HETA 87-097-1820
JULY 1987
DEVIL'S LAKE SIOUX MFG. CORP.
FORT TOTTEN, ND

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I. SUMMARY

In January 1987, the National Institute for Occupational Safety and Health (NIOSH) received a request from employees of Devil's Lake Sioux Manufacturing Corporation, Fort Totten, North Dakota, to determine if there was a health hazard from exposure to n-hexane and other organic solvents during the manufacture of Kevlar combat helmets. The primary area of interest expressed by the requestors and the focus of the evaluation was "edging" operators' exposures to organic solvents. In addition, from September 1984 through December 1986 ten (10) symptomatic workers, all who had worked as "edgers", were diagnosed by physicians as having carpal tunnel syndrome and received some form of treatment, including surgery.

An industrial hygiene evaluation was conducted by a NIOSH researcher on March 17 and March 18, 1987 to evaluate workers' exposures to organic solvents, including n-hexane. Personal breathing zone (PBZ) and general area air samples were taken throughout the helmet production area. Air samples were taken for methyl ethyl ketone, toluene, xylene, and n-hexane. Direct-reading colormetric tubes were used in the mold press area to sample for formaldehyde. Workers were informally interviewed to determine if there were any health complaints related to organic solvent exposure.

Airborne concentrations of xylene ranged from nondetectable (ND) to 6.44 mg/M^3 with an arithmetic average of 1.39 mg/M^3. All airborne concentrations were less than 5% of the evaluation criteria, 434 mg/M^3. Airborne concentrations of toluene ranged from 0.46 to 33.2 mg/M^3 with an arithmetic average of 9.23 mg/M^3. All airborne concentrations were less than 10% of the evaluation criteria, 377 mg/M^3. Airborne concentrations of hexane ranged from 0.27 to 83.3 mg/M^3 with an arithmetic average of 12.8 mg/M^3. Eleven of the thirteen airborne concentrations were less than 10% of the evaluation criteria, 180 mg/M^3. The highest hexane concentrations obtained were for a PBZ air sample from Gluer #2, measured at 83.3 mg/M^3 and a general area air sample taken in the paint mix area, measured at 30.6 mg/M^3. Airborne concentrations of MEK ranged from 20.0 to 310 mg/M^3 with an arithmetic average of 137 mg/M^3. The highest MEK exposures obtained were PBZ air samples from Gluer #3 (March 17 sample) measured at 310 mg/M^3 (53% of the evaluation criteria, 590 mg/M^3), from Edger #1 measured at 253 mg/M^3 (43% of the evaluation criteria), from Gluer #2 measured at 124 mg/M^3 (21% of the evaluation criteria), and for Gluer #3 (March 18 sample) measured at 257 mg/M^3 (44% of the evaluation criteria).

The ratio of concentration to TLV for the mixed organic solvents exposure to the glue spray booth operators was 1.07 for Gluer #2 and Gluer #3 on March 17, 1987, 0.76 for Gluer #2 on March 18, 1987, and 0.98 for Gluer #3 on March 18, 1987. Thus, the highest exposure was at the evaluation criterion (1.0) for the mixture. The ratio for the mixed exposure to one of the edgers was 0.54 and exceeded the action level criterion (0.50) for the mixture. The ratio for the mixed exposure to two edgers, the rubber edge gluing operator, and the helmet patch operator did not exceed 0.50. Two detector tube measurements for formaldehyde taken on March 17, 1987 indicated formaldehyde levels of 0.62 mg/M^3 and 1.23 mg/M^3. Six detector tube measurements for formaldehyde taken on March 18, 1987 ranged from 0.25 mg/M^3 to 0.62 mg/M^3.

Based upon results of environmental monitoring conducted during this evaluation, it was concluded that exposure among edgers and glue spray booth operators to a mixture of organic solvents poses a potential health hazard. A health hazard was found to exist due to off-gassing of formaldehyde in the mold press area. Recommendations, including ventilation improvements, are made in Section VIII of this report.

Keywords: SIC 2352 (Manufacture of hats and caps, except millinery), carpal tunnel syndrome, organic solvent neurotoxicity, hexane, toluene, xylene, methyl ethyl ketone.

