# HETA 95–0293–2655
# Dana Corporation, Spicer Axle Division
# Fort Wayne, Indiana

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# 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 or 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.

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# ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

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# Health Hazard Evaluation Report 95–0293–2655
# Dana Corporation, Spicer Axle Division
# Fort Wayne, Indiana
# October 1997

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## SUMMARY

In June 1995, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from the United Paperworkers International Union, Local 7903, to investigate (1) worker exposures to respiratory and dermatologic hazards from inhalation and contact with fungi– and bacteria–contaminated synthetic metal–working fluids (MWFs), oil mist, and grinding dust in the machining areas, and (2) ergonomic hazards at the Dana Corporation, Spicer Axle Division facility in Fort Wayne, Indiana.

In response to this request, an initial site visit was conducted on August 22–23, 1995, and a second site visit was conducted on June 19–20, 1996, to evaluate environmental exposures. A walk–through investigation of the north building, which contains the assembly area, was completed. An inspection of the make–up air units on the roof that served the south building was conducted, and the cleaning and performance of some of the SMOG HOG® air cleaning devices was observed. Personal breathing zone (PBZ) and area air samples were collected for phosphoric acid, oil mist, synthetic MWFs, ethanolamines, metals, and nitrosamines. Bulk MWF samples were collected for microbial, nitrosoamines, and ethanolamines analyses. A sample of flow–coat paint was collected for heated head–space analysis. Information was gathered from the Occupational Safety and Health Administration (OSHA) Log and Summary of Injuries and Illnesses (OSHA Form 200), and the occupational health nurse at the facility was interviewed.

A trace amount of phosphoric acid was detected in one sample in the large acid bath area. Oil mist, aluminum, iron, magnesium, molybdenum, and zinc air concentrations were below their respective occupational exposure limits. Area air concentrations of synthetic MWFs (collected as total particulates) ranged from 0.14 to 0.23 milligrams per cubic meter ($mg/m^3$), and PBZ concentrations ranged from 0.24 to 0.53 $mg/m^3$. One PBZ concentration, in a sample collected on an individual who worked at several operations at the transfer lines in Department 661, was over the proposed NIOSH recommended exposure limit (REL) of 0.5 $mg/m^3$ (total particulate) for MWFs.

Area air sample concentrations for ethanolamine were below the current occupational exposure criteria (range: trace to 0.19 parts per million [ppm]). The ethanolamine concentrations in the three bulk MWF samples were 1200 micrograms per milliliter of solution [µg/ml] (Unused Broach/Spec. 3364), 1300 µg/ml (Unused AP 7500), and 4000 µg/ml ("Unused" Reclaim). Traces of nitrosomorpholine were detected in the four area air samples. Nitrosoamines were not detected in the three bulk MWF samples. Several species of bacteria were found in the bulk MWF and sediment samples. The most prevalent species in terms of contamination of the most samples were *Clavibactor michiganese* ss *sepedonicum*, *Acinetobacter johnsonii*/Genospecies 7, and *Alcaligenes faecalis* ss *homari*. *Fusarium*, which produces mycotoxins, was the most prevalent fungi detected in the bulk and sediment samples.

Two of the SMOG HOG® air cleaning devices in Department 132 were not functioning. Potential sources of exhaust entrainment were noted during the inspection of the ventilation systems that serve the south building. Hydrochloric acid was the major decomposition product detected from heating the flow–coat paint used on some of the axles (employees were concerned about heating the paint during repair welding).

The workers do have skin exposure to MWFs and microbial contaminants and are at risk of developing dermatitis. Continued exposure to contaminated MWFs will likely result in increased employee complaints of skin and respiratory system irritation as well as skin and respiratory allergic sensitization among employees.

The industrial hygiene sampling data indicate that one worker was exposed to concentrations of synthetic MWF over the proposed NIOSH REL. Recommendations to reduce exposures to MWFs, improve the working environment, and establish an ergonomic program are provided in the Recommendations section of this report.

Keywords: SIC Code 3714 (Motor Vehicle Parts and Accessories), metal–working fluids, MWFs, ethanolamine, elements, nitrosoamines, oil mist, phosphoric acid, hydrochloric acid, microbial contamination, ergonomics.

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# INTRODUCTION

In June 1995, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from the United Paperworkers International Union, Local 7903, to investigate several occupational health issues at the Dana Corporation, Spicer Axle Division facility in Fort Wayne, Indiana. The HHE request described concerns over (1) worker exposures to respiratory and dermatologic hazards from inhalation and contact with microbial contaminants of metal–working fluids (MWFs), oil mist, and grinding dust in the machining areas, and (2) ergonomic hazards at the facility. In response to this request, an initial site visit was conducted on August 22–23, 1995, and a second site visit was conducted on June 19–20, 1996, to look at environmental exposures. A letter was sent to management and worker representatives in September 1995 to provide preliminary recommendations for both a medical and ergonomic surveillance program.

# BACKGROUND

The Dana Corporation, Spicer Axle Division, employing over 2,000 workers, produces axles for truck and recreational vehicles. The south building of the plant houses the machining areas, and the north building contains the painting and assembly areas. The facility operates 24 hours per day.

Six direct–heat make–up air units serve the south building. The units supply untreated outside air during the warmer months and supply air heated by natural gas in the colder months. Three different bath areas are located in the south building — the phosphoric acid bath, the alkaline bath, and the sodium nitrite salt bath.

The two synthetic MWFs in use at the facility are Metalub 3364® and Melkool AP 7500®, manufactured by Metal Lubricants Company, Harvey, Illinois. Broach machines use Metalub 3364® and grinders use Melkool AP 7500® from separate central tanks. These two coolant streams are combined and continuously recycled for use in lathes and drills. The composition of the recycled coolant (referred to as "Reclaim MWF") varies and is brought up to the appropriate volume using Melkool AP 7500®. The active components of these materials are 1–propoxy–2–propanol and s–triazine–1,3,5(2H,4H,6H)–triethanol, and 2–(hydroxymethylamino)–ethanol and monoethanolamine, for Metalub 3364 and Melkool AP 7500, respectively. The biocide used is Busan 1060® manufactured by Buckman Laboratories, Inc., Memphis, Tennessee. Hexahydro–1,3–tris(2–hydroxyethyl)–s–triazine, which releases formaldehyde, is the active biocidal agent in Busan 1060®.[1] Melchem C–65® and SPEC 5925, manufactured by Metal Lubricants Company, are used as a corrosion inhibitor (amine borate mixture) and a pH additive (potassium hydroxide), respectively. Metalite SGC 62D–Bulk is used as the machine cleaner. It has biocidal activity, can be used for pH control (potassium hydroxide), and contains monoethanolamine and triethanolamine.

A contractor from the Metal Lubricants Company monitors the MWFs pH levels, bacterial growth (bi–weekly using the dipslide method), and other factors such as tramp oil and concentration for specific machines using the different MWFs. Changes are made to the coolants, such as biocide or pH additions, based on these results. Initial environmental bulk sampling results for sediment provided by the company indicated that gram–negative bacteria and fungi (predominantly *Cylindrocorpum* and *Fusarium*) were present on machine surfaces in Departments 354, 356, and 375.

The scheduling of routine machine cleaning, which usually consists of emptying the machine, removing metal chips, and refilling the coolants, varies between departments based on production needs. Complete machine cleaning is ordered by the department supervisors and is completed when the maintenance work schedule permits. There is no set schedule for complete cleaning of the machines.

