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Pratt & Whitney TAPC
North Haven, Connecticut

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Max Kiefer and Doug Trout of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by David Sylvain and Angela Weber. Analytical support was provided by the NIOSH Division of Physical Sciences and Engineering. Desktop publishing was performed by Pat Lovell.

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Health Hazard Evaluation Report 98-0030-2697
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North Haven, Connecticut
June 1998

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SUMMARY

On November 24, 1997, the National Institute for Occupational Safety and Health received a union request for a health hazard evaluation (HHE) at the Pratt & Whitney Aircraft TAPC (P&W) facility in North Haven, Connecticut. The HHE request concerned reports of health problems possibly associated with exposure to metal working fluids (MWFs) in the Blohm grinding area. The reported health problems included flu-like symptoms, skin problems, and eye irritation.

On March 31-April 2, 1998, 12 bulk samples of MWF were collected for microbiological and endotoxin analysis, and personal breathing zone (PBZ) and area air sampling for MWFs was conducted on both the first and second shift in the Blohm grinding area. PBZ samples were also collected from employees in a comparison area (Business Unit 264), where MWFs are not used. Area air samples for endotoxin analysis were collected in both the Blohm grind and comparison area on both shifts. A questionnaire that included questions about symptoms potentially related to MWF exposure was administered to employees in the Blohm and comparison area on all three shifts.

Housekeeping was good in most locations throughout the work area inspected. Although machine operators are required to wear gloves during maintenance and the handling of parts, adherence to this requirement was poor. The MWF holding tanks vent MWF aerosol back into the work environment via the relief vent at the top of each tank. In 20 of the 21 PBZ samples, the MWF concentrations were below the NIOSH recommended exposure limit (REL) of 0.5 milligrams per cubic meter (mg/m^3) for total particulate; in one sample from a machine-repair worker, the MWF concentration (0.62 mg/m^3) exceeded the NIOSH REL. In six of the seven area samples collected in the Blohm area, the MWF concentrations were below the NIOSH REL. One area sample, collected approximately 6 inches from a holding tank vent, showed a total particulate concentration of 1.83 mg/m^3.

The endotoxin concentrations in the Blohm area were higher than the levels detected in Business Unit 264, for both the day and night shift samples. No microbial growth was detected in any of the bulk MWF samples. Endotoxin was detected in all bulk samples, indicating past microbial growth.

All eighty employees from the Blohm area who were working during the time of our site visit completed the questionnaire. Of the 106 BU 264 employees working during our site visit, 84 (79%) completed the questionnaire. The most frequently reported symptom was ‘a stuffy, runny, irritated nose,’ which was reported by 44 (57%) of the Blohm employees and 36 (43%) of the Business Unit 264 employees. All symptoms were more commonly reported among the Blohm area employees, with the prevalence ratios ranging from 1.13 to 2.18. No unusual number or pattern of reported medical diagnoses among participants was found.

One employee in the Blohm grinding area was identified as having an exposure to MWF aerosol above the NIOSH REL. However, because reports in the literature have documented work-related respiratory illnesses among workers exposed to MWF at concentrations below the NIOSH REL, MWF aerosol levels should be reduced when possible and workers with health symptoms that are potentially work-related should report all symptoms to appropriate health care personnel. Improvements in ventilation of the Blohm cabinet and supply tanks could be made to reduce exposures to MWF aerosol. Recommendations regarding the use of protective equipment, medical surveillance, ventilation, and additional environmental monitoring are provided in this report.

Keywords: SIC 3724 (Aircraft Engines and Engine Parts). Metal working fluids, coolants, endotoxin, *Mycobacterium chelonae*, bacteria, flu-like symptoms, skin problems, eye irritation

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INTRODUCTION

In response to a request for a health hazard evaluation (HHE) received on November 24, 1997, the National Institute for Occupational Safety and Health (NIOSH) conducted an initial site visit on December 18, 1997, and a follow-up survey on March 31-April 2, 1998, at the Pratt & Whitney (P&W) Aircraft TAPC facility in North Haven, Connecticut. The HHE was requested by the International Association of Machinists and Aerospace Workers [IAMAW] Local #707, representing employees at this facility. Health problems reported in the request included flu-like symptoms, skin problems, and eye irritation. The request asked NIOSH to determine if these reported health problems were associated with exposure to metal working fluids (MWFs) used in the Blohm grinding area.

During the site visits, work practices and the use of personal protective equipment were reviewed. On March 31-April 2, 1998, the following activities were conducted: (1) bulk MWF samples were collected for microbiological and endotoxin analysis; (2) air samples were collected to evaluate exposure to MWFs in both the Blohm grinding area and a comparison area; and (3) a questionnaire survey among employees in the Blohm and comparison areas to assess work-related health effects.

