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CENTERS FOR DISEASE CONTROL AND PREVENTION

NIOSH HEALTH HAZARD EVALUATION REPORT

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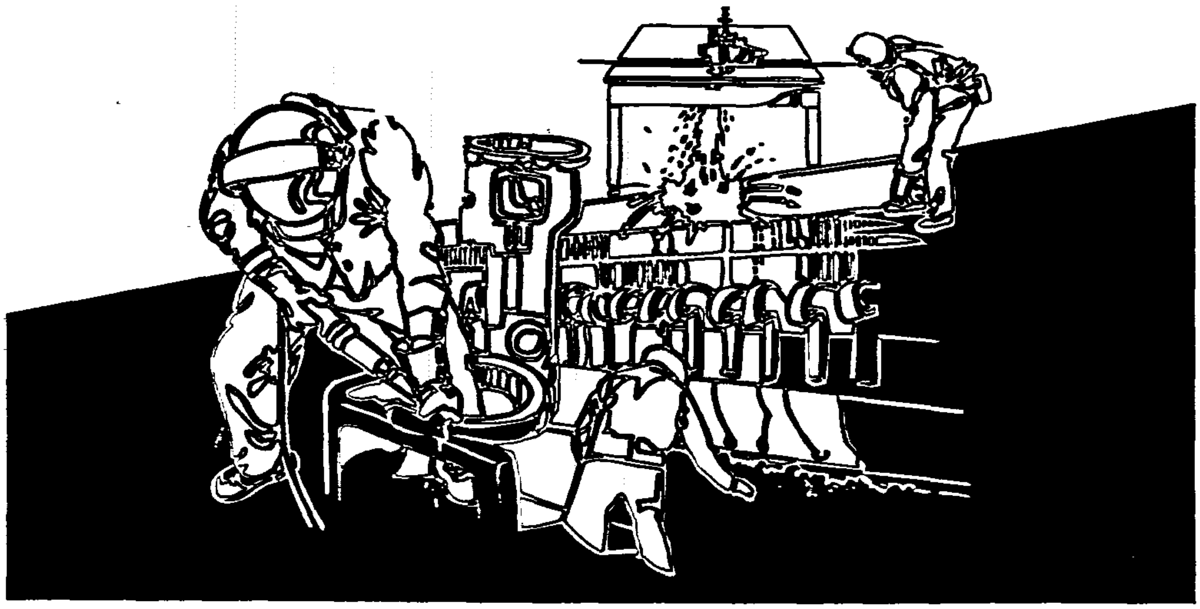
DURACELL BATTERY COMPANY
CLEVELAND, TENNESSEE



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer and authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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I. SUMMARY

A health hazard evaluation (HHE) was conducted by National Institute for Occupational Safety and Health (NIOSH) investigators at the Duracell Battery Company in Cleveland, Tennessee, following an occupational physician's report, in December 1990, of suspected neurological effects from manganese (Mn) exposure at this dry cell battery manufacturing operation. The objectives of the HHE were to estimate the workers' exposures to Mn dust, to evaluate the effectiveness of the respiratory protection program, and to screen the workers for any symptoms associated with Mn overexposure. Areas of concern included the powder processing tower where purified manganese dioxide (MnO_2) was blended and compacted with graphite and binders, and the press rooms where the processed Mn was pressed into pellets and inserted into battery cans.

Full-shift and short-term personal breathing zone (PBZ) monitoring was conducted on press operators, mechanics, material handlers, and other workers for total particle size Mn dust. Respirator *"in-mask"* and PBZ air sample comparisons were also performed; particle size evaluations were made using 10-millimeter nylon cyclones and Marple® impactors. Fifty-four full-shift time-weighted average (TWA) exposure concentrations of total Mn ranged from 0.1 to 5.4 milligrams per cubic meter (mg/m^3). Short-term exposure concentrations of total Mn were measured as high as 11.7 mg/m^3. The NIOSH Recommended Exposure Limit for Mn dust is an 8-hour TWA of 1.0 mg/m^3 total Mn, with a short term exposure limit (STEL) of 3.0 mg/m^3 due to central nervous system (CNS) effects and pneumonitis. The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for Mn dust is a ceiling criteria of 5.0 mg/m^3, total Mn. In 1992, the American Conference of Governmental Industrial Hygienists (ACGIH) published a notice of intended change to lower the elemental and inorganic Mn dust Threshold Limit Value (TLV®) from 5.0 mg/m^3 to 0.2 mg/m^3 to address adverse pulmonary effects, CNS effects, and male infertility. Area sample comparisons of total and respirable Mn revealed the mean respirable particulate Mn fraction to be 21% of the total Mn concentration.

The respirator performance evaluation was conducted using a *Program Protection Factor* (PPF) protocol. Fifteen *"in-mask"* and PBZ comparisons were conducted using Moldex® 2200 respirators (single use, disposable dust/mist respirators) and light-weight sampling probes. Individual PPF for Mn ranged from 5 to 215, with a geometric mean and standard deviation equal to 31 and 2.95, respectively. The assigned PPF calculated for this sample set was 5. The respirator performance was consistent with NIOSH expectations for this class of respiratory protection.

Private medical interviews were conducted with six (8%) of the employees from the powder processing area and press rooms. All denied awareness of symptoms of manganism, and none showed signs of this disease. Medical records from the company's medical department were reviewed and showed elevated urine Mn levels in six employees. Four of these had volunteered for interviews and showed no signs or symptoms of manganism.

A number of the measured Mn exposures exceeded the NIOSH RELs and OSHA PEL and most of the exposures were above the proposed ACGIH TLV® intended change value. All employees entering these locations were required to wear respiratory protection. The medical interviews did not identify any symptomatic workers. Recommendations include installing additional process enclosures and local exhaust ventilation, ventilation design improvements, increased filtration of recirculated air, elimination of dry sweeping, and medical surveillance of Mn-exposed workers.

KEYWORDS: SIC 3692 (dry cell battery manufacturing), manganese dioxide, dust, manganism, Parkinson-like symptoms, neurological disorder, respirator *"in-mask"* sampling, program protection factor, particle sizing, Marple impactors®.