II. INTRODUCTION

In January 1987, NIOSH received a confidential request from employees of Devil's Lake Sioux Manufacturing Corporation, Fort Totten, North Dakota, to determine if there was a health hazard from exposure to n-hexane and other organic solvents during the manufacture of Kevlar combat helmets. In addition, from September 1984 through December 1986 ten (10) symptomatic workers were diagnosed by physicians as having carpal tunnel syndrome and received some form of treatment, including surgery. An industrial hygiene evaluation was conducted by a NIOSH researcher on March 17 and March 18, 1987 to evaluate potential exposures to organic solvents, including n-hexane.

III. BACKGROUND

Devil's Lake Sioux Manufacturing Corporation manufactures Kevlar combat helmets. The primary area of interest expressed by the requestors and the focus of the evaluation was edging operators' exposure to organic solvents. The helmet manufacturing process occurs on one level.

Kevlar aramid fiber is woven into cloth and then coated with phenolic resin. Bulk containers of polymer, resin, and pigment blends are opened manually and placed into a mixing system. After mixing has occurred the resin is mechanically applied to the cloth and dried at an elevated temperature. The cloth is then cut into appropriate sizes and shapes and compression molded into a helmet shape. A rubber and gasket adhesive which contains n-hexane, methyl ethyl ketone, and toluene is sprayed on the helmets at a glue spray booth. A rubber edging strip and an interior suspension assembly are then added to the helmets. The rubber edging strip is also coated with adhesive at an unventilated workstation. The helmets are solvent wiped, painted with two coats of epoxy paint, allowed to dry, inspected and then packaged for shipping.

Mold presses were ventilated for removal of heat and off-gases. The rubber adhesive and epoxy paint were applied in paint spray booths. Solvent wiping prior to painting occurred in a partially enclosed and ventilated booth. After painting the helmets were dried in an enclosed, ventilated system. No local exhaust ventilation was provided at the edging tables where additional glue is applied prior to attaching rubber edging strips to the helmets.

Helmet assembly and attaching of rubber edging strips were performed during the day shift (7:30 AM - 4:00 PM). The compression molds were operated during the day shift and the night shift (7:30 AM - 11:30PM). Helmets were also painted during the day shift and the night shift. The looms were operated continuously, e.g., a 24 hour basis and three shifts.

From September 1984 through December 1986 ten (10) symptomatic workers were diagnosed by physicians as having carpal tunnel syndrome and received some form of treatment, including surgery. All ten workers were women who had worked as "edgers" attaching rubber edging strips to helmets with the rubber and gasket adhesive. Edgers also used a mixture of MEK and xylene to activate adhesive previously sprayed on the helmet. Edgers also apply additional adhesive if necessary. A small hand tool was used to apply the rubber strip to the helmet. The edgers job task was a highly repetitive manual act of arm and hand movements requiring force.

The plant nurse noted helmet production had increased early in 1984, prior to the appearance of carpal tunnel syndrome symptoms in the ten workers. The company started an education and training program for edging operators when the series of wrist problems manifested themselves. Education and training have focused on proper grip of the edging tool to avoid excessive wrist deviations. The edging tool and tool handle have not been redesigned.

Approximately 60 employees, male and female worked in helmet production. Total plant population was approximately 350 and included office personnel and a camouflage netting production operation.

IV. ENVIRONMENTAL METHODS AND MATERIALS

Personal breathing zone (PBZ) and general room air samples for methyl ethyl ketone (MEK), hexane, toluene, and xylene were collected throughout the helmet production area on March 17 and March 18, 1987. Eight air samples, six (6) (PBZ) and two (2) general room air samples were collected for methyl ethyl ketone (MEK) on Ambersorb XE sampling tubes and analyzed according to NIOSH Method 2500 with modifications.(1) Thirteen air samples, eleven (11) PBZ and two (2) general room air sample were collected on organic vapor charcoal sampling tubes and analyzed according to NIOSH Method 1501 with modifications.(2) Three solvents, hexane, toluene, and xylene were analyzed on each tube. Direct-reading colormetric detector tubes were used to sample for formaldehyde in the mold press area. Workers were informally interviewed to determine if there were any health complaints related to organic solvent exposure.