An interim report describing the actions taken by NIOSH during the initial site visit, and providing preliminary findings and recommendations, was issued January 29, 1998; a second interim report describing the results of the questionnaire survey was issued May 15, 1998.

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BACKGROUND

Facility and Process Description

The P&W facility in North Haven, Connecticut, manufactures various aircraft engine parts (blades and vanes) for jet engines. The main manufacturing facility and office were constructed in 1951, and are located on approximately 160 acres. With additions made in 1954 and 1961, the manufacturing area now encompasses over 1,000,000 square feet. Approximately 1600 employees work at the facility, which operates on a 24-hours/day, 7-days/week basis. Work shifts are 7:00 a.m.-3:30 p.m., 3:30 p.m.-12:00 a.m., and 12:00 a.m.-7:00 a.m. A variety of metal working operations are conducted at the North Haven facility, including forming, machining, heat-treating, welding, applying protective coatings, non-destructive testing, anodizing, and plating. High-nickel-content alloy bar stock is used as the primary raw material.

An environment, health, and safety council has been established at the site, and includes senior management and union safety representatives. Separate committees have been formed for several environmental and safety issues, and there is an accident investigation subcommittee. A safety and health department, which includes safety engineers and an industrial hygienist, support the facility. Nursing coverage is provided on the 1st and 2nd shifts, and a physician is on-site for approximately 20 hours/week. Employees are required to wear eye protection when on the factory floor. No special uniforms are required for working in the plant. An air-conditioning system for the factory floor (completed in 1996) provides heating and cooling.

Blohm area

The Blohm area encompasses approximately 15% of the main manufacturing floor space, and consists of 20 large automated grinding machines in three lines, with aisles between each line. The machines were installed between 1987 and 1991. One type of MWF is used on all machines in the Blohm area and, except for one Blohm machine with a stand-alone sump, the MWF is distributed from a central MWF distribution system. A soluble oil emulsion MWF (Trim VHP E200 PW®) has been in use at this facility for approximately 6 years. Prior to use at the machines, the MWF is diluted with water at a ratio of 9:1 (10% solution). When it is necessary to add makeup MWF, a 6% solution is used. Company representatives and employees reported that approximately 1000 gallons of MWF per day (2% of the 50,000-gallon central system) are lost and must be replenished. The loss is attributed to carry off, misting, leaks, and spills.

Two types of biocides are used in the MWF, Grotan® and Kathon FP®. The Grotan® is metered into the MWF during preparation, and additional amounts are fed into the system on a monthly basis. The Kathon FP® may be added once every 3-4 months.

MWF is added at the main distribution system from 300-gallon containers of concentrate. Return (dirty) MWF is piped from each machine into an overhead main pipe and delivered to the return tank, where a vacuum system pulls the MWF through one of three filter banks (roll filters) into the clean supply side. The MWF is then distributed back to the individual machines via overhead piping.

Each Blohm machine has a 1000-gallon MWF holding tank. The machines are equipped with chillers for temperature control, and the target MWF temperature is 68-70° F. The tanks are cleaned to remove grit approximately twice each year. The fluid is distributed into an enclosed grinding area (cabinet) during the machining cycle, and then drains through a trough into a sump after use. Each machine is equipped with an exhaust system that ventilates the cabinet when it is opened. The cabinet ventilation exhausts directly into the holding tank. One machine (Blohm # 9) has been equipped with a mist control device on the holding tank vent. The machines are computer controlled and are equipped with automated parts in/out systems. The cabinet is accessed by operators on a daily basis to change the grinding wheel or change fixtures and nozzles. Maintenance workers may have to access the cabinet for repairs or routine upkeep.

Approximately 80 maintenance personnel and machine operators work in the Blohm area across the three work shifts. A typical shift will have about 12 machine operators, 12 maintenance personnel, and 3 inspectors.

Business Unit 264

Business Unit 264 (BU 264), used to collect comparative environmental and questionnaire data, employs approximately 100 workers and is located in the same facility about 150 meters away from the Blohm area. Employees in BU 264 perform a variety of industrial processes, including heat treating, x-ray inspection, polishing, and dot peening (engraving), which do not involve substantial quantities of MWF, as is used in the Blohm area.

METHODS

Initial Site Visit

Prior to the initial site visit, descriptive information about the activities, processes, and materials in use at the North Haven facility was obtained. On December 18, 1997, NIOSH investigators held an opening conference with P&W safety and health, engineering, management, and union representatives at the North Haven facility. During this meeting, information about NIOSH was provided, and the HHE request was discussed. Various operational parameters regarding the use of MWFs were also reviewed. Following the opening conference, a walkthrough inspection of the Blohm grinding area and central MWF distribution system was conducted. Environmental surveillance and accident and illness records were reviewed.