II. INTRODUCTION

In December 1990, the National Institute for Occupational Safety and Health (NIOSH) received a report from an occupational physician of suspected Parkinson-like neurological effects as a result of manganese (Mn) exposure in the powder areas of the Duracell Battery Company in Cleveland, Tennessee. On March 13-14, 1991, NIOSH investigators conducted the initial site visit of the Health Hazard Evaluation (HHE) at this non-unionized dry cell battery manufacturing plant. The objectives of the HHE were to estimate the workers' exposures to Mn dust, to evaluate the effectiveness of the respiratory protection program, and to screen the workers for any symptoms associated with Mn overexposure. This investigation consisted of an opening conference, a walk-through survey of the plant, confidential employee interviews, management representative interviews, review of company records, industrial hygiene monitoring, and a closing conference.

During the initial site visit on March 13-14, 1991, NIOSH investigators conducted confidential interviews of selected current employees from the powder processing tower and press rooms to screen for Mn toxicity. A walk-through survey, focusing on the powder areas, was performed to obtain information pertaining to the manufacturing process and potential exposure conditions. The Occupational Safety and Health Administration (OSHA) Log and Summary of Occupational Injuries and Illnesses (Form 200) and workers compensation claims were also reviewed for reports of neurologic illnesses.

On December 11-12, 1991, an industrial hygiene monitoring survey was conducted which included the collection of personal and area air samples and bulk materials, that were submitted for Mn analysis. Because company records revealed worker exposure to Mn dust well above occupational inhalation criteria during a period with recurrent engineering equipment failures, concurrent respirator "*in-mask*" and lapel samples were also collected to determine the protection provided by the respirators used in the exposure locations. A follow-up industrial hygiene survey was conducted on August 26-27, 1992, to obtain additional data and to evaluate the effectiveness of the engineering controls installed since the first industrial hygiene survey.
In August 1992, prior to the follow-up investigation, an interim letter containing the monitoring results of the previous survey was sent to the company. In addition, preliminary recommendations were provided in the closing conferences of the site visits.

III. BACKGROUND

The Duracell Battery plant in Cleveland, Tennessee, manufactures size C and D alkaline batteries (and a limited number of lantern batteries). The manufacturing processes at this location include fabrication of metal battery cans and lids; processing of the manganese dioxide (MnO_2) powder; compression of Mn pellets into the cans; dispensing of caustic solution; blending zinc amalgam; battery assembly; and labeling, packaging, and distribution of the finished product. Three shifts operate at this facility; the second and third shifts may operate at reduced capacity depending on the production needs at the time. The MnO_2 powder and pellet-processing locations were the potential exposure areas of concern that were the focus of this investigation.

In the powder-processing area, purified MnO_2 is received in bulk, emptied into a hopper with a mechanical hoist, and pneumatically transferred to the powder processing tower. The powder-processing tower is a multi-story structure where MnO_2 is blended with graphite and binders, compacted, granulated, sifted, and conveyed into storage containers. The processed Mn is transferred to the press room where the granules are further compressed into pellets, inserted into battery cans, and conveyed out of the Mn processing area.

These powder processing and pellet press areas were separated from the adjacent manufacturing plant with floor to ceiling walls and were under negative pressure to minimize the release of dust from this vicinity. The powder-processing tower was under additional negative pressure with respect to the adjacent press rooms. Approximately two dozen employees worked in the Mn processing locations during a typical manufacturing shift; the majority of whom worked in the press rooms. Job descriptions include process and press operators, material handlers, mechanics, and supervisors. Company policy required all personnel in these powder-processing locations to wear disposable dust/mist respiratory protection.

IV. EVALUATION CRITERIA

Manganese

Manganese is an abundant and ubiquitous element present throughout the environment including soil, water, air, vegetation, and food items. Manganese is an essential trace element necessary for the formation of connective tissue and bone as well as the metabolism of carbohydrates and lipids; for these reasons, adult humans require 2 to 3 milligrams (mg) of dietary Mn per day.[WHO 1981] Elemental Mn is a light gray metal that does not occur naturally. Manganese is a very reactive metal that exists in numerous oxidation states and it is a component in over 100 minerals. One of the most common and commercially important Mn containing ores is pyrolusite, a black mineral typically containing approximately 60% MnO_2.[ACGIH 1992, Hathaway 1992] There are many important industrial uses for Mn; it is used in the steel and metal alloy industries to improve hardness and strength; it is also used in ceramic and glass products, in rubber and wood preservatives; and it is also used in dry-cell batteries. The health effects of excessive occupational Mn exposure are primarily neurological and respiratory (including irritation, pneumonitis, and chronic bronchitis). Metal fume fever has also been reported with exposure to Mn fume. Most notably, occupational exposure to Mn dust is known to cause *manganism*, a Parkinsonian-like syndrome with well recognized characteristics. This condition has also been referred to as Mn poisoning and chronic Mn toxicity.

Adverse health effects have been associated with heavy occupational exposures to Mn as early as 1837, when Couper reported a neurologic syndrome found in workers who had been grinding MnO_2 for several months.[Couper 1837] Further reports of Mn poisoning did not appear in the medical literature until 1901.[Von Jaksch 1901, Embden 1901] Most of the affected workers reported from 1901 to 1919 were MnO_2 grinders and the rest processed or handled Mn ore.[Von Jaksch 1901, Embden 1901, Friedel 1903, Seiffer 1904, Von Jaksch 1907, Von Jaksch 1910, Casamajor 1913, Seelert 1913, Edsall 1919] The findings in the affected workers resembled those of Parkinsonism and subsequent studies have shown that Mn affects the extrapyramidal system of the brain.[Canavan 1934] More recent reports or studies of chronic Mn toxicity has been described and studied in the mining, ore processing, and smelting industries.[ACGIH 1992]

Manganism is a progressive occupational disease. The symptoms of early disease, such as fatigue, somnolence, and irritability, are nonspecific and may be related to any of a number of factors. Advanced disease, however, is characterized by more specific symptoms such as slow or minimal speech or movement (brady- or hypokinesia); increased muscle tone (rigidity) especially of the limbs; a smooth and expressionless face; tremors; disturbed gait; postural instability (with difficulty in turning around, difficulty stopping when stepping forward [propulsion] or backward [retropulsion]); increasingly small handwriting (micrographia), and possibly psychological disturbance such as hallucinations, compulsive behavior, and emotional instability. The condition may develop insidiously after months or years of Mn exposure. Although the condition may be reversible after early removal from exposure, it is often unrecognized until the worker is severely and irreversibly affected.