V. EVALUATION CRITERIA

A. Environmental

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assesment of a number 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, however, important to note 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 level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.
The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH recommended exposure limits (RELs) , by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

SUBSTANCE	Environmental Exposure Limits 8-Hour Time-Weighted Average (TWA)
Methyl ethyl ketone (MEK)	590 mg/M^3 (NIOSH) 590 mg/M^3 (OSHA) 590 mg/M^3 (ACGIH)
n-Hexane	360 mg/M^3 (NIOSH) 1795 mg/M^3 C (NIOSH) 1760 mg/M^3 (OSHA) 180 mg/M^3 (ACGIH)
Toluene	377 mg/M^3 (NIOSH) 754 mg/M^3 C (NIOSH) 754 mg/M^3 (OSHA) 1131 mg/M^3 C (OSHA) 377 mg/M^3 S (ACGIH)
Xylene	434 mg/M^3 (NIOSH) 868 mg/M^3 C (NIOSH) 434 mg/M^3 (OSHA) 434 mg/M^3 (ACGIH)
Formaldehyde	LFL (NIOSH) 4.5 mg/M^3 (OSHA) 7.5 mg/M^3 C (OSHA) 1.5 mg/M^3 (ACGIH)*

mg/M^3 = milligrams of substance per cubic meter of air.
C = Ceiling value which should never be exceeded.
S = Skin absorption can be a significant factor in toxicity.
LFL = suspect human carcinogen–exposures should be reduced to the Lowest Feasible Level.
* = Industrial Substance Suspect of Carcinogenic Potential for Man.

When considering a mixed exposure in which the individual substances (e.g., toluene, xylene, n-hexane, and MEK) have similar toxicological effects, as in this case, ACGIH suggests that one add the concentrations of each substance divided by its TLV. If the sum is greater than unity (1) then the mixture as a whole exceeds the TLV for the mixture even though each of the components is below its individual TLV.

B. Toxicological

1. Methyl ethyl ketone (MEK)

MEK is a narcotic and an irritant of the eyes, mucous membranes, and skin. In humans, short-term exposure to 885 mg/M^3 was "objectionable," causing headache and throat irritation, 590 mg/M^3 caused mild irritation of the eyes, 295 mg/M^3 caused slight nose and throat irritation. MEK can be recognized at 74 mg/M^3 by its odor, which is similar to acetone but more irritating. The TLV recommended by the ACGIH (590 mg/M^3) was established at a level to prevent injurious effects and minimize complaints about odor and irritation.(3) MEK is sufficiently irritating to the eyes and respiratory tract to prevent voluntary overexposure to hazardous concentrations.

2. Xylene

Xylene has an irritant effect on the skin and mucous membranes and can have variable effects on the liver, kidneys, and gastrointestinal tract. Another major problem of xylene toxicity is its narcotic effect on workers, causing symptoms such as muscular weakness, lack of coordination, and mental confusion which may pose a risk to the worker and others. Current evidence indicates that xylene is not toxic to the blood and blood-forming organs.(4) Eye and upper respiratory tract irritation is noticeable at 868 mg/M^3 sufficiently so that the warning properties of xylene are considered adequate to prevent voluntary overexposure to an extent narcosis is a problem.

3. n-Hexane

Normal hexane is a mild upper respiratory irritant and causes central nervous system depression. In industry, mild symptoms of narcosis, such as dizziness, have been observed when concentrations exceeded 3520 mg/M^3 but not when below 1760 mg/M^3. Until recently, chronic effects from hexane and similar hydrocarbons had rarely been reported. However, in 1967 seventeen (17) cases of polyneuritis were reported among workers exposed to n-hexane at concentrations between 1760 - 3520 mg/M^3. Subsequent animal studies demonstrated functional disturbances of the peripheral nerves of mice at 880 mg/M^3 but not at 352 mg/M^3.(5) Other studies reported n-hexane neuropathy among furniture workers and among workers exposed to n-hexane used as a solvent in plastic cements. It is postulated that 2,5-hexanedione, a metabolite of n-hexane, is the neurotoxic agent.(3)