Exposure to oil mist and grinding dust were a concern in the machining areas. According to union representatives, employees in Departments 132, 152, and 172 seemed to have the most concern about oil mist and grinding dust exposures. Depending upon the part produced, the machines use either straight or synthetic MWFs. Union and management representatives reported that the oil mist problems are worse during the cooler months when the windows along the top of the walls are closed. In general, for control of environmental emissions, the SMOG HOG® is the air cleaning device used in these three departments. The ceiling–mounted SMOG HOGs use two–stage electrostatic precipitators to remove particles from the air. Each unit serves two to six machines. FILTERMIST® air cleaning devices are also in place in these areas. This device uses centrifugal impaction to remove about 95% of particles in the 0.5–10 micron range.

# METHODS

On the first site visit in August 1995, records were collected, including the Occupational Safety and Health Administration (OSHA) Log and Summary of Injuries and Illnesses (OSHA Form 200), meeting minutes of the coolant safety committee since February 1995, material safety data sheets (MSDSs) for the MWFs and their additives, coolant screening data, air sampling data, documentation on air cleaning systems, and a written respirator policy. In addition, the occupational health nurse was asked to describe any efforts directed at maintaining a surveillance system of occupational dermatoses or ergonomic injuries. A walk–through inspection of the north building, which contained the assembly area, was completed. An inspection of the make–up air units on the roof that served the south building was conducted, and the cleaning of a SMOG HOG® air cleaning device was observed. On the second site visit in June 1996, environmental samples were collected for the substances listed below and the performance of some of the SMOG HOG® air cleaning devices was evaluated.

## Industrial Hygiene

### *Phosphoric Acid*

Five area air samples for phosphoric acid were collected in two areas of the plant (three near the large acid bath in the lower north–west corner of the facility, and two near the acid bath line in the center of the facility). The area air samples were collected at a flowrate of 0.02 liters per minute (L/min) using solid sorbent tubes (silica gel) and analyzed for phosphoric acid according to NIOSH Method 7903 using ion chromatography.[2] The analytical limit of detection (LOD) was 10 micrograms (µg), which is equivalent to a minimum detectable concentration (MDC) of 0.12 milligrams per cubic meter (mg/m$^3$), assuming a sample volume of 82.6 liters. The limit of quantitation (LOQ) was 34 µg, which is equivalent to a minimum quantifiable concentration (MQC) of 0.41 mg/m$^3$, assuming a sample volume of 82.6 liters.

### *Oil Mist*

One area and eight personal breathing zone (PBZ) air samples were collected for oil mist on mixed–cellulose ester filters (37 millimeter [mm] diameter, 0.8 micrometer [µm] pore size) using a flowrate of 2.0 L/min. The filters were analyzed for oil mist according to NIOSH Method 5026 using infrared spectrometry.[3] The LOD was 9 µg, which is equivalent to a MDC of 0.01 mg/m$^3$, assuming a sample volume of 724 liters. The LOQ was 30 µg, which is equivalent to a MQC of 0.04 mg/m$^3$, assuming a sample volume of 724 liters.

### *Synthetic Metal–Working Fluids*

Six PBZ and four area air samples for synthetic MWFs were collected on tared polyvinyl chloride filters at a flowrate of 2 L/min. The samples were analyzed according to NIOSH Method 0500 for total weight using gravimetric analysis.[4] The LOD was 0.02 mg, which is equivalent to a MDC of 0.03 mg/m$^3$, assuming a sample volume of 682 liters.

### *Ethanolamines*

Six area air samples for ethanolamines were collected using impingers containing 2 millimolar hexanesulfonic acid at a flowrate of 1.0 L/min. The samples were analyzed according to NIOSH Method 2546 using ion chromatography.[5] The LODs were 20 µg for monoethanolamine and diethanolamine, and 60 µg for triethanolamine, which are equivalent to MDCs of 0.022 ppm, 0.013 ppm, and 0.028 ppm, respectively, assuming sample volumes of 368 liters. The LOQs were 67 µg for monoethanolamine and diethanolamine, and 190 µg for triethanolamine, which are equivalent to MQCs of 0.073 ppm, 0.042 ppm, and 0.089 ppm, respectively, assuming a sample volume of 368 liters. Three bulk samples of unused synthetic MWFs (one of each type) were collected and analyzed using the same analytical method.

### Metals

Nine PBZ and three area air samples were collected for selected metals on mixed–cellulose ester filters (37– mm diameter, 0.8–µm pore size) using a flowrate of 2.0 L/min. The filters were wet–ashed with nitric and perchloric acid and the resulting solution allowed to evaporate. The residues were dissolved into a nitric acid/perchloric acid solution and the resultant sample solutions were analyzed for metals according to NIOSH Method 7300[6], using inductively coupled plasma–atomic emission spectrometry. The laboratory–assigned LOQ for the sample set was 1.2 µg per filter, which is equivalent to a MQC of 0.0018 mg/m$^3$, using a sample volume of 676 liters.

### Nitrosamines

Four area air samples were collected for nitrosamines on Thermosorb/N™ using a flowrate of 2.0 L/min. The samples were desorbed into a solvent mixture of 75% dichloromethane and 25% methanol by volume. The desorbed samples were analyzed according to OSHA Method 27 using gas chromatography with a thermal energy analyzer (GC/TEA) and by high–resolution gas chromatography/mass spectrometry (GC/MS). The LODs for nitrosomorpholine were both 0.01 µg/sample, which are equivalent to MDCs of 0.02 µg/m$^3$, assuming sample volumes of 468 liters. The LOQ for nitrosomorpholine using the OSHA Method 27 was 0.044 µg/sample, which is equivalent to a MQC of 0.077 µg/m$^3$, assuming a sample volume of 468 liters. Three bulk samples of unused synthetic MWFs (one of each type) were collected and analyzed using the same analytical methods.

### Flow–Coat Paint

A bulk sample of hardened black flow–coat paint was submitted for head–space analysis of volatile organic compounds. The sample was heated to 300°C for 10 minutes to represent repair welding activities and analyzed using the Perkin–Elmer ATD thermal desorption unit in conjunction with a gas chromatograph and mass selection detector.

### SMOG HOG® Ventilation Measurements

Face velocity was measured for nine hoods attached to SMOG HOG® devices (three in Department 172 and six in Department 132). The measurements were made using a TSI VelociCalc Plus Model 8360® thermoanemometer. This instrument measures air velocity by detecting the cooling effect of air as it passes over a heated (hot–wire) filament at the end of the probe. The average velocities and flowrates were calculated.

## Microbial Samples

Twenty–one liquid bulk MWF samples and three sediment samples were collected from machines throughout the plant. Dilutions of the samples ($10^{-1}$ to $10^{-6}$) were plated on R2A agar for bacterial analysis and on malt extract agar for fungal analysis. The plates for bacterial analysis were incubated for 48–72 hours at 29°C, and the colonies were counted and speciated. The plates for fungal analysis were incubated for 96–120 hours at 25°C, and the colonies were counted and the genus identified.

## Epidemiologic Activities

The HHE request indicated that dermatologic and respiratory effects associated with exposure to MWFs colonized with bacteria and fungi, and ergonomic stressors in the assembly area, were issues of concern among employees. In order to gather information about these concerns, NIOSH investigators conducted a review of the 1994 and 1995 OSHA Log and Summary of Occupational Injuries and Illnesses (OSHA 200 logs), and interviewed the plant occupational health nurse and employee/management representatives.

# EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators employ environmental evaluation criteria for the assessment 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 even though 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 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 Recommended Exposure Limits (RELs),[7] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[8] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs).[9] In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH® TLVs®, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

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 (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short–term.

# Metal–Working Fluids (MWFs)

MWFs were developed to extend the tool life of metal–working machinery by reducing friction between the work surface and cutting tools, reducing the surface tension, taking away excessive heat, and washing away metal chips. There are four major classes of MWFs: straight MWFs (mineral and fatty oils); soluble MWFs (mineral and fatty oils emulsified with water); synthetic MWFs (solutions of inorganic salts, and organic compounds in water); and semi–synthetic MWFs (mineral oils, inorganic salts, and organic compounds emulsified with water). A variety of additives can be present in MWFS to meet specific operational requirements. These additives can improve coolant and lubricating effects and prevent bacterial build–up, corrosion, or rust.