Chronic Mn toxicity has been found in workers exposed to Mn during operations in which high concentrations of dust or fume were generated. Such operations have included mining, ore processing, purification processes, metallurgical and manufacturing processes, and welding of Mn alloys or use of welding rods containing Mn.[Tanaka 1993] Inhalation is the primary route of occupational exposure, but most inhaled Mn dust is mobilized from the lungs and swallowed.[Mena 1969] Thus, the gastrointestinal tract is an important route of absorption for inhaled as well as ingested Mn dust. An experimental study of adult humans showed that 3% of ingested Mn is absorbed by healthy subjects, 3 to 5% by subjects with chronic Mn toxicity, and up to 10% by unexposed anemic subjects.[Mena 1969]

In 1837, Couper reported that the neurologic findings reversed in workers who were promptly removed from exposure when early signs of toxicity were recognized.[Couper 1837] Because of the irreversible nature of the disease, Edsall, et. al. recommended preventive measures, such as elimination of dust from the work environment.[Edsall 1919] They also recommended medical surveillance of exposed workers and removal of symptomatic workers from exposure.[Edsall 1919]

The NIOSH Recommended Exposure Limit (REL) for Mn dust is an 8-hour time-weighted average (TWA) of 1.0 milligrams per cubic meter (mg/m^3) total Mn, with a short term exposure limit (STEL) of 3.0 mg/m^3 based on central nervous system (CNS) effects and pneumonitis.[NIOSH 1988, NIOSH 1992] The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for Mn dust is a ceiling criteria of 5.0 mg/m^3.[OSHA 1993] The American Conference of Governmental Industrial Hygienists (ACGIH) current Threshold Limit Value (TLV®) for Mn dust is an 8-hour TWA of 5 mg/m^3, while the Mn fume TLV® is 1 mg/m^3.[ACGIH 1993] In 1992, the ACGIH published a notice of intended change to lower the TLV® for elemental and inorganic Mn dust and fume to 0.2 mg/m^3, to address adverse pulmonary effects, CNS effects, and male infertility.[ACGIH 1992] Reports of Parkinsonian-like symptoms have been reported for high Mn dust (and fume) exposures, but the significance of lower dust exposure levels for producing neurological effects is uncertain.

V. EVALUATION METHODS

Industrial Hygiene

On December 11-12, 1991, and August 26-27, 1992, industrial hygiene monitoring surveys were conducted in the Mn powder processing areas and press rooms; each of the surveys were performed on two consecutive days during the first shift when manufacturing production approached maximum capacity. These surveys included personal breathing zone (PBZ) monitoring, area air samples, as well as *"in-mask"* and PBZ sample comparisons and a particle size analysis.

A total of 54 full-shift and 5 short-term PBZ evaluations for total particle size Mn dust were completed on press operators, mechanics, material handlers, and other workers. In addition, 45 area air samples were collected throughout these locations, including

20 side-by-side area air samples, comparing total versus respirable dust levels to characterize the particle size of the airborne Mn.

Fifteen respirator *"in-mask"* and PBZ sample comparisons were also performed using Moldex® 2200 respirators (single use, disposable dust/mist respirators) and light-weight sampling probes.[Liu 1984] Eight of the PBZ measurements collected during these *"in-mask"* comparisons were performed with eight-stage Marple® personal impactor particle size selectors to provide multiple particle size cut-points. The in-mask and PBZ air samples were collected simultaneously while the workers performed their normal work activities during an entire workshift. The respirator performance evaluation was conducted using a *Program Protection Factor* (PPF) protocol. The PPF is defined as the contaminant concentration outside the respirator divided by the contaminant concentration measured inside the respirator face-piece as the respirator is used in the context of the existing respiratory protection program. If any of the respirator program elements are deficient (i.e., proper fit, donning, selection, maintenance, etc.) or otherwise compromised by the activity of the worker, then the PPF will be adversely affected.[Myers 1983, Guy 1985]

The PBZ and area samples for total Mn were collected on 0.8 micron (μ) pore size, mixed cellulose ester (MCE) filters at a flowrate ranging between 2 and 2.5 liters per minute (lpm), and the respirable Mn evaluations were made using MCE filters in 10-millimeter nylon cyclones at a flowrate of 1.7 lpm. An anti-bounce spray coating could not be used on the impactor substrates due to complications with the Mn digestion. In this case, the increased potential for particle bounce was the accepted compromise in order to obtain some degree of Mn particle sizing, which was desired information to supplement the *"in-mask"* data. The Marple® impactor samples were collected using polyvinyl chloride (PVC) substrates to allow both gravimetric weight gain and Mn analysis and were collected at a flowrate of 1.5 lpm to minimize particle bounce.

All samples were analyzed for elemental Mn by inductively coupled argon plasma, atomic emission spectroscopy (ICP-AES) via NIOSH method 7300 utilizing a modified acid digestion consisting of hydrochloric (HCl), nitric, and perchloric acids in a 3:1:1 ratio. The modified acid digestion (addition of HCL) was necessary to ensure that particulate Mn was completely dissolved prior to analysis. Distilled water rinses of the in-mask probes were also analyzed for Mn; the weight of Mn detected in the probe rinse was added to the quantity detected on the in-mask filter.

Geometric means and geometric standard deviations of Mn concentrations were calculated for the PBZ exposure to total Mn as well as the PPF respirator performance evaluations. An assigned protection factor for the sample set of all PPF respirator evaluations was calculated by using the following expression (where Z equals 1.64;

this Z value corresponds with 95% of the individual PPF measurements exceeding the calculated assigned PPF):

$$\text{Assigned PPF} = \text{Geometric Mean}_{PPF} \div (\text{Geometric Standard Deviation}_{PPF})^{Z}$$

Particle size analysis of the Marple® impactor particle size selectors was performed by extrapolating the mass median diameter and standard deviations from a log probability plot for each of the eight PBZ samples collected with this device.