4. Toluene

Acute exposure to toluene may cause narcosis (i.e., fatigue, weakness, confusion, headache, dizziness, and drowsiness) and irritation to the eyes, respiratory tract and skin. Prolonged, repeated skin contact may result in defatting dermatitis. One study found that human subjects exposed at 750 mg/M^3 suffered slight but definite changes in muscular coordination. Another study found that experimental human subjects exposed at 750 mg/M^3 showed prolongation of reaction time, decrease in pulse rate and in systolic blood pressure. Chronic exposure does not cause the severe injury to the bone marrow characteristic of benzene poisoning. Extensive animal studies have clearly indicated that toluene is not a bone marrow poison. Reversible liver and kidney damage can occur in overexposed workers. Hippuric acid in urine is an index of worker exposure to toluene.(4,5)

5. Organic Solvent Neurotoxicity

The term "organic solvent" refers to a group of volatile compounds or mixtures that are chemically stable and exist in the liquid state at temperatures of 0° to 250°C (32° to 482°F). Many common solvents often exist as mixtures or blends of chemical compounds. Toluene, xylene, MEK, and n-hexane are common organic solvents. NIOSH believes that the collective toxicological and epidemiological data on organic solvent nuerotoxicity provide sufficient evidence to warrant concern about adverse health effects from occupational exposure to these chemicals.(6) The acute effects of solvent inhalation in both humans and animals include narcosis, anesthesia, central nervous system (CNS) depression, respiratory arrest, unconsciousness, and death. Acute experimental exposures of human volunteers to one or several organic solvents have impaired psychomotor function. Chronic animal studies with a limited number of organic solvents support the evidence for peripheral neuoropathy and mild toxic encephalopathy in solvent-exposed workers. The majority of organic solvents have yet to be tested for chronic neurotoxic effects in animals. Chronic neurotoxicity in workers exposed to organic solvents over a period of months to years includes (1) peripheral neuropathies such as axonal degeneration seen in workers exposed to hexacarbon solvents (e.g., n-hexane, methyl n-butyl ketone), (2) CNS symptoms such as fatigability, irritability, and memory impairment, and (3) mild toxic encephalopathy, including sustained personality or mood changes, diminished impulse control and motivation, and impairment in intellectual function. Epidemiological studies have also demonstrated correlations with changes in neurophysiologic parameters such as nerve conduction velocities. These effects can persist for months to years after removal from solvent exposure. The extent to which chronic neurotoxicity is reversible remains to be established.(6)

6. Formaldehyde

The primary health effects of exposure to formaldehyde are irriation of the respiratory tract, eyes, and skin. Eye and respiratory tract irritation has been reported in workers exposed to concentrations of less than 1.5 mg/M^3.(7) Recent studies have found that formaldehyde induced nasal cancer in rats exposed to high levels (23 mg/M^3) of formaldehyde over a long period of time.(8) An excess risk in humans has not been observed; epidemiological studies to investigate this possibility are planned. NIOSH recommends that formaldehyde be handled in the workplace as a potential occupational carcinogen.(9) Safe levels of exposure to carcinogens have not been demonstrated, but the probability of developing cancer should be reduced by decreasing exposure. NIOSH recommends that engineering controls and stringent work practices be employed to reduce occupational exposure to the lowest feasible level.

VI. RESULTS AND DISCUSSION

Thirteen (13) air samples, eleven (11) PBZ and two (2) general area, were collected on March 17 and March 18, 1987 for xylene. Results of the airborne monitoring for xylene are presented in Table I. Airborne concentrations of xylene ranged from nondetectable (ND) to 6.44 mg/M^3 with an arithmetic average of 1.39 mg/M^3. All airborne concentrations were less than 5% of the evaluation criteria, 434 mg/M^3. The highest xylene exposure obtained on March 17, 1987 was from an "edger", measured at 6.44 mg/M^3. The highest xylene exposure obtained on March 18, 1987 was from the painter, measured at 2.13 mg/M^3.

Thirteen (13) air samples, eleven (11) PBZ and two (2) general area, were collected on March 17 and March 18, 1987 for toluene. Results of the airborne monitoring for toluene are presented in Table II. Airborne concentrations of toluene ranged from 0.46 to 33.2 mg/M^3 with an arithmetic average of 9.23 mg/M^3. All airborne concentrations were less than 10% of the evaluation criteria, 377 mg/M^3. The highest toluene exposure obtained on March 17, 1987 was from Gluer #2, measured at 31.3 mg/M^3. The highest toluene exposure obtained on March 18, 1987 was from Mold Press Operator #2, measured at 10.0 mg/M^3.