## Health Effects

Dermatoses are considered a common health effect from skin exposure to MWFs.[10] The straight (mineral) oils have been historically associated with folliculitis (oil acne). The majority of occupational dermatitis cases in machinists are likely due to exposure to water–based MWFs (emulsified oil and synthetic machining fluids).[11] Both irritant and allergic contact dermatitis have been documented.[12,13] Additives such as amines, petroleum sulfonate, and biocides are also associated with irritant contact dermatitis, and isothiazalones, formaldehyde, and mercaptobenzothiazoles, and possibly the biocides can cause allergic contact dermatitis. The alkalinity of the fluid is also a risk factor for contact dermatitis.

Chronic exposure to MWFs has resulted in an increased prevalence of respiratory symptoms, such as cough and phlegm. Kennedy and associates conducted a pulmonary study of employees from two facilities (one produced gears and axles; the other manufactured automatic transmission pads).[14] The study compared cross–shift lung function changes among machine operators who had been exposed to machining fluids to lung function results among unexposed assembly workers at the same facilities. The study found that machine operators exposed to various MWFs were significantly more likely to have an acute drop in forced expired volume in 1–second ($FEV_1$) than unexposed workers. The investigation also found a correlation between a cross–shift decrease in $FEV_1$ to increasing air concentration of inhalable aerosol (above approximately 0.2 $mg/m^3$). In another study, some workers had asthmatic responses to unused MWFs while others responded to used MWFs, suggesting that different agents in these fluids may be responsible for asthma in different employees.[15]

Carcinogenicity has been difficult to characterize due to long latency and changing composition of metal–working fluids. Several studies have been conducted that looked at the issue of carcinogenicity. Excesses of respiratory, gastrointestinal, pancreatic, and skin (scrotal) cancers have been noted among workers exposed to MWFs.[16,17,18,19,20] The International Agency for Research on Cancer (IARC) determined that there is sufficient evidence for carcinogenicity to humans, based on epidemiologic studies of uncharacterized mineral oils containing additives and impurities; there is inadequate evidence for carcinogenicity to humans for highly refined oils.[21] Eisen and associates in a case–control study demonstrated a two–fold excess of cancer of the larynx in machinists in the automotive industry.[22] This study found an association between the excess larynx cancer risk and exposure to straight mineral oils. There was also an association with elemental sulfur which is added to MWFs to maintain physical properties under extreme pressure and high temperature.

## Microbial Contamination

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. MWFs provide the necessary conditions such as water and nutrients for the growth of microorganisms.[23,24,25] Both bacteria and fungi have been identified in MWFs, and biocide addition is the most common method for controlling the growth. Three major groups of organisms have been noted in MWFs: obligate anaerobes (sulfate reducers), specifically Desulfovibrio desulfuricans; aerobic bacteria, especially Pseudomonas species and coliforms; and imperfect fungi, including members of the genus Fusarium, Cephalosporium, and Candida.[24]

Some individuals manifest increased immunologic responses to bacteria, fungi, or their metabolites encountered in the environment. These responses and the subsequent expression of allergic disease is based, partly, on a genetic predisposition. Allergic respiratory diseases resulting from exposures to microbial agents have been documented in agricultural, biotechnology, machining, office, and home environments.[26,27,28,29,30,31,32,33,34] Acceptable levels of airborne microorganisms or bioaerosols have not been established, primarily because allergic reactions can occur even with relatively low air concentrations of allergens, and individuals differ with respect to immunogenic susceptibilities.

Endotoxins are lipopolysaccharide components found in the cell wall of gram–negative bacteria; they are chemically stable, heat–resistant, and maintain their biological activity even when the original cell is dead. Exposure to endotoxins has been associated with fever, fatigue, and decreased pulmonary function.[35,36,37] Fusarium produce mycotoxins, including trichothecenes, which have been associated with headache, dizziness, and immunosuppression, and zearaleone which has been associated with hyperestrogenism.[38]

Although some pathogenic organisms have been identified in oil emulsion MWFs in the past,[39,40] most pathogens do not persist well in MWFs.[41,42,43,44] One major outbreak of illness occurred at an engine manufacturing plant when the biocide failed to control microbial growth, which resulted in an overgrowth of Legionella feeleii and more than 300 workers developed Pontiac fever.[45] A Swedish study showed that metal workers exposed to aerosol from MWFs that contained Pseudomonas pseudoalcaligenes, developed antibodies against the bacteria. However, the employees reported no acute or chronic respiratory discomfort resulting from this exposure.[46] In a U.S. automobile parts manufacturing plant, six employees who worked in a machining area that used water–based MWF developed work–related cough, dyspnea (shortness of breath), and fatigue.[47] The employees were diagnosed as having hypersensitivity pneumonitis (HP), an immune–mediated disorder which develops after exposure to bacterial or fungal antigens in organic materials. The study found antibodies to Pseudomonas fluorescens in all six workers but no antibodies were found in the non–exposed comparison employees. All six workers also had antibodies to at least one other organism that had been cultured from the MWFs.

## Occupational Exposure Criteria for MWFs

Several factors can affect the employee's exposure to MWFs. These factors can include the type of local ventilation controls, the distance from the source of contaminant generation, and indoor environmental parameters such as temperatures and humidity.[48] Occupational exposure criteria for mineral oil mists have been established. OSHA has an 8–hour TWA PEL of 5 mg/m$^3$.[9] The NIOSH REL is 5 mg/m$^3$ for a 10–hr TWA and a short–term exposure limit of 10 mg/m$^3$.[7] The American Conference of Governmental Industrial Hygienists (ACGIH) also has a Threshold Limit Value (TLV) for oil mist of 5 mg/m$^3$ for an 8–hr TWA.[8] ACGIH has also published an intended change which would establish a TLV of 5 mg/m$^3$ for an 8–hr TWA for severely refined mineral oil mist and a TLV of 0.2 mg/m$^3$ for an 8–hr TWA for mildly refined mineral oil mist.[8] However, since the role of additives and oil fume from partial heat–decomposition have yet to be completely evaluated experimentally, NIOSH suggests that these criteria may not be applicable to all forms of oil mists.[49]

Water–soluble MWFs cannot be analyzed using the oil mist sampling method. Thus, a total mass measurement is made, knowing that the water–soluble oil portion of the sample collected must be less than the total mass. This measurement is the same one that is used for particulates not otherwise classified (PNOC). At this time, there is no generic occupational exposure standard or guideline for water–soluble MWFs. NIOSH has proposed a REL of 0.5 mg/m$^3$ of total particulate for these water–soluble MWFs.[50] There are no occupational exposure criteria that address microbial contamination in MWFs.

## Metals

A list of selected metals along with a brief summary of their primary health effects and the evaluation criteria for occupational exposures to these contaminants is presented in Table 1.

## Ethanolamines

Ethanolamines (EAs), which include monoethanolamine (MEA), diethanolamine (DEA), and triethanolamine (TEA), are used in MWFs as corrosion inhibitors or for adjusting pH. Inhalation exposures to MEA have been reported to cause asthma. There have also been case reports of asthma associated with EAs in spray painting and aluminum soldering operations.[51,52]

One study has determined the levels of EAs in bulk MWF samples and personal air samples that were collected at automobile parts manufacturing facilities.[53] The concentrations of MEA, DEA, and TEA in the bulk samples were found to range from 1%–11%, 4%–5%, and 0.3%–40%, respectively. The investigation found that the PBZ concentrations of TEA varied among machining operations and did not necessarily correspond to the amount of TEA in the MWF used in that operation.