Medical

Employees in the powder processing tower and press rooms were informed by Duracell management that NIOSH representatives were available for private medical interviews. Interviews and a limited medical examination were conducted on employees who volunteered to participate. The interviews focused on symptoms associated with manganism. Examinations were aimed at detecting findings consistent with Mn toxicity, such as tremor, abnormal gait, and rigidity. The company's medical monitoring program and employee medical records were also reviewed for information pertinent to the hazard request. The OSHA Log and Summary of Occupational Injuries and Illnesses (Form 200) and workers compensation claims were also reviewed for reports of neurologic illnesses.

VI. RESULTS and DISCUSSION

Industrial Hygiene

Table 1 and Table 2 present the results of the full-shift PBZ monitoring conducted in the Mn powder and pellet press locations for the initial survey, respectively, for December 11 and December 12, 1991. The full-shift PBZ Mn exposure measured during the follow-up survey in August 1992, is provided in Table 3. In addition, Table 4 lists the statistical summary of the full-shift PBZ TWAs, including maximum and minimum values, the geometric mean, geometric standard deviation, and the number of samples collected for the overall data set, the processing tower, the pellet press rooms, and job titles. Overall, 54 full-shift TWA exposures to total Mn ranged from 0.09 to 5.4 mg/m^3 with the geometric mean and geometric standard deviation of this sample set equal to 0.62 mg/m^3 and 2.4, respectively. The 17 full-shift TWA exposures to total Mn in the processing tower ranged from 0.09 to 5.41 mg/m^3 with a geometric mean equal to 0.87 mg/m^3 and a geometric standard deviation of 3.3. (The bulk loader monitoring results were included in the data set for the powder processing tower.) The press room full-shift exposures to total Mn samples ranged from 0.1 to 2.52 mg/m^3; the geometric mean was 0.53 mg/m^3 and the geometric standard deviation was 1.9 for the press rooms PBZ TWA measurements. As expected, the highest total Mn PBZ exposures were observed on the bulk loader and powder unloader jobs, with the TWA exposure ranging from 0.47 to 5.41 mg/m^3. A total of 11 TWA exposures exceeded the NIOSH REL of 1 mg/m^3; two TWA exposures exceeded the current ACGIH TLV of 5 mg/m^3. Furthermore, 93% of the full-shift PBZ exposures (50 of the 54 exposure measurements) exceeded the proposed ACGIH TLV intended change of 0.2 mg/m^3. The company required the use of disposable dust/mist respiratory protection for everyone who entered these locations. It is important to note that substantially lower exposure concentrations were observed during the follow-up survey after the company had implemented engineering changes including, but not limited to, powder drop process enclosure, an improved dilution ventilation and air filtration system to reduce the background levels, and reduced reliance on dry sweeping.

Five 15-minute short-term PBZ exposure samples were collected during this investigation. Table 5 provides the results of these samples along with all of the PBZ exposure concentrations that exceeded the NIOSH STEL, regardless of the sampling time. Short-term exposure to total Mn was observed as high as 11.7 mg/m^3 for the bulk loader and as high as 6.50 mg/m^3 for the powder unloader on the drop floor. A total of 12 samples surpassed the NIOSH STEL of 3 mg/m^3, 10 of which were during much longer time periods than 15 minutes; and five exposures also exceeded the OSHA PEL, a 5 mg/m^3 ceiling limit.

Forty-five area samples for Mn were collected throughout the bulk material receiving area, the processing tower, the press rooms, and in other locations throughout the plant. These samples include 20 side-by-side samples comparing total versus respirable Mn dust (as selected by a MSA cyclone particle size sampling device). Refer to Table 6 for the results of the area samples. Area sample comparisons of total and respirable Mn revealed the mean respirable particulate Mn fraction to be 21% of the total Mn mass concentration. The mean respirable particulate Mn fraction of the total Mn mass concentration for the processing tower and the press rooms were calculated to be 25% and 18%, respectively.

Fifteen "*in-mask*" and PBZ respirator performance evaluations for Mn were conducted using Moldex® 2200 respirators, light-weight sampling probes, and PPF protocol. The results of this evaluation are presented in Tables 7 through 10. The individual PPFs ranged from 5 to 215, with a geometric mean and standard deviation equal to 31 and 2.95, respectively. The assigned PPF calculated for this sample set was 5, based on the generally accepted proportion that 95% of the individual PPFs exceed the calculated assigned PPF.[Lenhart 1984, Reed 1987, Hyatt 1976]

Eight particle size analyses of the PBZ Mn exposures using the Marple® impactor particle size selectors are provided in Table 11. The mass median diameters (MMD) for these samples were determined to range from 6 to 19 microns and the standard deviation ranged from 3.3 to 4.8. Although one (out of eight) of the MMDs for Mn was 6, the other seven MMDs were 10 microns or above. It is interesting to note that both the highest and the lowest MMD were measured on press operators. The data collected by both the MSA cyclone and Marple® impactor particle size selectors suggests that the majority of the particle mass was due to non-respirable particle sizes.

Medical

Six (8%) of the 80 employees who worked in the powder processing and press room locations volunteered to be interviewed. Two of these employees worked in the press room and four in the powder processing area. Three of the six employees were smokers or former smokers, and three reported never smoking. On examination, none exhibited Parkinson-like findings (tremors, gait disturbances, rigidity, or mask-like facial expressions) and all denied awareness of any of these effects. In addition, all denied behavioral and psychological changes, such as increased irritability, trouble sleeping, or personality change.

Review of the company's medical records revealed that six employees had histories of elevated urine Mn levels in 1989 and 1990. Four of these employees were among the six who had volunteered to be interviewed; none had symptoms associated with manganism. The other two employees with a history of elevated urine Mn levels did not wish to be interviewed.

The company's "Manganese Surveillance Program" was reviewed. It consists of urine and serum Mn evaluation, questions regarding personality changes (irritability, excitability), questions about symptoms that could be associated with Mn overexposure (headaches, fatigue, insomnia, metal taste, salivation, tremor, gastrointestinal problems, muscle weakness, memory loss, numbness, clumsiness, dizziness), and a physical examination for neurological disorders (tremors, nystagmus, reflexes, strength, touch, vibration, gait).

Frequency of surveillance is based on Mn exposure monitoring by the company. Employees working in areas with total Mn dust levels above 0.5 mg/m^3 are to have yearly exams and to be referred to company physicians for any abnormal finding. Persons found to have blood Mn levels of 14 milligrams per deciliter (mg/dL) or higher or symptoms are removed from exposure areas and given monthly exams until symptoms resolve and/or blood levels return to < 14 mg/dL. Permanent restrictions were to be considered for employees with incurable peripheral neuropathy, CNS disease, psychiatric disease, liver disorders, pulmonary disease, or persistent elevation of blood Mn levels despite adequate use of personal protective equipment.