Thirteen (13) air samples, eleven (11) PBZ air samples and two (2) general area, were collected on March 17 and March 18, 1987 for n-hexane. Results of the airborne monitoring for hexane are presented in Table III. Airborne concentrations of hexane ranged from 0.27 to 83.3 mg/M^3 with an arithmetic average of 12.8 mg/M^3. Eleven of the thirteen airborne concentrations were less than 10% of the evaluation criteria, 180 mg/M^3. The highest hexane exposure obtained was on March 17, 1987 for a PBZ air sample from Gluer #2, measured at 83.3 mg/M^3.

Eight (8) air samples, six (6) PBZ air samples and two (2) general area, were collected on March 17 and March 18, 1987 for MEK. Results of the airborne monitoring for MEK are presented in Table IV. Airborne concentrations of MEK ranged from 20.0 to 310 mg/M^3 with an arithmetic average of 137 mg/M^3. Four of the eight airborne concentrations were less than 10% of the evaluation criteria, 590 mg/M^3. The highest MEK exposures obtained on March 17, 1987 were from Gluer #3, measured at 310 mg/M^3 and from Edger #1, measured at 253 mg/M^3. Gluer #2 spent most of the March 17 workday at the glue paint spray booth spraying glue adhesive on helmets and Gluer #3 spent most of the workday solvent wiping helmets with MEK. The gluers alternate performing the two tasks based on production needs. A large, free standing fan had been placed to one side of the solvent wipe booth. Visual observation of airflow movement with smoke tubes demonstrated that the fan was interfering with air movement into the solvent wipe booth. The highest MEK exposures obtained on March 18, 1987 were from Gluer #2 measured at 124 mg/M^3 and from Gluer #3 measured at 257 mg/M^3. Gluer #2 and Gluer #3 spent the majority of the March 18 workday at the glue paint spray booth spraying glue adhesive on helmets.

On March 17, 1987 the mixed exposure (ratio of concentration to TLV) for Gluer #2 and Gluer #3 exceeded unity and was thus above the evaluation criterion for the mixture. The mixed exposure was calculated to be 1.07 using the airborne concentrations of xylene, toluene, and hexane obtained from the PBZ air sample for Gluer #2 and the airborne concentration of MEK obtained from the PBZ air sample for Gluer #3. The mixed exposure for Gluer #3 on March 18, 1987 was calculated to be 0.98 using the March 18 airborne concentration of MEK obtained from the PBZ air sample for Gluer #3 and the March 17 airborne concentrations of xylene, toluene and hexane obtained from the PBZ air sample for Gluer #2. The mixed exposure for Gluer #2 on March 18, 1987 was calculated to be 0.76 using the March 18 airborne concentration of MEK obtained from the PBZ air sample for Gluer #2 and the March 17 airborne concentrations of xylene, toluene, and hexane obtained from the PBZ air sample for Gluer #2. Ideally, PBZ air sampling results for each shift and for each chemical substance are collected from each worker when calculating a mixed exposure. The mixed exposures for Gluer #2 and Gluer #3 on March 17, 1987 were calculated using exposures which represent two different job tasks. The mixed exposures for Gluer #2 and Gluer #3 on March 18, 1987 were calculated using exposures which represent two different shifts. The calculated mixed exposures should therefore be considered as an indication of the potential for exposure among gluers to a mixture of MEK, toluene, xylene, and hexane.

The mixed exposure for Edger #1 on March 17 was calculated to be 0.54. This was calculated using the airborne concentration of MEK obtained from the March 17 PBZ air sample from Edger #1 and the airborne concentrations of xylene, toluene, and hexane obtained from the March 17 PBZ air sample from Edger #3. Mixed exposures similarly calculated for Gluer #1, Edger #2, Edger #3, and the helmet patch operator did not exceed 0.50.

Informal interviews with workers, including edging operators and gluers, did not reveal any health complaints related to organic solvent exposure.