OSHA has established an 8–hr TWA PEL of 3 parts per million (ppm) for ethanolamine.[9] ACGIH® has established 8–hr TWA TLV®s for ethanolamine, diethanolamine, and triethanolamine of 3 ppm, 0.46 ppm, and 5 mg/m$^3$, respectively.[8] NIOSH has established 10–hr TWA–RELs of 3 ppm for both ethanolamine and diethanolamine.[7]

## Inorganic Acids

Inorganic acids, including hydrochloric acid and phosphoric acid, are primary irritants and are corrosive in high concentrations.[54,55] These acids will cause chemical burns when in contact with the skin and mucous membranes, and are a particular hazard to the eye. Vapors and mists are respiratory tract irritants, and ingestion of inorganic acids can result in severe tissue destruction in the throat and stomach. The NIOSH REL, OSHA PEL, and ACGIH® TLV® for hydrochloric acid are 7.0 mg/m$^3$, 7.0 mg/m$^3$, and 7.5 mg/m$^3$ as ceiling values.[7,8,9] The NIOSH REL, OSHA PEL, and ACGIH® TLV® for phosphoric acid are all 1 mg/m$^3$ as a TWA.[7,8,9]

## Nitrosamines

Nitrosamines are compounds characterized by the –N—N=O functional group. They result from the combination of primary, secondary, or tertiary amines with nitrite. Occupational exposures have been observed in rubber industries, leather tanning industries, metal–working industries, chemical industries, mining, pesticide production, detergent production, and fish factories. Nitrosamines have been detected as a contaminant in MWFs.[56,57] They can also be generated when MWFs containing ethanolamines are used in conjunction with a salt bath containing sodium nitrite.

Most nitrosamines are suspected to be human carcinogens, but direct causal associations have not yet been proven. One study examined cancer morbidity among employees of a Swedish bearing ring manufacturer.[58] The cohort study compared men who had worked at least one year with MWFs that contained amines and nitrates with the general population of the same city. The employee population was followed from 1966 to 1983. There was no difference between the two populations in terms of cancer deaths. In 1956, Magee and Barnes demonstrated the carcinogenic potential of nitrosodimethylamine (NDMA) in rats.[59] Since then, nitrosamines have been studied extensively in laboratory animals. Approximately 90% of the 300 tested nitrosamines have shown carcinogenic effects in bioassays and laboratory animals. Of the approximately 40 animal species tested, none has been resistant. Nitrosamine affects have been demonstrated in the bladder, bronchi, central nervous system, earduct, esophagus, eyelid, duodenum, forestomach, glandular stomach, hematopoietic system, intestine, jaw, kidney, larynx, nasal cavity, oral cavity, ovary, liver, mammary glands, pancreas, pelvis, peripheral nervous system, pharynx, respiratory tract, skin, testes, trachea, uterus, and vagina.[60]

All of the biochemical, pathological, and experimental data provide little evidence that humans might be resistant to the carcinogenic potential of nitrosamines.[61] Human tissues from the trachea, lung, esophagus, colon, pancreatic duct, bladder, and buccal mucosa have been shown to metabolize nitrosamines into DNA–binding compounds.[61] Human liver tissue appears to metabolize nitrosamines with a similar activity to rodent liver tissue, and rodents have similar acute symptoms of liver necrosis and cirrhosis that have been observed in humans.[61] A few human DNA adduct studies have revealed higher levels of nitrosamine–related DNA adducts in cancer cases than in controls.[62,63] Studies in experimental animals have shown similar DNA adduct formation to those detected in the human studies.[64,65,66]

Only one nitrosamine, nitrosodimethylamine, is regulated in the United States. Both OSHA and NIOSH consider NDMA to be an occupational carcinogen. NIOSH recommends that its exposure be reduced as much as possible and OSHA regulates its' handling and conditions of use. There are no established numerical exposure limits for nitrosamine in the United States. Germany, however, has strict regulations for occupational exposures to nitrosamines. In general industry, the total exposure to all nitrosamines present may not exceed 1 microgram per cubic meter ($\mu g/m^3$). In special cases, such as tire storage warehouses, exposures to all nitrosamines present may not exceed 2.5 $\mu g/m^3$. In addition to these regulations, eight nitrosamines are regulated individually in Germany: nitrosodimethylamine, nitrosomorpholine, nitrosopiperidine, phenyl-ethylnitrosamine, phenyl–methylnitrosamine, di–N–butylnitrosamine, di-iso-propylnitrosamine, and diethylnitrosamine.

## Ergonomics

The component of ergonomics (i.e. the study of the interrelationship between the individual and the physical work environment) that has gained considerable attention in recent years involves work conditions associated with musculoskeletal disorders. Musculoskeletal disorders refer to injuries involving nerves, muscles, tendons and bones. Occupational and non–occupational factors can contribute to the development and exacerbation of these conditions. These disorders have also been referred to in the literature as cumulative trauma disorders, repetitive strain injuries, repeated motion disorders, repetitive trauma disorders, and overuse syndromes.[67,68,69] Briefly, the risk factors associated with work–related musculoskeletal disorders (WMSDs) include forceful exertion, awkward postures, repetitive movements, temperature extremes, and vibration.[68] Given an understanding of the conditions that increase a worker's risk of musculoskeletal injury, it becomes the goal of an ergonomics program to identify, modify, or redesign specific work tasks to prevent the development of WMSDs.

# RESULTS/DISCUSSION

## Industrial Hygiene

### Phosphoric Acid

The results of the phosphoric acid environmental sampling are presented in Table 2. A trace amount of phosphoric acid was detected in one sample in the large acid bath area. Phosphoric acid was not detected in the other four area air samples.

### Oil Mist

The results for the straight oil mist sampling are presented in Table 3. The oil mist air concentrations ranged from 0.08 to 0.33 mg/m$^3$, well below the occupational exposure limit of 5 mg/m$^3$.

## Synthetic Metal–Working Fluids

The results for the synthetic MWF sampling are shown in Table 4. The four area air concentrations ranged from 0.14 to 0.23 mg/m$^3$. The PBZ air sample concentrations ranged from 0.24 to 0.53 mg/m$^3$. The one PBZ concentration that was over the proposed NIOSH REL of 0.5 mg/m$^3$ was collected on an individual who was working at several operations at the transfer lines in Department 661. Two other PBZ samples were close to the proposed standard (0.43 and 0.46 mg/m$^3$), indicating a potential for over–exposure to MWFs.

## Metals

The nine PBZ and three area air sample concentration results for metals are shown in Table 5. The air concentrations of aluminum (none detected to 0.024 mg/m$^3$), iron (none detected to 0.023 mg/m$^3$), magnesium (none detected to 0.003 mg/m$^3$), molybdenum (none detected to 0.002 mg/m$^3$), and zinc (none detected to 0.003 mg/m$^3$) were well below their respective occupational exposure limits.

## Flow–Coat Paint

Hydrochloric acid was the major decomposition product detected in the head–space analysis of the flow–coat paint. The high temperature was used to represent repair welding. Other compounds identified were numerous chlorinated aliphatics and aromatics, propanoic acid esters, propanal, p–dioxane, methyl methacrylate, and $C_8H_{12}$ isomers. A copy of the ion chromatogram is included in Appendix A.

## Ethanolamines

The area air sampling results for ethanolamine are shown in Table 6. Sample concentrations (range: trace to 0.19 ppm) were all below current occupational exposure limits. Diethanolamine and triethanolamine were not detected in the area air samples at MDCs of 0.013 ppm and 0.028 ppm, respectively. The ethanolamine concentrations in the three bulk MWF samples were 1200 µg/ml (Unused Broach/Spec. 3364), 1300 µg/ml (Unused AP 7500), and 4000 µg/ml ("Unused" Reclaim).