VII. CONCLUSIONS

The vast majority of the PBZ exposures were below the current ACGIH TWA TLV and the OSHA ceiling PEL of 5 mg/m^3. The powder unloader job, which required a powered air purifying respirator, had exposures that exceeded the ACGIH TLV during the first NIOSH site visit. However, exposure was reduced by the company prior to the follow-up survey through the use of engineering controls. Some of the observed PBZ exposures exceeded the NIOSH RELs (both the full-shift and short- term limits of 1 & 3 mg/m^3, respectively) and the OSHA ceiling PEL. Furthermore, 93% of the PBZ exposures were above the proposed ACGIH TLV® intended change value of 0.2 mg/m^3 for total Mn.

In general, the respiratory protection program at this location was effective, with cooperative employee participation and firm supervisory enforcement. The assigned PPF of 5 calculated for this evaluation is half the protection factor of 10 assigned to disposable dust/mist respirators by the American National Standards Institute (ANSI)[ANSI 1992] However, the respirator performance was consistent with NIOSH expectations for this class of respiratory protection as it is used in the context of an effective respiratory protection program.[NIOSH 1987] Based on the assigned PPF of 5 observed in this evaluation and the NIOSH REL of 1 mg/m^3, this type of respirator would be expected to provide protection up to 5 mg/m^3. The use of this class of respirator protection would also be expected to provide protection below the proposed ACGIH intended change TLV given the current level of Mn exposure for most of the jobs. (This class of respirator does not provide sufficient protection for the bulk loader and powder unloader Mn exposures.) However, NIOSH recommends that "respirators *only* be used when engineering controls are not feasible or effective, while controls are being installed or repaired, or for emergency and other temporary (intermittent) situations."[NIOSH 1987]

None of the interviewed workers exhibited signs of overexposure to Mn during our site visit, although only a limited number (8% of the workforce) of voluntary interviews were conducted. The levels of Mn measured by NIOSH investigators suggest that a risk for overexposure exists for some employees. Unfortunately, there is no "gold standard" biological exposure index for determining an individual's exposure risk to Mn toxicity. Therefore, medical personnel responsible for evaluating employees must be skilled in assessing the often subtle neurological and behavioral signs and symptoms of Mn toxicity.

VIII. RECOMMENDATIONS

The following recommendations are provided to reduce worker exposure to Mn, decrease the potential risk for Mn toxicity, and to improve the overall occupational health program implemented for the processing tower and press room employees:

1. Potential sources of exposure (e.g., routine emission sources, potential system leaks, etc.) should be periodically reexamined, and the adequacy of control systems should be reassessed. Installation of additional process enclosures and local exhaust ventilation will be required to reduce Mn exposures below the proposed ACGIH TLV intended change of 0.2 mg/m^3 full-shift exposure.

2. Local exhaust ventilation design improvements are warranted to further reduce the generation of the Mn dust at the source of the emissions. In particular, the "hogs head" plenum and multiple branch junctions of each pellet press should be modified to make the exhaust ventilation more effective. The latest edition of the ACGIH Industrial Ventilation Manual should be consulted when designing or re-designing local exhaust ventilation systems.[ACGIH 1992]

3. Continue to upgrade the general (dilution) ventilation and increased filtration of recirculated air to reduce background levels of Mn.

4. Local exhaust ventilation should be provided at the bulk bag disposal cart.

5. Reusable bags should be cleaned before reuse. (Implementation of this recommendation may require the cooperation of the ore purification mills that supply the Mn powder to the company, or the bags could be cleaned prior to returning them to the Mn supplier.)

6. Dry sweeping of Mn-containing dust accumulations should be eliminated. Wet methods should be used for environmental dust control, if practical. If dry clean-up methods are used, they should be done only by a vacuum system equipped with a high efficiency particulate air (HEPA) filter.

7. Equipment should be HEPA vacuumed prior to preventive or corrective maintenance.

8. Continue to implement the respiratory protection program during the interim period prior to the installation of additional engineering controls or if engineering controls are not feasible to reduce the Mn exposure below the pertinent occupational inhalation exposure criteria.

9. Provide a higher level of respiratory protection for the bulk loader and powder unloader jobs.

10. Ensure that respirator users are clean shaven in the area of the face-piece seal. (Some of the workers wearing respirators were observed to have a few days of facial hair growth.)

11. Prohibit tobacco smoking in the hallway and locker rooms adjacent to the exposure locations due to the background Mn levels detected in these areas. Smoking this close to the exposure area increases the potential for Mn exposure from inhalation and ingestion, especially if cigarettes contact contaminated hands.

12. Cigarettes and food should also not be allowed in any Mn dusty area because of the possibility of contamination. Workers should be instructed to wash their hands before handling cigarettes or food to prevent contamination and the subsequent inhalation and/or ingestion of Mn as a result of that contamination.

13. Employees should be educated as to the symptoms of Mn toxicity and should be encouraged to report any such symptoms to medical personnel.

14. Employees should be evaluated by medical personnel aware of the symptoms and signs of Mn toxicity. Any employee found to exhibit signs or symptoms of Mn toxicity should be provided with an alternative position that is removed from potential Mn exposure areas.