Follow-up Site Visit

Industrial Hygiene

Air Sampling - MWF

On April 1 (evening shift) and April 2 (day shift) air sampling was conducted to assess personal exposures to MWFs in the Blohm grinding area and the comparison area (BU 264). Full-shift personal breathing zone (PBZ) and area air samples for MWF were collected on pre-weighed 37-mm polytetrafluoroethylene (PTFE - Zefluor®) filters in closed-face cassettes using battery-powered Gillian air pumps. In the Blohm area, samples were collected from machine operators, machine repair workers, and inspectors. Manufacturing activity at the facility was considered by management and employee representatives to be slightly slower than normal during the monitoring.

All samples were collected for total particulate at an airflow rate of 2.0 liters per minute (L/min). The calibrated air sampling pumps were attached to selected workers and connected, via tubing, to sample collection media placed in the employees' breathing zone. Monitoring was conducted throughout the employees' work-shift. After sample collection, the pumps were post-calibrated and the samples submitted to the NIOSH contract laboratory (Data Chem, Salt Lake City, Utah) for analysis. Field blanks and bulk samples (shipped separately) of the MWF were submitted with the air samples.

The filters for all samples were analyzed gravimetrically to determine the total particulate collected, and by a provisional American Society for Testing and Materials (ASTM) E34.50 Committee method modified by NIOSH to separate MWF from co-sampled material.[1] This method removes interferences from contaminating materials, such as environmental dusts and metal particles. In the laboratory, the filters were weighed on a microbalance and extracted using a solvent blend (the solvent blend was selected from solubility tests on the respective MWF). The difference in the weight of the filter before and after sample collection yielded the total particulate mass sampled. The difference in the weight of the filter before and after extraction was the weight of the MWF.

Because the gravimetric analytical technique is non-specific, it is susceptible to interference from non-MWF contaminants such as dusts. As such, methods to determine the component of the total particulate sample that can be attributed to MWF would be useful. The ratio of the extracted-MWF (EMWF) concentration to the total particulate (TP) concentration provides information on the relative contribution of MWF aerosol on the sample. For example, if the TP concentration is significantly greater than the EMWF concentration then it is likely that there is another particulate source in the work area

Air Sampling - Endotoxin

Area air samples for endotoxin were collected in both the Blohm and comparison area on both shifts. Full-shift air samples were collected at an airflow rate of 2.0 L/min using calibrated air sampling pumps. The monitoring protocol used to collect and analyze the endotoxin samples was provided by the laboratory (Harvard School of Public Health, Don K. Milton, M.D., Dr. P.H.). Sample collection and analysis for the endotoxin samples was by the KLARE method (Kinetic Limulus Assay with Resistant-Parallel-Line Estimation).[2,3] The samples were collected on polycarbonate 0.40 micrometer (µm) capillary-pore membranes (Nuclepore) in three piece polystryrene cassettes with glass fiber backup pads. The filters and pads were loaded at the laboratory using sterile technique. Following collection, a desiccator was attached to the outlet side of the sample cassette and the inlet side was capped. The samples were then sealed in a plastic bag and stored in a refrigerator until shipment (cooler and blue ice) via overnight express to the analytical laboratory.

Bulk Sampling

Twelve bulk MWF samples were collected in quadruplicate (48 total) from various points on the central distribution system (return sumps, holding tanks, etc.). Bulk samples of unused concentrate were also collected. Three of the four samples from each set were collected in 50 ml sterile conical containers; the other sample set was collected in 150 ml containers. For each sample set, MWF was collected in a clean, unused container and then decanted into the four sample vials.

The pH of each bulk MWF sample was recorded at the time of collection. The pH was measured with pHydrion Insta-Check paper (Micro Essential Laboratory, Brooklyn, New York). The wet pH paper was compared to a color chart to determine the pH of the tested material.

The bulk samples were labeled and shipped cold via overnight delivery to one of three analytical laboratories. Two samples from each set were shipped to the NIOSH contract microbiological laboratory (Microbiology Specialists Incorporated [MSI], Houston, Texas). At MSI, the samples were cultured for total aerobic bacteria with species identification and total count at 25°C, and for *Mycobacterium* species. One sample from each set was shipped to the NIOSH Division of Respiratory Disease Studies (DRDS) Immunology Section Laboratory for endotoxin analysis. The fourth sample from each set, collected in the larger volume containers, was shipped to the Miami (Ohio) University Department of Microbiology Laboratory, and analyzed for lipid content. These latter samples were collected for preliminary work in the evaluation of an experimental technique attempting to measure the fatty acid component in a sample of MWF as an potential indicator of past and present microbiological growth. Because these samples were collected for internal research purposes, and because of the preliminary nature of this work, these results will not be reported.