## Nitrosamines

The environmental sampling results for nitrosoamines are presented in Table 7. Traces of nitrosomorpholine were detected in the four area air samples. The other six nitrosamines (nitrosodimethylamine, nitrosopyrrolidine, nitrosopiperidine, nitrosodibutylamine, nitrosodipropylamine, and nitrosodiethylamine) were not detected in any of the samples at the MDCs. Nitrosamines were not detected in the three bulk MWF samples.

## Microbial Sampling

The microbial sampling results are given in Table 8. Several species of bacteria were found in the bulk MWF and sediment samples. Clavibactor michiganese ss sepedonicum was detected in five bulk samples, Pseudomonas alcaligenes B in three bulk samples, Acinetobacter johnsonii/Genospecies 7 in four bulk samples, Acinetobacter lwoffii/Genospecies 8 in one bulk and one sediment sample, Alcaligenes faecalis ss homari in three bulk samples, Leucibistoc paramesenteroides in one bulk sample, Comamonas terrigena in one bulk and one sediment sample, and Buttiauxella agrestis in one bulk and two sediment samples. Aeromonas media–like DNA group 5A was found in one sediment sample. The concentrations were highly variable between samples, ranging from $1x10^3$ to $2.6x10^8$ CFU/milliliter or gram of material.

Fusarium was the fungus found in the most samples (six bulk and three sediment samples); Sporotrichum was detected in two bulk and one oil sample; yeast was detected in two bulk and one sediment samples; and Aspergillus terrus was found in one sediment sample. No bacteria were found in the oil samples; low levels of fungi were detected in two oil samples (Cladosporium, Sporotrichum, Penicillium). The concentrations were highly variable between samples, ranging from $1x10^1$ to $2.35x10^6$ CFU/milliliter or grams of material.

All of the bacterial species identified are commonly found in the outdoor environment. Pseudomonas, Acinetobacter, and Buttiauxella are opportunistic pathogens that can infect immunocompromised people. Pseudomonas, Acinetobacter, Alcaligenes, and Buttiauxella are gram–negative species which produce endotoxins. Endotoxins have been associated with various health effects including fever and reduced pulmonary function. Some Fusarium species produce mycotoxins which can cause adverse health effects. According to employees and management representatives, several of these machines had been cleaned shortly before these samples had been collected which could contribute to the relatively low bacteria counts in some samples.

## Air Cleaning Device Evaluation

The SMOG HOG® air cleaning device is used in Departments 132, 152, and 172. The ceiling–mounted units use two–stage electrostatic precipitators to remove about 95% of particles in the 0.5–10 micron range. The units are cleaned monthly by two individuals who replace the metal filters with clean filters, check the motor fan belt, clean the springs, wipe out excess oil that has accumulated in the bottom of the unit, and qualitatively check for airflow.

The average face velocity and average flowrate for each SMOG HOG® device with a measurable face velocity are shown in Table 9. The average face velocity and average flowrate varied between units. The equipment manual indicates that the units' face velocities were set at the factory but should be verified at installation and 48 hours after installation to make sure the units are performing at specification. According to employees, the face velocities were not measured, rather a qualitative assessment was made to determine if there was any airflow. Information concerning the manufacturer's factory–set face velocities was not available. Two ventilation hoods, connected to SMOG HOG® devices in Department 132, did not have any measurable airflow. This was reported to management and union representatives who said that these units are the oldest in the plant and have been in operation for about 30 years.

A few FILTERMIST® air cleaning devices are also used in these departments. This device uses centrifugal impaction to remove about 95% of particles in the 0.5 to 10–micron range. Maintenance is performed on these units only when a malfunction occurs. According to manufacturer specifications, these units should be cleaned annually.

## Other Observations

Six direct–heat make–up air units serve the south building. The units supply untreated outside air during the warmer months and supply air heated by natural gas in the colder months. There are no filters for these units. There were no balancing records available for these make–up air units. During the evaluation of these units, we noted that the exhausts for the heat–treat furnaces could potentially be entrained into the plant through the make–up air units, depending on wind direction. Some of the machines which used MWFs also exhausted into the walk way on the roof about 12 feet from the open windows for another portion of the plant; this could also lead to entrainment of air contaminants. Union and management representatives reported that the general air quality in the facility worsens during the cooler months when the windows along the top of the walls are closed. There were some local exhaust ventilation controls in operation but there was visible overspray on some of the machines using synthetic MWFs.

# Health Effects

In response to the HHE request to evaluate both the dermatologic and respiratory effects associated with exposure to MWFs colonized with bacteria and fungi, the 1994 and 1995 OSHA 200 logs were examined. While reports from the union representatives indicated that workers were complaining of breathing difficulties related to the MWFs and biocide additives, none of the OSHA 200 log entries for 1994 or 1995 included any respiratory illnesses, however, eight cases of irritant dermatitis were listed. Discussions with the occupational health nurse indicated that some employees routinely visit the clinic with complaints of allergic respiratory symptoms; however, the clinic personnel generally attribute these symptoms to seasonal allergies.

Employee complaints of allergic symptoms (nasal congestion, runny nose, itchy watery eyes, etc.) may be the result of seasonal allergies or may be a reaction to constituents or contaminants of the MWFs. Given an absence of any notation in the OSHA 200 logs for respiratory illness, and the lack of a clinic log that describes the nature of each employee visit to the clinic, there was not enough information available to ascertain whether or not worker respiratory complaints were indeed related to working conditions.

The magnitude of the ergonomic problems at the Dana Spicer Axle plant is presently difficult to evaluate and quantify due to incomplete record keeping. OSHA 200 logs for 1994 and 1995 list 13 cases (in a worker population of approximately 2000) in which a disorder was related to cumulative trauma. These cumulative trauma disorders include 2 of the hand, 1 of the elbow, 4 of the wrist, and 2 of the arms. In contrast, a representative from the health clinic reported that approximately 40–60 persons are treated each year for lateral epicondylitis by air splinting and, in some cases, injection of the site to relieve pain. None of the cases of lateral epicondylitis appeared on the OSHA injury and illness logs. In addition to the cumulative trauma disorders mentioned in the OSHA 200 logs, and anecdotal reports of lateral epicondylitis, the OSHA 200 logs did show frequent injuries involving the lower back, upper back, and shoulders. Low back strain and sprain was most common in the axle shafts, tubes, and carrier lines. Upper back and shoulder strain were noted most often in the knuckles, axle shafts, variable shafts, and assembly lines.

Potentially complicating the assessment of ergonomic conditions at this plant is the worker incentive program and its impact upon the pace, effort, and duration of work cycles. Work teams are allowed to set the pace and production goal for the group, and thereby, the rate at which the team will be compensated. Rates of production, reported by both representatives of Dana management and the union, ranged from 105% to 170% of base rate. (The base rate for each production step was established during a time and motion study conducted in 1965.) Because faster work groups tend to earn higher rates of pay, positions on fast work teams are in demand by the employees. Thus, according to the union representatives, fast work teams generally consist of workers with greater seniority, while jobs that are slower or are associated with a slow machining process in which the base rate is difficult to exceed, are held by low seniority and/or female employees.

To design an effective ergonomics program at Dana Corporation, an understanding of each production step and an awareness of which phases of the process put employees at increased risk of WMSD is required. Thus, an effective ergonomics program is virtually impossible without accurate medical/safety surveillance for musculoskeletal disorders that details the production process involved and the frequency of occurrence. As described above, the OSHA 200 log presently fails to capture the full spectrum of musculoskeletal disorders among the workers (cumulative trauma disorders are incorrectly charted in column 7g rather than 7f, and many of these disorders are apparently not getting recorded). Furthermore, once the production areas of greatest risk are determined, an effective ergonomic program will have to evaluate the potential contribution to musculoskeletal disorders that may be attributed to the existing wage incentive program and the pace of work that it promotes.