15. Continue to perform industrial hygiene monitoring and record keeping to identify problematic locations and job tasks, to evaluate the effectiveness of new engineering controls, and to assess work methods that can be altered to reduce exposure potential.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

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1. Duracell Battery Company, Cleveland, TN
2. Employee representative, Cleveland, TN
3. U.S. Department of Labor, OSHA, Region IV

In order to comply with the NIOSH regulation that affected employees shall be notified about the determination of this health hazard evaluation (CFR, Title 42, Part 85, Section 85.11), the employer shall post copies of this report in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1
Full- Shift PBZ Manganese Dust Exposure
Duracell Battery Company, Cleveland, TN
December 11, 1991
HETA 91-109

Location	Job Title	Time (min)	Total Mn conc. (mg/m3)	TWA actual (mg/m3)
Variable	Tower Operator	235	0.48	0.62
		109	0.94	
Drop Floor	Powder Unloader	225	5.56	5.41
		52	2.69	
		100	6.50	
Press # 11 (1400)	Press Operator	231	0.69	0.56
		214	0.41	
Press # 9 (1400)	Press Operator	230	0.40	0.44
		213	0.48	
Press # 7 (1300)	Press Operator	236	1.42	1.41
		199	1.41	
Press # 3 (1300)	Press Operator	230	0.91	0.78
		204	0.64	
1300 Presses	Material Handler	206	1.33	0.79
		216	0.26	
1400 Presses	Material Handler	239	0.56	0.51
		204	0.45	
Bag House	Material Handler	232	0.88	0.93
		175	1.00	
Press # 7 (1300)	Mechanic	265	0.83	0.84
		130	0.85	
Press # 9 (1400)	Mechanic	230	0.26	0.25
		150	0.24	
Press # 5 (1300)	Mechanic	221	1.34	1.37
		190	1.41	
Receiving Area	Bulk Loader	132	4.17	4.85
		65	4.54	
		48	2.71	
		54	5.56	
		47	11.70	
		40	1.15	
Variable	Reworker	143	0.88	1.00
		92	0.91	
		92	1.26	
Variable	Mechanic	148	0.78	1.11
		98	1.68	
		145	1.07	

Table 2
Full- Shift PBZ Manganese Dust Exposure
Duracell Battery Company, Cleveland, TN
December 12, 1991
HETA 91-109

Location	Job Title	Time (min)	Total Mn conc. (mg/m3)	TWA actual (mg/m3)
Receiving Area	Bulk Loader	278	3.06	2.16
		160	0.59	
Variable	Tower Operator	206	0.41	0.36
		190	0.29	
Variable	Reworker	268	0.62	0.70
		95	0.95	
Drop Floor	Powder Unloader	225	4.00	4.11
		152	4.28	
Variable	Mechanic	256	1.82	1.68
		128	1.41	
Bag House	Material Handler	230	0.93	0.77
		183	0.57	
Press # 7 (1300)	Press Operator	227	0.25	0.25
		43	0.04	
Press # 11 (1400)	Press Operator	223	0.56	0.53
		204	0.49	
1400 Presses	Material Handler	219	0.43	0.43
		203	0.42	
Press # 3 (1300)	Mechanic	232	1.21	0.96
		154	0.57	
Press # 11 (1400)	Mechanic	223	0.30	0.31
		182	0.32	
Press # 3 (1300)	Press Operator	120	1.42	2.52
		110	1.59	
		145	4.14	
Press # 9 (1400)	Press Operator	110	0.77	1.00
		149	0.91	
		122	1.31	
1300 Presses	Material Handler	191	0.58	0.58

Table 3
Full- Shift PBZ Manganese Dust Exposure
Duracell Battery Company, Cleveland, TN
August 26-27, 1992
HETA 91-109

Location	Job Title	Time (min)	Total Mn conc. (mg/m3)	TWA actual (mg/m3)
Press # 7 (1300)	Press Operator	218	0.47	0.51
		212	0.55	
Press # 3 (1300)	Press Operator	88	0.48	0.39
		202	0.36	
Press # 11 (1400)	Press Operator	226	0.50	0.47
		215	0.43	
Press # 9 (1400)	Press Operator	222	1.30	0.89
		214	0.47	
1400 Presses	Material Handler	212	0.23	0.22
		203	0.20	
1300 Presses	Material Handler	207	0.24	0.23
		186	0.22	
Press # 11 (1400)	Mechanic	221	0.37	0.42
		126	0.52	
Press # 3 (1300)	Mechanic	257	0.28	0.23
		136	0.13	
Variable	Tower Operator	180	0.11	0.10
		188	0.09	
Receiving Area	Bulk Loader	371	1.63	1.63
Drop Floor	Material Handler	350	1.19	1.19
Press # 5 (1300)	Press Operator	377	0.84	0.84
Variable	Mechanic	404	0.28	0.28
Receiving Area	Bulk Loader	199	0.70	0.47
		207	0.24	
Variable	Mechanic	153	0.09	0.09
Drop Floor	Powder Unloader	214	0.55	0.62
		207	0.68	
Bag House	Material Handler	223	0.61	0.51
		135	0.35	
Press # 7 (1300)	Mechanic	215	0.20	0.17
		196	0.13	
Press # 9 (1400)	Mechanic	189	0.17	0.14
		203	0.11	
Press # 5 (1300)	Press Operator	204	0.55	0.59
		208	0.63	
Press # 11 (1400)	Press Operator	196	0.71	0.58
		202	0.45	
Press # 7 (1300)	Press Operator	398	0.67	0.67
Press #5 (1300)	Mechanic	339	0.52	0.52
Press # 9 (1400)	Press Operator	414	0.34	0.34
Press # 3 (1300)	Press Operator	398	0.65	0.65

Table 4
Statistical Summary of Full-Shift PBZ Manganese Dust Exposure
Duracell Battery Company, Cleveland, TN
December 11-12, 1991 and August 26-27, 1992
HETA 91-109

Job Title	Number	Minimum	Maximum	Average	Std Dev	Geometric Mean	Geometric Std Dev
Overall	54	0.09	5.41	0.93	1.07	0.62	2.38
Processing Tower	17	0.09	5.41	1.55	1.66	0.87	3.34
Press Room	37	0.14	2.52	0.64	0.44	0.53	1.86
Bulk Loader	4	0.47	4.85	2.28	1.85	1.68	2.64
Tower Operator	3	0.10	0.62	0.36	0.26	0.28	2.60
Reworker - Tower	2	0.70	1.00	0.85	0.21	0.84	1.28
Mechanic - Tower	4	0.09	1.68	0.79	0.74	0.47	3.81
Powder Unloader	3	0.62	5.41	3.38	2.48	2.39	3.26
Material Handler	10	0.22	1.19	0.62	0.31	0.54	1.75
Press Operator	18	0.25	2.52	0.75	0.52	0.64	1.70
Mechanic - Presses	10	0.14	1.37	0.52	0.41	0.40	2.16
Bag House Worker	3	0.51	0.93	0.74	0.21	0.72	1.36
Overall, Dec 91	29	0.25	5.41	1.28	1.34	0.89	2.26
Overall, Aug 92	25	0.09	1.63	0.51	0.35	0.40	2.08
Processing Tower, Dec 91	10	0.36	5.41	2.20	1.89	1.52	2.55
Processing Tower, Aug 92	7	0.09	1.63	0.62	0.58	0.39	3.11
Press Room, Dec 91	19	0.25	2.52	0.80	0.53	0.67	1.82
Press Room, Aug 92	18	0.14	0.89	0.47	0.22	0.41	1.73