Medical

Questionnaire Survey

During the site visit, a four-page questionnaire was provided to all employees working in the Blohm area (three shifts) and to 1st and 2nd shift workers in BU 264. For this evaluation, employees in the Blohm area are considered 'exposed' to MWF, and those from BU 264 are considered 'unexposed' to MWF. The questionnaire included questions about demographic factors (age, gender, etc.), symptoms potentially related to MWF exposure, and medical and work history.

The questionnaires were analyzed using Epi Info software.[4] The magnitude of the association between reported symptoms and MWF exposure was assessed by the prevalence ratio; a 95% confidence interval which excluded 1 was considered to indicate a statistically significant difference.

EVALUATION CRITERIA

General

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff 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)[5], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®)[6], and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[7] 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 are used for lubrication, cooling, and removal of metal chips during machining operations. There are four major types of MWFs – straight oils, water soluble oils, semi-synthetic, and synthetic.– and the evaluation of the potential health hazard from exposure to MWFs would vary depending on which type is being used. Straight oils (neat oils) are solvent-refined petroleum oils not designed to be mixed with water. The other three types are water-based MWFs. Acute health effects that have been associated with exposure to MWFs include dermatitis and respiratory health effects. Epidemiologic studies have also found a number of types of cancer to be associated with past MWF exposure. These health effects, and other information relevant to occupational exposure to MWF, are discussed further in the NIOSH booklet, "What You Need to Know About Occupational Exposure to Metal Working Fluids," and also in the recently published NIOSH criteria document, "Occupational Exposure to Metalworking Fluid."[8,9]

To prevent or greatly reduce the risk of adverse health effects due to MWF exposure, NIOSH recommends that airborne exposures to MWF aerosols be limited to 0.5 milligrams per cubic meter air (mg/m^3) for total particulate mass as a time-weighted average for up to 10 hours per day during a 40-hour week.[9] This concentration is approximately equal to 0.4 mg/m^3 as thoracic particulate mass, and is used to approximate the thoracic concentration.* This NIOSH REL was established primarily to eliminate or reduce respiratory health effects; other considerations included sampling and analytical feasibility, the selection of an index for assessing MWF exposure, the applicability of the REL to all types of MWFs, and technological feasibility. Concentrations of

* *Thoracic particulate mass is the portion of MWF aerosol that penetrates beyond the larynx and may be deposited in the lung airways and/or gas exchange region.*

MWFs should be kept below the REL where possible because some workers have developed work-related asthma, hypersensitivity pneumonitis, or other adverse respiratory health effects when exposed to MWF concentrations less than the REL. Neither the Occupational Safety and Health Administration (OSHA) or American Conference of Governmental Industrial Hygienists (ACGIH) has exposure limits for all MWF aerosol, although both have an 8-hour TWA limit of 5 mg/m^3 for mineral oil mist.

In this evaluation, the extracted MWF concentration was also determined from the air samples. NIOSH is evaluating this extracted MWF method; currently, little or no evidence suggests that measuring "extractable" MWF mass is superior to total particulate mass measurement as a predictor of adverse health effects from MWF aerosols. However, extractable MWF aerosol measurement may be helpful in environments where there are simultaneous exposures to other particulate.[9]

In addition to the REL, NIOSH recommends that a comprehensive safety and health program be developed and implemented as part of the employer's management system.[9] The major elements of a comprehensive, effective safety and health program are (1) safety and health training, (2) worksite analysis, (3) hazard prevention and control, and (4) medical monitoring of exposed workers.

Endotoxin

Endotoxin is a lipopolysaccharide (LPS) compound that is part of the outer cell wall of all gram-negative bacteria (GNB). The LPS consists of a lipid (lipid A) that is embedded in the outer cell membrane and a polysaccharide that protrudes out from the cell membrane. Portions of the LPS evoke a specific antibody response. The lipid A component is thought to be responsible for the ill effects of endotoxin exposure.[10,11,12]

GNB, and therefore endotoxins, are ubiquitous in nature. Endotoxins are released when the bacterial cell is lysed (broken down) or when it is multiplying.[11,12] They are found in water, soil, and living organisms. Endotoxins have been found in a variety of agricultural settings in many types of agricultural materials. Endotoxins have also been quantified in machining operations where water-based MWFs are used, in waste disposal, sewage, and sewage composting operations, in biotechnology processes, and in industrial and non-industrial environments associated with cooling towers, humidifiers, air-conditioners, and other water-associated processes.[12,13,14,15]