Direct-reading colormetric detector tubes were used in the mold press area to sample for formaldehyde. The two detector tubes measurements taken on March 17 indicated formaldehyde levels of 0.62 mg/M^3 and 1.23 mg/M^3. The six detector tube measurements taken on March 18 ranged from 0.25 mg/M^3 to 0.62 mg/M^3. The NIOSH investigator, standing next to a helmet trimming table, experienced eye irritation right after helmets were taken from the molds and placed on the table.

VII. CONCLUSIONS

Airborne concentrations of hexane were below the evaluation criteria. Peripheral neuropathy should not occur at levels below the evaluation criteria. The carpal tunnel syndrome complaints and treatment by physicians seems to be related to ergonomic factors and is not being confused with peripheral neuropath. A potential health hazard was found to exist due to exposure of edgers and glue spray booth operators to a mixture of organic solvents (MEK, n-hexane, toluene, and xylene). Employees' exposures to the individual organic solvents were all less than 55% of the most restrictive evaluation criteria, including the OSHA federal standards, ACGIH TLVs, and the NIOSH RELs. A health hazard was found to exist due to off-gassing of formaldehyde in the mold press area.

VIII. RECOMMENDATIONS

1. Substitution is the recommended method for controlling occupational exposures to toxic substances. Solvent wiping with MEK should be replaced, if technically feasible, by a substitute with the lowest possible toxicity. The use of a substitute would prevent MEK exposure. MEK was the largest contributor when calculating the organic solvent mixture ratio.

2. Application of engineering control methods (isolation, enclosure, and ventilation) should be used to control occupational exposure to MEK if a technically feasible substitute does not exist.

3. The local exhaust ventilation at the solvent wiping station should be improved in order to reduce workers' exposure to MEK. The use of free standing fans in such a way as to interfere with local exhaust ventilation should not be allowed.

4. A local exhaust ventilation system should be installed at the edging table in order to reduce and/or eliminate edgers' exposure to organic solvents.

5. The glue spray booth ventilation should be improved in order to reduce glue spray booth operators' exposure to organic solvents.

6. A local exhaust ventilation system should be installed at the helmet trimming tables in the mold press area in order to reduce and/or eliminate mold press operators' exposure to formaldehyde.

7. Personal protective clothing, including gloves and aprons, should be provided to employees required to handle mixtures containing toluene (e.g., adhesive and paint) due to the potential for skin absorption.

8. Further sampling of employees for organic solvents should be conducted to further define exposures exceeding a mixed exposure of 0.50 and to evaluate the effect of ventilation improvements.

9. Employees should be informed of all hazards related to organic solvent exposure, including the additive effects of exposure to organic solvents in which the individual substances have similar toxicological effects. Employees should be informed of appropriate precautions to use to limit exposure, including safe work practices.

10. The company should continue educational efforts concerning carpal tunnel syndrome and should also study other alternatives, including tool redesign.

IX. REFERENCES

1. National Institute for Occupational Safety and Health. 1985 Supplement to NIOSH Manual of Analytical Methods, 3rd Edition. NIOSH Method No. 2500 for 2-Butanone. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1985. DHHS (NIOSH) Publication No. 84-100.

2. National Institute for Occupational Safety and Health. 1985 Supplement to NIOSH Manual of Analytical Methods, 3rd Edition. NIOSH Method No. 1501 for Aromatic Hydrocarbons. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1985. DHHS (NIOSH) Publication No. 84-100.

3. Documention of the Threshold Limit Values, Supplemental Documentation, 1983. American Conference of Governmental Industrial Hygienists (ACGIH) 4th Edition, Cincinnati, Ohio: ACGIH; 1980.

4. NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards, DHHS (NIOSH) Publication No. 81-123: U.S. Government Printing Office, Washington, D.C.; January 1981.

5. Proctor, N. H., J.P. Hughes, "Chemical Hazards of the Work Place". J.P. Lippincott Co., New York, 1978.

6. National Institute for Occupational Safety and Health (NIOSH). Current Intelligence Bulletin 48 - Organic Solvent Neurotoxicity. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1987. (DHHS (NIOSH) Publication No. 87-104).

7. National Institute for Occupational Safety and Health. Criteria for a recommended standard: occupational exposure to formaldehyde. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1977. (DHEW (NIOSH) publication no. 77-126).