Table 5
STEL or Half-Shift PBZ Manganese Dust Exposure
Duracell Battery Company, Cleveland, TN
December 11-12, 1991
HETA 91-109

Location	Job Title	Time (min)	TWA actual (mg/m3)
Receiving Area	Bulk Loader	15	5.78
Receiving Area	Bulk Loader	15	1.91
Relief-Drop	Reworker	15	0.53
Drop Floor	Powder Unloader	15	4.00
Bag House	Material Handler	15	0.69
Drop Floor	Powder Unloader	225	5.41
Drop Floor	Powder Unloader	100	6.50
Receiving Area	Bulk Loader	132	4.17
Receiving Area	Bulk Loader	65	4.54
Receiving Area	Bulk Loader	54	5.56
Receiving Area	Bulk Loader	47	11.70
Receiving Area	Bulk Loader	278	3.06
Drop Floor	Powder Unloader	225	4.00
Drop Floor	Powder Unloader	152	4.28
Press # 3 (1300)	Press Operator	145	4.14

Table 6
Area Manganese Dust Concentrations
Duracell Battery Company, Cleveland, TN
December 11-12, 1991 and August 26-27, 1992
HETA 91-109

Location	Sample Type	Time (min)	TWA actual (mg/m3)	% Resp. Mn
Receiving Area, Bulk Hopper	Total Mn	401	1.74	15.6
	Resp Mn-Cyclone	401	0.27	
Processing Tower, 3rd Floor, Blendors	Total Mn	429	2.14	14.3
	Resp Mn-Cyclone	186	0.31	
Processing Tower, 2nd Floor, Compactors	Total Mn	431	1.28	1.2
	Resp Mn-Cyclone	431	0.02	
Processing Tower, 2nd Floor, Control Room	Total Mn	444	0.09	5.6
	Resp Mn-Cyclone	444	0.005	
Processing Tower, 1st Floor, Rotary Sieves	Total Mn	429	1.36	20.5
	Resp Mn-Cyclone	430	0.28	
Processing Tower, Drop Floor	Total Mn	427	1.56	6.1
	Resp Mn-Cyclone	427	0.10	
Press Room -1300	Total Mn	388	0.73	13.2
	Resp Mn-Cyclone	389	0.10	
Press Room - 1400	Total Mn	400	0.24	72.0
	Resp Mn-Cyclone	400	0.17	
Smoking Hallway	Total Mn	415	0.16	8.5
	Resp Mn-Cyclone	415	0.01	
Locker Room, Men's	Total Mn	82	0.13	
Locker Room, Women's	Total Mn	78	0.10	
Auto Palletizer	Total Mn	390	0.02	14.3
	Resp Mn-Cyclone	390	0.003	
Battery Sub-Assembly	Total Mn	350	0.03	12.9
	Resp Mn-Cyclone	387	0.003	
Cafeteria	Total Mn	380	0.005	
Receiving Area, Waste Bag Cart	Total Mn	352	0.70	20.2
	Resp Mn-Cyclone	351	0.14	
Processing Tower, 3rd Floor, Blendors	Total Mn	305	2.10	32.0
	Resp Mn-Cyclone	306	0.67	
Processing Tower, 2nd Floor, Compactors	Total Mn	314	0.31	27.7
	Resp Mn-Cyclone	314	0.09	
Processing Tower, 2nd Floor, Control Room	Total Mn	312	0.15	31.0
	Resp Mn-Cyclone	312	0.05	
Processing Tower, 1st Floor, Rotary Sieves	Total Mn	328	1.52	28.1
	Resp Mn-Cyclone	329	0.43	
Processing Tower, Drop Floor	Total Mn	333	1.98	22.3
	Resp Mn-Cyclone	333	0.44	
Press Room - 1300	Total Mn	348	1.04	22.6
	Resp Mn-Cyclone	348	0.24	
Press Room - 1400	Total Mn	348	0.24	24.2
	Resp Mn-Cyclone	348	0.06	
Can Making	Total Mn	315	0.16	16.5
	Resp Mn-Cyclone	315	0.03	
Auto Palletizer	Total Mn	322	0.13	

Table 7
Results of Lapel and In-mask Sampling for Manganese
Duracell U.S.A.
Cleveland, Tennessee
December 11, 1991
HETA 91-109

Job Title	LAPEL SAMPLING			IN-MASK SAMPLING			Program Protection Factor (A/B)
	Sampling Period	Manganese Concentration (μg/m³)	(A) 8-hr TWA MN Concentration (μg/m³)	Sampling Period	Manganese Concentration (μg/m³)	(B) 8-hr TWA MN Concentration (μg/m³)	
Bulk Loader	0723-0935	4170	3900	0723-0935	11.7	14.2 [18.1][a]	215[b]
	0946-1051	4540		0946-1139	12.7		
	1051-1139	2710		(1216-1230 & 1237-1404)	35.6		
	(1216-1230 & 1237-1317)	5560		1421-1501	6.2		
	1317-1404	11700					
	1421-1501	1150					
3-story Rework	0729-0952	883	680	0729-0952	14.4	41.6 [43.8][a]	16[b]
	1034-1206	915		1034-1206	94.8		
	1332-1504	1260		1332-1504	100		
3-story Mechanic	0728-0956	777	906	0729-0956	13.9	76.7 [81.5][a]	11[b]
	1000-1138	1680		1000-1138	146		
	1209-1434	1070		1209-1434	141		

MN: manganese
TWA: Time-weighted average
μg/m³: micrograms per cubic meter

a: Concentration including manganese washed from inside the sampling probe.
b: Calculated using adjusted in-mask concentration.