Employees did have skin contact with the MWFs, and informal conversations with some of the employees revealed that there were complaints of skin irritation that the workers associated with working with the MWFs.

# CONCLUSIONS

Among the many industrial hygiene samples collected during this health hazard evaluation, one PBZ sample for MWFs exceeded the proposed NIOSH REL and two were close to that level. However, it should be understood that the MWF reservoirs observed at this plant are grossly contaminated with microorganisms. Overall, the machines have a dense biomass on internal and external surfaces, and this biomass readily contaminates and recolonizes any fresh MWFs that are added to the machine's MWF reservoir. Thus, because the machines are not thoroughly cleaned prior to adding new MWFs, the MWFs continue to be contaminated, and workers continue to be exposed to these contaminated MWFs. Continued exposure to contaminated MWFs will likely result in increased employee complaints of skin and respiratory system irritation and possibly skin and respiratory allergic sensitization among employees.

The following recommendations are offered to reduce employee exposures to MWFs, to obtain information on possible illnesses and/or injuries associated with the workplace, and to develop an ergonomics program for the facility.

# RECOMMENDATIONS

(1) Proper management of MWFs plays an important part in reducing potential health effects related to working with MWFs. A thorough preventive maintenance program should be developed and implemented for all MWF systems and machine tools. This type of program should follow, at a minimum, the recommendations of the MWF and machine tool manufacturers. The following are important factors to consider in planning this program. Thorough cleaning of machines is important to prevent recontamination of MWFs with bacteria and fungi.

- Frequent and consistent monitoring of MWF concentrations and bacterial growth, the appropriate use of additives (such as biocides), and routine cleaning (including cleaning of associated ventilation equipment such as mist collectors and washers) should be performed. A record should be maintained of these activities.

- Any preventive maintenance program developed should include plans for staffing that is adequate to perform the necessary maintenance duties;

- Employees and management should be educated about the MWF systems and the importance of proper fluid management.

(2) Employees should be encouraged to report all possible work–related health problems to the medical department. These problems should be investigated on an individual basis by the company and consulting health care providers. Each person with potential work–related health problems should be fully evaluated by a health care professional, preferably one with expertise in occupational health. In some cases, reassignment to areas where exposure is minimal or nonexistent may be necessary to control health problems. The Dana Corporation physician and clinic nurses should maintain a log of all clinic visits. The log should include the reason for the employee's visit. This surveillance procedure would help determine whether various conditions have a work– related etiology and may provide early detection of problem areas.

(3) In order to reduce dermal (skin) exposure to MWFs, the following preventive measures could be used:

- Substitution of MWFs, additives, or constituents as appropriate (several studies have indicated varying skin irritancy potential for different types of MWFs);

• Process modification, isolation, and ventilation to limit the dispersal of MWFs;

**• Work practice and administrative controls to assure the proper maintenance of MWFs and workplace cleanliness;**

**• The proper use of personal protective equipment such as protective, impermeable gloves (not cotton), aprons, and clothing;**

**• Education and training for employees regarding the dermal effects of MWFs and the importance of workplace personal hygiene is very important. MWF–saturated clothing should be changed as soon as possible and skin surfaces that have come in contact with MWFs should be washed as soon as possible with non–irritating and non–abrasive soaps. Barrier creams may be useful for some individuals, although their protective effects are controversial. The use of non–barrier cream emollients may also be protective since they replace the skin oils removed by washing with soap.**

**(4) It may be helpful for those responsible for completing the OSHA 200 logs to attend training sessions on the record keeping requirements of the OSHA occupational injuries and illness log. Up to date training in the maintenance of the OSHA 200 log may improve the usefulness of this log for the identification of problem areas throughout the plant.**

**(5) Management should retain a qualified ergonomist to conduct an ergonomic assessment of the plant to help establish priority areas for ergonomic intervention and evaluate each of the production steps to determine how ergonomic intervention may reduce injury and improve production. There are seven elements in an effective ergonomics program that should be developed to prevent WMSDs. These elements are (1) identification of WMSDs, (2) management commitment and worker involvement, (3) training of management and workers, (4) gathering data on jobs or work conditions that are problematic, (5) developing controls, (6) establishing health care management, and (7) minimizing risk factors when designing new operations.[69]**

**(6) In order to control oil mist emissions, the SMOG HOG® units in Department 132 that were not functioning should be repaired. A routine maintenance program for the FILTERMIST® air cleaning devices should be developed. The roof exhausts should be evaluated to ensure that entrainment of contaminants into the south building does not occur.**

**(7) Due to the high concentrations of hydrochloric acid which can be generated from heating the flow coat paint, precautions such as additional exhaust ventilation should be used while performing operations such as repair welding on metal coated with the paint.**

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*Table 1*
*Health Effects and Occupational Exposure Limit Summary for Selected Metals**
*Dana Corporation, Spicer Axle Division*
*Ft. Wayne, Indiana*
*HETA 95–0293*

| Metal | Primary Health Effects[54,55] | OSHA PEL ($mg/m^3$)[9] | NIOSH REL ($mg/m^3$)[7] | ACGIH®TLV® ($mg/m^3$)[8] |
|---|---|---|---|---|
| Aluminum (Al) | Metallic aluminum dust is considered a relatively benign "inert dust." | 15^ | 10 | 10 |
| Iron (Fe) | Inhalation of iron oxide dust may cause a benign pneumoconiosis (X–ray findings without symptoms) called siderosis. | 10 | 5 | 5 |
| Magnesium (Mg) | Magnesium can cause eye and nasal irritation. Exposure to magnesium oxide fume has been associated with the development of metal fume fever. | 15^ | None | 10 (fume) |
| Molybdenum (Mo) | Based on animal studies, molybdenum can cause eye and mucous membrane irritation. Chronic exposure to molybdenum and/or molybdenum trioxide has resulted in pneumoconiosis. | 15^ | None | 10 (insoluble) 5 (soluble) |
| Zinc (Zn) | Zinc oxide exposure has been associated with shortness of breath, minor lung function changes, and metal fume fever. | 15^ | 5 | 10 |

* = These occupational exposure criteria are for metal dust.
^ = These are considered particulates not otherwise regulated.

*Table 2*
*Phosphoric Acid Sampling Results*
*Dana Corporation, Spicer Axle Division*
*Ft. Wayne, Indiana*
*HETA 95–0293*
*June 19, 1996*

| Job Description/Area | Sample Time | Sample Volume (liters) | Concentration ($mg/m^3$)^ |
|---|---|---|---|
| Area | | | |
| Entrance to Large Acid Bath | 7:52 a.m. – 3:25 p.m. | 90.6 | ND* |
| Head Space of Part Take–off | 7:55 a.m. – 2:52 p.m. | 82.6 | ND |
| Acid Tank Thermometer | 8:03 a.m. – 2:56 p.m. | 82.6 | Trace# |
| Beginning of Second Line Near Employee | 8:12 a.m. – 3:05 p.m. | 82.6 | ND |
| Mid–Acid Bath Second Line | 8:10 a.m. – 3:03 p.m. | 83.4 | ND |
| OSHA PEL | | | 1 |
| ACGIH® TLV® | | | 1 |
| NIOSH REL | | | 1 |
| Minimum Detectable Concentration (MDC) | | 82.6 | 0.12 |
| Minimum Quantifiable Concentration (MQC) | | 82.6 | 0.41 |

^ = $mg/m^3$ (milligrams per cubic meter)
* = ND (not detected at the minimum detectable concentration)
# = Between MDC and MQC