8. Chemical Industry Institute of Toxicology, Progress Report on CIIT Formaldehyde Studies (January 16, 1980) Leon Goldberg, President, Research Triangle Park, NC.

9. National Institute for Occupational Safety and Health (NIOSH). Current Intelligence Bulletin 34 - Formaldehyde: Evidence of Carcinogenicity. Cincinnati, Ohio: National Institute for Occupational Safety and Health, 1981. (DHHS (NIOSH) Publication No. 81-111).

X. AUTHORSHIP AND ACKNOWLEDGMENTS

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XI. DISTRIBUTION AND AVAILABILITY

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from NIOSH, Publications Office, at the Cincinnati address.

Copies of this report have been sent to:

1. Devil's Lake Sioux Mfg. Corp., Fort Totten, North Dakota
2. U.S. Department of Labor/OSHA - Region VIII.
3. NIOSH, Denver Regional Office
4. Colorado Department of Health

For the purpose of informing affected employees, a copy of this report shall be posted in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE I

Personal Breathing Zone and General Area Air Concentrations For Xylene

Devil's Lake Sioux Manufacturing Corporation
Fort Totten, North Dakota

DATE	SAMPLE #	SAMPLING TIME	JOB/AREA	CONCENTRATION (mg/M^3)
3/17/87	1	7:51 - 3:22	Coating Room Op. #1/Coating Room	0.66
3/17/87	2	8:04 - 3:50	Mold Press Op. #1/Mold Press Area	0.63
3/17/87	3	8:13 - 3:38	Helmet Patch Op./Helmet Patch Table	0.87
3/17/87	4	8:19 - 3:34	Gluer #1/Glue To Rubber Edging Table	0.91
3/17/87	5	8:28 - 3:35	Gluer #2/Glue Spray Booth	0.83
3/17/87	9	8:42 - 3:36	Edger #3/Edging Table	6.44
3/17/87	10	9:01 - 3:41	Ink Stamp Op./Ink Stand	ND
3/17/87	11	9:12 - 3:21	Paint Mixing Area	1.55
3/18/87	1	7:44 - 3:50	Coating Room Op. #2/Coating Room	0.40
3/18/87	2	7:49 - 3:46	Painter/Paint Spray Booth	2.13
3/18/87	8	8:21 - 3:12	Mold Press Op. #2/Mold Press Area	1.53
3/18/87	9	8:23 - 3:12	Mold Press Op. #3/Mold Press Area	ND
3/18/87	10	8:35 - 3:37	Edging Table/General Area Air Sample	2.09

EVALUATION CRITERIA:

OSHA 434 mg/M^3
ACGIH 434 mg/M^3 (TWA)
NIOSH 434 mg/M^3 (TWA)

LABORATORY LIMIT OF DETECTION: 0.03 mg/sample

mg/M^3 = milligrams of substance per cubic meter of air
mg/sample = milligrams per sample
TWA = Time Weighted Average
ND = none detected

TABLE II

Personal Breathing Zone and General Area Air Concentrations For Toluene

Devil's Lake Sioux Manufacturing Corporation
Fort Totten, North Dakota

DATE	SAMPLE #	SAMPLING TIME	JOB/AREA	CONCENTRATION (mg/M^3)
3/17/87	1	7:51 - 3:22	Coating Room Op. #1/Coating Room	5.09
3/17/87	2	8:04 - 3:50	Mold Press Op. #1/Mold Press Area	0.46
3/17/87	3	8:13 - 3:38	Helmet Patch Op./Helmet Patch Table	4.80
3/17/87	4	8:19 - 3:34	Gluer #1/Glue To Rubber Edging Table	9.59
3/17/87	5	8:28 - 3:35	Gluer #2/Glue Spray Booth	31.3
3/17/87	9	8:42 - 3:36	Edger #3/Edging Table	7.92
3/17/87	10	9:01 - 3:41	Ink Stamp Op./Ink Stand	0.54
3/17/87	11	9:12 - 3:21	Paint Mixing Area	33.2
3/18/87	1	7:44 - 3:50	Coating Room Op. #2/Coating Room	2.38
3/18/87	2	7:49 - 3:46	Painter/Paint Spray Booth	7.45
3/18/87	8	8:21 - 3:12	Mold Press Op. #2/Mold Press Area	10.0
3/18/87	9	8:23 - 3:12	Mold Press Op. #3/Mold Press Area	2.33
3/18/87	10	8:35 - 3:37	Edging Table/General Area Air Sample	5.02