Endotoxins have a wide range of biological activities involving inflammatory, hemodynamic, and immunological responses.[14] Of most importance to occupational exposures are the activities of endotoxin in the lung.[16] The primary target cell for endotoxin-induced damage by inhalation is the pulmonary macrophage. Human macrophages in particular have been shown to be extremely sensitive to the effects of endotoxin in vitro.[17] Endotoxin, either soluble or associated with particulate matter, will activate the macrophage, causing the cell to produce a host of mediators.[16]

Clinically, little is known about the response to inhaled endotoxins. Exposure of previously unexposed persons to airborne endotoxin can result in acute fever, dyspnea, coughing, and small reductions in one-second forced expiratory volume (FEV_1), although some investigators have not been able to demonstrate acute changes in FEV_1.[16] The effects of repeated exposure to aerosols of endotoxins in humans are not known, although animal studies have suggested that repeated exposure may cause a syndrome similar, if not identical, to chronic bronchitis.[16]

Occupational exposure limits have not been established for endotoxin by either OSHA, NIOSH, or ACGIH. However, Rylander has reported that sufficient toxicological data are available for establishing an occupational limit for endotoxin based on acute changes in pulmonary function.[18] Eight-hour (8-hr) TWA air concentrations of endotoxin have been suggested as being related to the specified health effects: (1) 200 endotoxin units

(EU)/m^3 - airway inflammation with increased airway reactivity; (2) 2000 EU/m^3 - cross-shift decline in FEV_1; (3) 3000 EU/m^3 - chest tightness; and (4) 10,000-20,000 EU/m^3 - toxic pneumonitis. Castellan has reported a calculated "zero pulmonary function effect" concentration of 90 EU/m^3.[19]

Microbial Growth in MWF

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. The saprophytic varieties (those utilizing non-living organic matter as a food source) inhabit soil, vegetation, water, or any reservoir that can provide an ample supply of a nutrient substrate. Under the appropriate conditions (optimum temperature and pH, and with sufficient moisture and available nutrients), saprophytic microorganism populations can be amplified; water-based metal-working fluids (MWFs) provide a suitable environment for microbial amplification.

Both bacteria and fungi are commonly 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: obligative anaerobic sulfate reducers, specifically *Desulfovibrio desulfuricans*; aerobic bacteria, especially *Pseudomonas* species and coliforms; and imperfect fungi, including members of the genus *Fusarium*, *Cephalosporium*, and *Candida*[20]. Well-maintained MWF systems should have bacterial concentrations of less than 10^6 colony forming units per milliliter (CFU/ml).[21] Although the acid-fast organism *Mycobacteria chelonae* has been found to be present in MWF associated with outbreaks of hypersensitivity pneumonitis, the significance of finding any particular fungal or bacterial species in MWF is not clear at this time.[22]

Some individuals manifest increased immunologic responses to bacteria, fungi, or their metabolites encountered in the environment. Although microbial contamination of MWFs poses a potential occupational hazard, there are insufficient data to determine acceptable levels of microbial growth in MWF or in the air. In addition, allergic or hypersensitivity reactions can occur even with relatively low air concentrations of allergens (such as microorganisms), and individuals differ with respect to immunogenic susceptibilities.

RESULTS

Observations

Housekeeping was good in most locations throughout the work areas inspected. Aisles were clear of debris and the floors were clear. However, the drain sump on each Blohm machine was uncovered, and spilled MWF was visible around the sumps of some machines.

As part of the quality control program for the MWF system, samples are collected from the central sump every Monday, and analyzed for pH, MWF concentration, bacteria, calcium, zinc, total oil, and biocide concentration. Control charts tracking the results of these analyses are posted at the central distribution system. An upper control limit of 10^5 colonies CFU/ml has been established by the Engineering Department, and action is taken if the concentration reaches 10^3 CFU/ml. Occasional periods of elevated bacteria counts (>10^5 CFU/ml) have been recorded, which were typically associated with drops in pH. The target pH range for the MWF is 8.6-8.9. A centrifuge to scavenge tramp oil has been installed and it's effectiveness was under evaluation at the time of the first NIOSH site visit. The engineering effort to monitor the MWF and maintain quality control appeared to be vigilant.