Table 8
Results of Lapel and In-mask Sampling for Manganese
Duracell U.S.A.
Cleveland, Tennessee
December 12, 1991
HETA 91-109

Job Title	LAPEL SAMPLING			IN-MASK SAMPLING			Program Protection Factor (A/B)
	Sampling Period	Manganese Concentration ($\mu g/m^3$)	(A) 8-hr TWA MN Concentration ($\mu g/m^3$)	Sampling Period	Manganese Concentration ($\mu g/m^3$)	(B) 8-hr TWA MN Concentration ($\mu g/m^3$)	
Line Operator (#3)	0739-0939	1420	1970	(0739-0939 & 1000-1150)	10.0	10.2 [13][a]	150[b]
	1000-1150	1590		1216-1408	17.9		
	1216-1408	4140					
Line Operator (#9)	0742-0932	773	739	0742-0932	3.2	8.6 [9.5][a]	78[b]
	0956-1225	738		0956-1427	13.9		
	1225-1427	1310					
Material Handler	(0746-0937 & 0958-1118)	576	---	(0746-0937 & 0958-1005)	18.6	---	31[c]
				1010-1118	17.6		

MN: manganese
TWA: Time-weighted average
$\mu g/m^3$: micrograms per cubic meter

a: Concentration including manganese washed from inside the sampling probe.
b: Calculated using adjusted in-mask concentration.
c: Program protection factor for sampling period only.

Table 9
Results of Lapel and In-mask Sampling for Manganese
Duracell U.S.A.
Cleveland, Tennessee
August 26, 1992
HETA 91-109

Job Title	LAPEL SAMPLING			IN-MASK SAMPLING			Program Protection Factor (A/B)
	Sampling Period	Manganese Concentration ($\mu g/m^3$)	(A) 8-hr TWA MN Concentration ($\mu g/m^3$)	Sampling Period	Manganese Concentration ($\mu g/m^3$)	(B) 8-hr TWA MN Concentration ($\mu g/m^3$)	
Bulk Loader	0739-0930	4170	1630	0739-0930	33	25.3[d] (Worker A)	64[c]
	0958-1055			0958-1055	9.6	30.2[d] (Worker B)	54[c]
	1146-1509			(1146-1246 & 1325-1406)	30.2		
Material Handler	0744-0949	1190	868	0744-0934	26.8	25.7	34
	1012-1145			1012-1145	13.4		
	1218-1430			1218-1345	69.0		
Line Operator (#5)	0738-0944	838	658	0738-0944	246	112	6
	1008-1152			1008-1152	43.3		
	1217-1444			1217-1444	126		
3-story Mechanic	0748-0956	284	239	0748-0956	50.8	44.8	5
	1021-1457			1021-1157	72.9		
	1209-1434			1157-1457	44.4		

MN: manganese
TWA: Time-weighted average
$\mu g/m^3$: micrograms per cubic meter

c: Program protection factor for sampling period only.
d: MN concentration for sampling period.

Table 10
Results of Lapel and In-mask Sampling for Manganese
Duracell U.S.A.
Cleveland, Tennessee
August 27, 1992
HETA 91-109

Job Title	LAPEL SAMPLING			IN-MASK SAMPLING			Program Protection Factor (A/B)
	Sampling Period	Manganese Concentration (μg/m³)	(A) 8-hr TWA MN Concentration (μg/m³)	Sampling Period	Manganese Concentration (μg/m³)	(B) 8-hr TWA MN Concentration (μg/m³)	
Line Operator (#7)	0751-0954	670	556	0751-0954	40.6	45.2	12
	0958-1153			0958-1153	19.1		
	1217-1423			1217-1504	111		
	1430-1504			1430-1504	14.7		
Mechanic	0750-0927	520	367	0750-0927	5.2	12.2	30
	0957-1134			0957-1134	10.8		
	1215-1440			1215-1440	30.0		
Line Operator (#9)	0740-1154	344	297	(0740-1014 & 1014-1115)	7.9	9.9	30
	1214-1454			(1118-1154 & 1214-1454)	15.6		
Line Operator (#3)	0745-0941	652	540	0745-0941	10.3	14.2	38
	0955-1150			0955-1150	27.0		
	1216-1412			1216-1412	17.2		
	1423-1514			1423-1514	9.8		

MN: manganese
TWA: Time-weighted average
μg/m³: micrograms per cubic meter

Table 11
PBZ Manganese Dust Exposure Particle Size
Duracell Battery Company, Cleveland, TN
August 26-27, 1992
HETA 91-109

	Full-Shift TWA actual (mg/m3)									
Job Title	Total TWA actual	Mn conc. >27 u	Mn conc. 18-27 u	Mn conc. 12-18 u	Mn conc. 7-12 u	Mn conc. 4-7 u	Mn conc. 2.5-4 u	Mn conc. 1-2.5 u	Mn conc. 0.5-1 u	Mn conc. <0.5 u
Bulk Loader	1.63	0.182	0.456	0.272	0.229	0.161	0.095	0.091	0.059	0.089
Powder Unloader	1.19	0.197	0.253	0.302	0.174	0.106	0.069	0.025	0.022	0.040
# 5 Press Operator	0.84	0.124	0.154	0.135	0.109	0.093	0.101	0.045	0.043	0.033
Tower Mechanic	0.28	0.060	0.055	0.069	0.043	0.027	0.014	0.002	0.005	0.009
# 7 Press Operator	0.67	0.068	0.096	0.096	0.081	0.114	0.088	0.028	0.071	0.029
# 5 Mechanic	0.52	0.052	0.071	0.147	0.095	0.062	0.043	0.016	0.020	0.014
# 9 Press Operator	0.34	0.059	0.042	0.061	0.067	0.021	0.049	0.020	0.009	0.016
# 3 Press Operator	0.65	0.127	0.099	0.188	0.058	0.009	0.045	0.016	0.015	0.012

Table 12
PBZ Manganese Dust Mass Median Diameter
Duracell Battery Company, Cleveland, TN
August 26-27, 1992
HETA 91-109

Job Title	Full-Shift TWA actual (mg/m3)	Mass Median Diameter	Standard Deviation
Bulk Loader	1.63	11	4.4
Powder Unloader	1.19	14	3.8
# 5 Press Operator	0.84	10	3.7
Tower Mechanic	0.28	15	3.3
# 7 Press Operator	0.67	6	3.8
# 5 Mechanic	0.52	10	3.4
# 9 Press Operator	0.34	10	4
# 3 Press Operator	0.65	19	4.8