EVALUATION CRITERIA:

OSHA 754 mg/M^3
ACGIH 377 mg/M^3 (TWA), S
NIOSH 377 mg/M^3 (TWA)

LABORATORY LIMIT OF DETECTION: 0.01 mg/sample

mg/M^3 = milligrams of substance per cubic meter of air
mg/sample = milligrams per sample
TWA = Time Weighted Average
S = Skin absorption can be a significant factor in toxicity
ND = none detected

TABLE III

Personal Breathing Zone and General Area Air Concentrations For Hexane

Devil's Lake Sioux Manufacturing Corporation
Fort Totten, North Dakota

DATE	SAMPLE #	SAMPLING TIME	JOB/AREA	CONCENTRATION (mg/M^3)
3/17/87	1	7:51 - 3:22	Coating Room Op. #1/Coating Room	2.43
3/17/87	2	8:04 - 3:50	Mold Press Op. #1/Mold Press Area	1.89
3/17/87	3	8:13 - 3:38	Helmet Patch Op./Helmet Patch Table	2.18
3/17/87	4	8:19 - 3:34	Gluer #1/Glue To Rubber Edging Table	16.0
3/17/87	5	8:28 - 3:35	Gluer #2/Glue Spray Booth	83.3
3/17/87	9	8:42 - 3:36	Edger #3/Edging Table	12.9
3/17/87	10	9:01 - 3:41	Ink Stamp Op./Ink Stand	0.27
3/17/87	11	9:12 - 3:21	Paint Mixing Area	30.6
3/18/87	1	7:44 - 3:50	Coating Room Op. #2/Coating Room	0.99
3/18/87	2	7:49 - 3:46	Painter/Paint Spray Booth	5.32
3/18/87	8	8:21 - 3:12	Mold Press Op. #2/Mold Press Area	1.74
3/18/87	9	8:23 - 3:12	Mold Press Op. #3/Mold Press Area	0.93
3/18/87	10	8:35 - 3:37	Edging Table/General Area Air Sample	7.53

EVALUATION CRITERIA:

OSHA 1760 mg/M^3
ACGIH 180 mg/M^3 (TWA)
NIOSH 360 mg/M^3 (TWA)

LABORATORY LIMIT OF DETECTION: 0.01 mg/sample

mg/M^3 = milligrams of substance per cubic meter of air
mg/sample = milligrams per sample
TWA = Time Weighted Average
ND = none detected

TABLE IV

Personal Breathing Zone and General Area Air Concentrations For MEK

Devil's Lake Sioux Manufacturing Corporation
Fort Totten, North Dakota

DATE	SAMPLE #	SAMPLING TIME	JOB/AREA	CONCENTRATION (mg/M^3)
3/17/87	6	8:28 - 3:15	Gluer #3/Glue Spray Booth	310
3/17/87	7	8:39 - 3:37	Edger #1/Edging Table	253
3/17/87	8	8:40 - 3:36	Edger #2/Edging Table	49.0
3/18/87	3	7:55 - 3:12	Helmet Patch Op./Helmet Patch Table	20.0
3/18/87	4	9:45 - 3:37	Edging Table/General Area Air Sample	47.0
3/18/87	5	8:05 - 3:15	Edgint Table/General Area Air Sample	35.0
3/18/87	6	8:10 - 3:12	Gluer #3/Glue Spray Booth	257
3/18/87	7	8:12 - 3:12	Gluer #2/Glue Spray Booth	124

EVALUATION CRITERIA:

OSHA 590 mg/M^3
ACGIH 590 mg/M^3 (TWA)
NIOSH 590 mg/M^3 (TWA)

LABORATORY LIMIT OF DETECTION: 0.01 mg/sample

mg/M^3 = milligrams of substance per cubic meter of air
mg/sample = milligrams per sample
TWA = Time Weighted Average
ND = none detected