Personal Protective Equipment

Machine operators are required to wear gloves during maintenance and handling of parts (cut-resistant leather palm gloves for parts, N-DEX nitrile disposable gloves for contaminated areas). However, adherence to this safety requirement appeared to be poor. For example, at the central MWF system, high nickel content grit is removed as the filter paper indexes and is discharged into hoppers. Personnel were observed working on this system and contacting the grit without wearing gloves. Skin contact with nickel (metallic and certain nickel compounds) can cause a sensitization dermatitis that is referred to as "nickel itch."[23] Once nickel sensitivity is acquired it is apparently not lost. As such, prevention of contact should be the primary control strategy.

Ventilation

Venting the cabinet exhaust system back into the holding tank appears to create a situation where MWF mists exhaust back into the work environment via the relief vent at the top of the holding tank. Conditions inside the cabinet enclosure of the Blohm machines, after the machine is turned off, are such that there is considerable dripping and pooling of MWF in the area that must be accessed by the operator or maintenance worker.

Central heating, ventilating, and air-conditioning (HVAC) systems have been installed in the manufacturing area and are equipped with ceiling-level air intakes. There are 22 HVAC systems in the entire plant, six of which support the Blohm grinding area. These are roof -mounted systems equipped with filters and pre-filters. After installation of the system, fluid that had been entrained into the air intake was detected dripping back into the work area. Attempts to control the dripping with drip pans and physical cleaning have not been effective in all cases.

Record Review

Review of the OSHA Log and Summary of Occupational Injuries and Illnesses (form 200) revealed 29 entries for machine operators in the Blohm area for the years 1995-1997. One entry was for dermatitis, one was for 'chemical exposure' related to gastrointestinal symptoms, and one for 'chemical exposure' related to sinus symptoms. The remainder of the entries were for minor injuries, including lacerations and foreign bodies, and musculoskeletal problems.

Industrial Hygiene

Air Sampling - MWF

The results of the air samples collected for MWFs are shown in Tables 1-4. PBZ samples were collected on both shifts from eight machine-repair workers, ten machine-operators, and three inspectors. All of the PBZ samples except one were below the NIOSH REL of 0.5 mg/m^3 for total particulate. The one full-shift PBZ sample which exceeded the NIOSH REL was from a day shift (April 2, 1998) machine-repair worker conducting electronic maintenance in the Blohm grinding area. The specific task(s) conducted during the work shift that were the primary contributor(s) to the concentration measured (0.62 mg/m^3 [total particulate] and 0.57 mg/m^3 [extracted MWF]) were not determined. For the other seven Machine-Repair workers monitored, the full-shift TWA concentrations (total particulate) ranged from 0.10 mg/m^3 to 0.15 mg/m^3 for the night shift, and 0.16 mg/m^3 to 0.23 mg/m^3 for the day shift.

Full-shift TWA total particulate concentrations measured on the 2nd shift machine-operators ranged from 0.12 mg/m^3 to 0.36 mg/m^3, and from 0.19 mg/m^3 to 0.30 mg/m^3 for workers during the 1st shift. The concentration measured on the 2nd shift inspector was 0.09 mg/m^3, while the two inspectors monitored on the day shift had measured exposures of 0.25 mg/m^3, and 0.16 mg/m^3, as full-shift TWA's.

The results of the seven full-shift area samples (both shifts) collected in various locations in the Blohm grinding area are shown in Tables 2 and 4. All of the samples except one were below the NIOSH REL of 0.5 mg/m^3. One sample, collected approximately 6 inches from the holding tank vent on Blohm #9 showed a total particulate concentration of 1.83 mg/m^3, and an extracted-MWF (EMWF) concentration of 1.76 mg/m^3.

Full-shift TWA total particulate concentrations measured on workers in BU 264 (comparison area) were 0.04 mg/m^3 on both workers monitored during the 2nd shift, and 0.03 mg/m^3 and 0.12 mg/m^3 on the two workers monitored during the 1st shift. The EMWF concentration measured on these workers ranged from less than 0.001 mg/m^3 to 0.02 mg/m^3.

In the Blohm area, the relative contribution of EMWF to the total particulate (TP) concentration ranged from 50% to 100% (mean =77%, n=22), suggesting that for most of the samples, MWF aerosol was the primary contributor to the total concentration measured. In the comparison area, the EMWF contribution to the total sample was much less, and ranged from 17% to 50% (mean.=28%, n =3). Although only a few samples were collected, these results indicate that non-MWF particulate was the major contributor to the total concentration measured. One sample (98-153) had a higher measured EMWF concentration than TP concentration; this was attributed to analytical error.