*Table 3*
*Oil Mist Sampling Results*
*Dana Corporation, Spicer Axle Division*
*Ft. Wayne, Indiana*
*HETA 95–0293*
*June 20, 1996*

| Job Description/Area | Sample Time | Sample Volume (liters) | Concentration (mg/m$^3$)* |
|---|---|---|---|
| **Personal** | | | |
| Lathing/H3 | 7:19 a.m. – 2:14 p.m. | 830 | 0.08 |
| Burr Drill/H6 | 7:25 a.m. – 2:03 p.m. | 796 | 0.10 |
| Gear Cutter/K6 | 7:30 a.m. – 2:00 p.m. | 780 | 0.23 |
| Burnisher/K6 | 7:31 a.m. – 2:00 p.m. | 778 | 0.13 |
| Screw Machine | 7:46 a.m. – 2:05 p.m. | 758 | 0.13 |
| Gear Cutter/N9 | 7:58 a.m. – 2:20 p.m. | 764 | 0.30 |
| Gear Cutter/N7 | 8:00 a.m. – 2:24 p.m. | 768 | 0.25 |
| Gear Cutter/Grinder | 8:26 a.m. – 2:28 p.m. | 724 | 0.26 |
| **Area** | | | |
| Gleason Cutting Machines/N5 | 8:20 a.m. – 2:26 p.m. | 732 | 0.33 |
| OSHA PEL | | | 5 |
| ACGIH® TLV® | | | 5 |
| NIOSH REL | | | 5 |
| Minimum Detectable Concentration (MDC) | | 724 | 0.01 |
| Minimum Quantifiable Concentration (MQC) | | 724 | 0.04 |

* = mg/m$^3$ (milligrams per cubic meter)

*Table 4*
*Synthetic Metal–Working Fluids (Total Weight) Sampling Results*
*Dana Corporation, Spicer Axle Division*
*Ft. Wayne, Indiana*
*HETA 95–0293*
*June 20, 1996*

| Job Description/Area | Sample Time | Sample Volume (liters) | Concentration ($mg/m^3$)* |
|---|---|---|---|
| **Personal** | | | |
| Several Operations at Transfer Lines/ Dept. 661 | 7:19 a.m. – 2:01 p.m. | 804 | 0.53 |
| Roughing/ Dept. 661 | 7:16 a.m. – 2:02 p.m. | 812 | 0.43 |
| Four–Way/ Dept. 541 | 7:30 a.m. – 2:02 p.m. | 784 | 0.46 |
| Multiple/ Dept. 373 | 8:19 a.m. – 2:18 p.m. | 718 | 0.22 |
| Screw Machine–Lathing/ Dept. 171 | 7:52 a.m. – 2:09 p.m. | 754 | 0.24 |
| Apex Drill/ Dept. 151 | 7:58 a.m. – 2:11 p.m. | 746 | 0.24 |
| **Area** | | | |
| Threader/ Dept. 373 | 8:12 a.m. – 2:17 p.m. | 730 | 0.14 |
| Broaching/ Dept. 375 | 8:30 a.m. – 2:19 p.m. | 698 | 0.17 |
| Apex Drill/ Dept. 354 | 8:08 a.m. – 2:17 p.m. | 738 | 0.23 |
| Lunch Tables/ Dept. 375 | 8:39 a.m. – 2:20 p.m. | 682 | 0.21 |
| Minimum Detectable Concentration (MDC) | | 682 | 0.03 |

* = $mg/m^3$ (milligrams per cubic meter)

*Table 5*
*Trace Metal Sampling Results*
*Dana Corporation, Spicer Axle Division*
*Ft. Wayne, Indiana*
*HETA 95–0293*
*June 20, 1996*

| Job Description/Area | Sample Time | Sample Volume (liters) | Concentration (mg/m³)*# | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Al | Fe | Mg | Mo | Na | Zn |
| **Personal** | | | | | | | | |
| Grinding Steel/ Dept. 359 | 8:44 a.m. – 2:22 p.m. | 676 | ND^ | 0.023 | ND | ND | 0.009 | 0.003 |
| Milling/ Dept. 841 | 7:41 a.m. – 2:07 p.m. | 772 | 0.024 | 0.015 | 0.003 | ND | 0.010 | ND |
| Grinder/ Dept.151 | 8:30 a.m. – 2:14 p.m. | 748 | ND | 0.009 | ND | ND | 0.007 | ND |
| Broach Machine/G5 | 7:21 a.m. – 2:16 p.m. | 830 | ND | ND | ND | ND | 0.007 | ND |
| Gear Cutting/J1 | 7:36 a.m. – 2:02 p.m. | 772 | ND | 0.015 | ND | ND | 0.008 | ND |
| Changing Cutters/H9 | 7:40 a.m. – 2:09 p.m. | 778 | ND | 0.008 | ND | ND | 0.010 | ND |
| Acme Screw Machine | 7:45 a.m. – 2:05 p.m. | 760 | ND | 0.008 | ND | 0.002 | 0.007 | ND |
| Pinon Cutter/D6 | 8:07 a.m. – 2:22 p.m. | 750 | ND | 0.003 | ND | ND | 0.012 | ND |
| Machine Fixer/N7 | 8:11 a.m. – 2:26 p.m. | 750 | ND | 0.003 | ND | ND | 0.006 | ND |
| **Area** | | | | | | | | |
| Gleason Cutter/H6 | 7:55 a.m. – 2:11 p.m. | 752 | ND | 0.007 | ND | ND | 0.008 | ND |
| Gleason Cutter/N7 | 8:10 a.m. – 2:24 p.m. | 748 | ND | 0.004 | 0.002 | ND | 0.009 | ND |
| Gleason Cutter/N5 | 8:25 a.m. – 2:26 p.m. | 722 | ND | 0.003 | ND | ND | 0.008 | 0.002 |
| OSHA PEL^^ | | | 15 | 10 | 15 | 5 | —— | 15 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***ACGIH® TLV®*** | | | ***10*** | ***5*** | ***10*** | ***10*** | ——— | ***10*** |
| ***NIOSH REL*** | | | ***10*** | ***5*** | ——— | ——— | ——— | ***5*** |
| ***Minimum Quantifiable Concentration (MQC)*** | ***676*** | | ***0.0018*** | | | | | |

***** = *mg/m3 (milligrams per cubic meter)*

^ = *ND (not detected at the minimum detectable concentration)*

***#** = Al – Aluminum; Fe– Iron; Mg– Magnesium; Mo – Molybdenum; Na– Sodium; Zn – Zinc*

^^ = ***Occupational criteria are given for the metal except for iron oxide and zinc oxide.***

***Table 6***
***Monoethanolamine Sampling Results***
***Dana Corporation, Spicer Axle Division***
***Ft. Wayne, Indiana***
***HETA 95–0293***
***June 19, 1996***

| Job Description/Area | Sample Time | Sample Volume (liters) | Concentration (ppm)* |
|---|---|---|---|
| **Area** | | | |
| Salt Bath – End of First Tank | 8:24 a.m. – 11:14 p.m. | 170 | 0.19 |
| Broach 1–5–36 | 8:59 a.m. – 3:07 p.m. | 368 | Trace# |
| Broach 1–55–43 | 8:52 a.m. – 3:13 p.m. | 381 | Trace# |
| Broach 1–15–10 | 9:00 a.m. – 3:09 p.m. | 369 | Trace# |
| Grinding 1–16–161 | 8:48 a.m. – 3:11 p.m. | 383 | 0.08 |
| Grinding 1–16–115 | 8:45 a.m. – 3:20 p.m. | 395 | 0.07 |
| OSHA PEL | | | 3 |
| ACGIH® TLV® | | | 3 |
| NIOSH REL | | | 3 |
| Minimum Detectable Concentration (MDC)** | | 368 | 0.02 |
| Minimum Quantifiable Concentration (MQC)** | | 368 | 0.07 |

