A disorder or disease. For purposes of this regulation, a condition or disease affecting the ear, which should be treated by a physician specialist.

Noise dose—The ratio, expressed as a percentage, of (1) the time integral, over a stated time or event, of the 0.6 power of the measured SLOW exponential time-averaged, squared A-weighted sound pressure and (2) the product of the criterion duration (8 hours) and the 0.6 power of the squared sound pressure corresponding to the criterion sound level (90 dB).

Noise dosimeter—An instrument that integrates a function of sound pressure over a period of time in such a manner that it directly indicates a noise dose.

Otolaryngologist—A physician specializing in diagnosis and treatment of disorders of the ear, nose and throat.

Representative exposure—Measurements of an employee's noise dose or 8-hour time-weighted average sound level that the employers deem to be representative of the exposures of other employees in the workplace.

Sound level—Ten times the common logarithm of the ratio of the square of the measured A-weighted sound pressure to the square of the standard reference pressure of 20 micropascals. Unit: decibels (dB). For use with this regulation, SLOW time response, in accordance with ANSI S1.4-1971 (R1976), is required.

Sound level meter—An instrument for the measurement of sound level.

Time-weighted average sound level—That sound level, which if constant over an 8-hour exposure, would result in the same noise dose as is measured.

[39 FR 23502, June 27, 1974, as amended at 46 FR 4161, Jan. 16, 1981; 46 FR 62845, Dec. 29, 1981; 48 FR 9776, Mar. 8, 1983; 48 FR 29687, June 28, 1983]

§ 1910.96 Ionizing radiation.

(a) *Definitions applicable to this section.* (1) "Radiation" includes alpha rays, beta rays, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other atomic particles; but such term does not include sound or radio waves, or visible light, or infrared or ultraviolet light.

(2) "Radioactive material" means any material which emits, by spontaneous nuclear disintegration, corpuscular or electromagnetic emanations.

(3) "Restricted area" means any area access to which is controlled by the employer for purposes of protection of individuals from exposure to radiation or radioactive materials.

(4) "Unrestricted area" means any area access to which is not controlled by the employer for purposes of protection of individuals from exposure to radiation or radioactive materials.

(5) "Dose" means the quantity of ionizing radiation absorbed, per unit of mass, by the body or by any portion of the body. When the provisions in this section specify a dose during a period of time, the dose is the total quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body during such period of time. Several different units of dose are in current use. Definitions of units used in this section are set forth in paragraphs (a) (6) and (7) of this section.

(6) "Rad" means a measure of the dose of any ionizing radiation to body tissues in terms of the energy absorbed per unit of mass of the tissue. One rad is the dose corresponding to the absorption of 100 ergs per gram of tissue (1 millirad (mrad) = 0.001 rad).

(7) "Rem" means a measure of the dose of any ionizing radiation to body tissue in terms of its estimated biological effect relative to a dose of 1 roentgen (r) of X-rays (1 millirem (mrem) = 0.001 rem). The relation of the rem to other dose units depends upon the biological effect under consideration and upon the conditions for irradiation. Each of the following is considered to be equivalent to a dose of 1 rem:

(i) A dose of 1 roentgen due to X- or gamma radiation;

(ii) A dose of 1 rad due to X-, gamma, or beta radiation;

(iii) A dose of 0.1 rad due to neutrons or high energy protons;

(iv) A dose of 0.05 rad due to particles heavier than protons and with sufficient energy to reach the lens of the eye;

(v) If it is more convenient to measure the neutron flux, or equivalent, than to determine the neutron dose in rads, as provided in subdivision (iii) of this subparagraph, 1 rem of neutron radiation may, for purposes of the provisions in this section be assumed to be equivalent to 14 million neutrons per square centimeter incident upon the body; or, if there is sufficient information to estimate with reasonable accuracy the approximate distribution in energy of the neutrons, the incident number of neutrons per square centimeter equivalent to 1 rem may be estimated from Table G-17:

TABLE G-17—NEUTRON FLUX DOSE EQUIVALENTS

Neutron energy (million electron volts (Mev))	Number of neutrons per square centimeter equivalent to a dose of 1 rem (neutrons/cm²)	Average flux to deliver 100 millirem in 40 hours (neutrons/cm² per sec.)
Thermal	970×10^6	670
0.0001	720×10^6	500
0.005	820×10^6	570
0.02	400×10^6	280
0.1	120×10^6	80
0.5	43×10^6	30
1.0	26×10^6	18
2.5	29×10^6	20
5.0	26×10^6	18
7.5	24×10^6	17
10	24×10^6	17
10 to 30	14×10^6	10

(8) For determining exposures to X- or gamma rays up to 3 Mev., the dose limits specified in this section may be assumed to be equivalent to the "air