Air Sampling - Endotoxin

The results of the endotoxin sampling are listed in Table 5. The area endotoxin concentrations in the Blohm area were significantly higher than the levels detected in Business Unit 264, for both the day and night shift samples. Although toxicological information on endotoxin is limited, the concentrations detected on these area samples were below levels suggested to cause health effects in Rylander's studies.[18] However, the concentration of the area sample collected adjacent to column D-17 in the Blohm area during the day shift on April 2 (126.1 EU/m^3) was above the calculated "no pulmonary effect level" reported by Castellan.[19]

Bulk Samples

The results of the bulk MWF samples are shown in Table 6. As previously described, the bulk samples were analyzed for aerobic bacteria, *mycobacterium sp.*, endotoxin, pH, and by an experimental technique to evaluate the lipid (fatty acid) component in the sample as a potential indicator of microbiological growth. No aerobic bacteria or *Mycobacterium* species were identified in any of the samples. Endotoxin concentrations ranged from 19,921 endotoxin units per milliliter (EU/ml) to 75,000 EU/ml. All MWF's sampled were alkaline, with a pH of 9 or 10.

Medical

All eighty employees from the Blohm area who were working during the time of our site visit completed the questionnaire. One hundred and six employees from BU 264 were working during our site visit; 84 (79%) completed the questionnaire. Subsequent review of the questionnaires revealed that three of the Blohm employees completing the questionnaires did not work primarily in the machining areas (or in BU 264); those three were excluded from subsequent analysis. Therefore, a total of 161 questionnaires was analyzed.

The mean age of all participants was 49 years (the mean age of Blohm employees was 47; that of BU 264 employees was 50). Blohm employees were more likely to be male (61 [79%] of 77 vs. 51 [61%] of 84). The mean time working at Pratt & Whitney among all participants was 22.4 years and did not differ substantially between the groups. Blohm employees reported working more days per week (mean 6.1) than BU 264 employees (mean 5.7); BU 264 employees reported working more hours per day (mean 8.9) than Blohm employees (mean 7.6). Twenty-one (27%) of the Blohm employees reported currently smoking cigarettes, compared to 16 (19%) of the BU 264 employees.

Table 7 presents the numbers and percentages of participants reporting symptoms, episodes of pneumonia, and "asthma attacks." The most frequently reported symptom was 'a stuffy, runny, irritated nose,' which was reported by 44 (57%) of the Blohm employees and 36 (43%) of the BU 264 employees. All symptoms were reported more frequently among the Blohm area employees, with the prevalence ratios ranging from 1.13 to 2.18. Confidence intervals for the prevalence ratios excluded one (indicating a statistically significant difference between the two groups) for only two of the symptoms -- chest tightness and sore throat.

Discussion and Conclusions

An industrial hygiene and medical health hazard evaluation was conducted to determine if reported health problems (flu-like symptoms, skin problems, eye irritation) were possibly associated with exposure to MWFs in the Blohm area. During this evaluation, a questionnaire was administered to workers in the Blohm grind and a comparison area, and environmental monitoring was conducted to assess exposure to MWFs.

In all PBZ air samples for MWF except one, MWF concentrations were below the NIOSH REL for the sampling period. In one full-shift sample from a machine repair worker, the MWF concentration exceeded the REL; the specific activities contributing to the concentration detected were not determined. Nozzle adjustments, the use of compressed air, or work on lines under pressure are activities that could contribute to elevated exposure to MWFs. Full-shift exposures for the other seven machine repair workers were all less than one-half of the NIOSH REL. Five of the ten PBZ air samples collected from machine operators had MWF concentrations greater than one-half of the NIOSH REL. The relative contribution of extracted-MWF aerosol to the total particulate measurement suggest that the majority of the measured particulate in the Blohm area was due to MWF aerosol and not another particulate source. These results indicate additional environmental surveillance is necessary to identify specific tasks contributing to exposure to MWF, assess the efficacy of controls, and determine where additional controls are needed. The NIOSH REL is intended to reduce respiratory disorders associated with MWF exposure. Because workers in other MWF environments have developed adverse health effects from exposures below the REL, lower exposures are desirable whenever possible.[9]

One of the area samples collected adjacent to the supply tank vent shows that MWF aerosols are being emitted into the work area, and that ventilation modifications to control emissions from this source are warranted. The ratio of the measured airborne extracted-MWF concentration to the total particulate concentration indicates, not unexpectedly, that the relative contribution of MWF aerosol to the total concentration was much higher in the Blohm area than in the comparison area.