** = ppm (parts per million)*
*# = Between MDC and MQC*

***Table 7***
***Sampling Results for Nitrosoamines***
***Dana Corporation, Spicer Axle Division***
***Ft. Wayne, Indiana***
***HETA 95–0293***
***June 19, 1996***

| Job Description/Area | Sample Time | Sample Volume (liters) | Nitrosomorpholine | |
|---|---|---|---|---|
| | | | Concentration ($\mu g/m^3$)* (GC/MS) | Concentration ($\mu g/m^3$) (OSHA 27) |
| **Area** | | | | |
| Beyond Salt Bath | 8:32 a.m. – 3:07 p.m. | 790 | Trace# | Trace |
| Beginning of Salt Bath | 11:12 a.m. – 3:07 p.m. | 468 | Trace | Trace |
| End of Salt Bath | 8:26 a.m. – 3:07 p.m. | 802 | Trace | Trace |
| Worker's Station at Heating Area (Nearest Worker) | 8:37 a.m. – 3:07 p.m. | 780 | ND | Trace |
| Minimum Detectable Concentration (MDC)** | | 468 | 0.02 | 0.02 |
| Minimum Quantifiable Concentration (MQC)** | | 468 | | 0.077 |

* = $\mu g/m^3$ (micrograms per cubic meter)
\# = Between MDC and MQC

**Table 8**
**Microbial Sampling Results from Bulk/Sediment Samples**
**Dana Corporation, Spicer Axle Division, Ft. Wayne, Indiana**
**HETA 95–0293**
**June 19, 1996**

| Description/Area | Type of MWF | Bacteria Species Identified | CFU/ml | Fungi Genius Identified | CFU/ml |
|---|---|---|---|---|---|
| **Liquid** | | | | | |
| Dept. 661 (at end) | AP 7500 | Clavibactor michiganese ss sepedonicum | $2.5x10^3$ | None Detected | |
| Dept. 661 (at beginning) | AP 7500 | None Detected | | Sporotrichum | $2x10^1$ |
| Dept. 661 (at beginning) [was Dept. 361] | AP 7500 | Clavibactor michiganese ss sepedonicum<br>Pseudomonas alcaligenes B | $5x10^2$<br>$5x10^1$ | Fusarium | $3x10^2$ |
| Dept. 661 (at end) [was Dept. 361] | AP 7500 | None Detected | | None Detected | |
| Dept. 541 (at beginning) | AP 7500 | Acinetobacter johnsonii/Genospecies 7 | $4x10^3$ | Fusarium | $6x10^3$ |
| Dept. 541 (at end) | AP 7500 | Clavibactor michiganese ss sepedonicum | $6x10^3$ | None Detected | |
| Dept. 172 Conamatic | Oil | None Detected | | Cladosporium<br>Sporotrichum | $1x10^1$<br>$1x10^1$ |
| Dept. 172 Honing | Oil | None Detected | | None Detected | |
| Dept. 172 Honing | Oil | None Detected | | Penicillium | $1x10^1$ |
| Dept. 171 Lathe (OP40 9–46–1) | Reclaim | None Detected | | Fusarium | $1x10^1$ |
| Dept. 171 Lathe | Reclaim | None Detected | | None Detected | |
| Dept.151 Apex Drill | Reclaim | Alcaligenes faecalis ss homari<br>Leucibistoc paramesenteroides | $4x10^5$<br>$2x10^5$ | None Detected | |
| Dept. 354 Drill | Reclaim | Acinetobacter johnsonii/Genospecies 7<br>Acinetobacter lwoffii/Genospecies 8 | $8.5x10^7$<br>$1.5x10^7$ | Yeast<br>Sporotrichum | $6x10^4$<br>$3x10^3$ |

***No Thermophilic Actinomycetes were detected in any samples.  The limit of sensitivity for liquid samples is 10 CFU/ml (colony–forming units per milliliter).***

***Table 8***
***Microbial Sampling Results from Bulk/Sediment Samples (continued)***
***Dana Corporation, Spicer Axle Division, Ft. Wayne, Indiana***
***HETA 95–0293***
***June 19, 1996***

| Description/Area | Type of MWF | Bacteria Species Identified | CFU/ml | Fungi Genius Identified | CFU/ml |
|---|---|---|---|---|---|
| **Liquid** | | | | | |
| Dept. 373 Drill | Reclaim | Clavibactor michiganese ss sepedonicum<br>Comamonas terrigena | $1x10^4$<br>$2x 10^2$ | None Detected | |
| Dept.373 Mill 153–74 | Reclaim | Buttiauxella agrestis<br>Alcaligenes faecalis ss homari | $4.2x10^6$<br>$2x10^5$ | Fusarium | $4x10^3$ |
| Dept. 373 Threader 171–17 | Reclaim | Alcaligenes faecalis ss homari | $2x10^6$ | Fusarium | $7x10^3$ |
| Dept. 375 Broach Bottom Pan | Spec 3364 | Pseudomonas alcaligenes B | $9x10^6$ | Yeast–like mold | $2x10^2$ |
| Unused Broach | Spec 3364 | Pseudomonas alcaligenes B | $1.2x10^3$ | None Detected | |
| Unused MWF | AP 7500 | Acinetobacter johnsonii/Genospecies 7 | $2x10^5$ | None Detected | |
| "UNUSED" Reclaim | Reclaim | Clavibactor michiganese ss sepedonicum<br>Acinetobacter johnsonii/Genospecies 7 | $1x10^3$<br>$1x10^3$ | Fusarium | $1x10^1$ |
| **Solid Sediment** | | | | | |
| **Description/Area** | **Type of MWF** | **Bacteria Species Identified** | **CFU/g** | **Fungi Genius Identified** | **CFU/g** |
| Dept. 354 Drain Pan | | Buttiauxella agrestis | $2.5x10^7$ | Fusarium | $4x10^5$ |
| Dept. 354 Ledge of Machine | | Aeromonas media–like DNA group 5A | $3.45x10^7$ | Yeast<br>Fusarium<br>Aspergillus terrus | $9.2x10^5$<br>$6.9x10^5$<br>$2.3x10^3$ |
| Dept. 373 Inside Threader 171–17 | | Comamonas terrigena<br>Buttiauxella agrestis<br>Acinetobacter lwoffii/Genospecies 8 | $2.585x10^8$<br>$4.75x10^7$<br>$4.7x10^7$ | Fusarium | $2.35x10^6$ |

*No Thermophilic Actinomycetes were detected in any samples. The limit of sensitivity for liquid samples is 10 CFU/ml (colony–forming units per milliliter) and for solid samples was 10 CFU/gram (g), 47 CFU/g, and 23 CFU/g, respectively.*

***Table 9***
***SMOG HOG® Ventilation Measurements***
***Dana Corporation, Spicer Axle Division***
***Ft. Wayne, Indiana***
***HETA 95–0293***
***June 19, 1996***

| Machine Number | Duct Size (Inches) | Type of Machine | Average Face Velocity (fpm)* | Average Flowrate (cfm)** |
|---|---|---|---|---|
| 2–92–67 | 3.5 | Gear Cutter | 2719 | 134 |
| 2–92–67 | 5.5 | Gear Cutter | 1475 | 243 |
| 2–92–38^ | 5.5 | Gear Cutter | 401 | 66 |
| 2–92–38^ | 5.5 | Gear Cutter | 447 | 74 |
| 2–92–39^ | 3.0 | Gear Cutter | 710 | 35 |
| 2–92–39^ | 3.0 | Gear Cutter | 631 | 31 |
| | Hood Size (Square Foot) | | | |
| A–2728 | 1 | Pinion Cutter | 285 | 285 |
| H–2776 | 1 | Pinion Cutter | 530 | 530 |
| HAW–3619 | 1 | Ring Cutter | 138 | 138 |
| ATC–5339 | 1 | Ring Cutter | 799 | 799 |

*   =   fpm (feet per minute)
** =   cfm (cubic feet per minute)
^   =   connected to same SMOG HOG® Unit

# *Appendix A*