Skin contact can be a significant route of exposure to MWFs. Contact dermatitis affecting exposed skin of workers who use MWFs is a common problem. In general, exposure to soluble oils such as the MWF used at P&W can cause irritant contact dermatitis and occasionally allergic contact dermatitis.[9] The prognosis for MWF dermatitis is considered to be poor, and primary prevention of MWF dermatitis should be emphasized. Skin rash was reported among Blohm area employees and the BU 264 employees with approximately the same frequency. Our evaluation did not attempt to determine whether there may also be other potential skin irritants (or allergens) being used in BU 264. During our evaluation in the Blohm area we observed that skin contact with MWF and metal debris is occurring and that, at least in some instances, skin contact with potential irritants and/or allergens could be decreased with appropriate work practices and glove use.

In addition to potential health problems, microbial contamination of MWF has historically been a problem in the metalworking industry because of problems such as fluid degradation, corrosion (pH reduction), generation of disagreeable or toxic gases (e.g., hydrogen sulfide), and mechanical clogging.[9] In this study, no viable bacteria were detected in any of the bulk samples, suggesting that efforts to control microbial growth in the Blohm area have been effective. This is consistent with workplace observations that an effective fluid-maintenance program has been implemented at P&W. However, endotoxins are released from the cells of gram-negative bacteria as a result of cell death, indicating that microbial growth has previously occurred in the MWF system and that continued diligence is necessary. Because no aerobic bacteria were detected in any of the bulk MWF samples, the source of the endotoxin is likely from non-viable (dead) organisms, or from bacteria species that were not detectable by the culturing technique used for these samples. Airborne endotoxin was found in much higher concentrations in the Blohm area than in the comparison area. This was an expected result, as microbial contamination of MWF is likely the primary source of endotoxin, and there were no such sources in the control area.

Exposure to MWF is known to be associated with increased prevalence of respiratory symptoms, decreases in airflow over a work shift, and the occurrence of occupational asthma and hypersensitivity pneumonitis.[9] This survey found a small but consistent increase in reporting of respiratory and irritant symptoms among those employees who worked with MWFs, and is thus consistent with findings of previous studies.[24] Our survey did not reveal an unusual number or pattern of reported medical diagnoses among participants. It is possible that certain medical conditions (e.g., hypersensitivity pneumonitis, asthma) have not yet been diagnosed among Blohm workers, or that more severely affected workers have left the workplace; the questionnaire used does not provide information needed to evaluate those possibilities. Although BU 264 was an area without substantial MWF use, it is an area in which other industrial processes are taking place; an industrial hygiene evaluation was not conducted in BU 264 to assess potential causes of workplace symptoms in that area.

RECOMMENDATIONS

1. Additional attention to housekeeping around the sump areas of the Blohm machines should be implemented to ensure that all spills and leaks are promptly cleaned. There may be areas where additional covers or baffles could be installed to ensure containment and proper drainage from the grinding machine into the sump.

2. A delay prior to employee entry into the grinding cabinet should be implemented to reduce the potential for skin or inhalation exposure to MWFs when the Blohm machine door is opened and the grinding area is accessed. This delay will allow the ventilation system to clear the grinding space. The feasibility of implementing a clean water flush or rinse when the machine is deactivated prior to entry should be investigated and implemented if possible.

3. Glove use should be mandatory when handling MWFs. The Pratt & Whitney Safety and Health Department has developed criteria for the type of glove required for specific jobs, and gloves are available for use by employees. These criteria should be posted and the requirements enforced. Prevention of skin contact, and the reduction of opportunities for skin contact, should be a primary focus of a MWF safety and health program.

Dermal contact with MWFs should be reduced as much as possible by the use of appropriate personal protective equipment and modification of work practices. Employees should be provided with and required to wear rubber gloves that cover the forearm and a rubber-front apron to prevent MWF from saturating their clothing. Nitrile gloves would be suitable because they afford good chemical resistance and are also rated as "excellent" for flexibility and resistance to abrasions, tears, and punctures.

4. At the main distribution system, the filter sludge contains metals, including nickel, and precautions to prevent skin contact should be implemented. Gloves and protective suits (e.g., disposable Tyvek®) should be worn when maintaining or working on the MWF filter banks.

5. The Blohm grinding cabinet exhaust system should be evaluated and, if necessary, redesigned or modified. The efficacy of the system is questionable because the cabinet exhaust is venting the MWF mist directly into the holding tank. The holding tank is vented to the atmosphere of the plant, and all discharges release into the work area. It may be possible to install MWF mist collection devices, either centrally or specific to each machine, to better control the release of MWF into the work area. The evaluation should also include assessing the capacity

of the ventilation to clear MWF mist from the grinding cabinet. Additional mechanisms for controlling fluid drips from the air intake of the main HVAC systems should be investigated. This effort should include controlling the source (reducing the release of MWF into the work area). The American National Standards Institute Technical Report B11 TR-2-1997 contains guidelines for ventilating machining and grinding operations.[25]

6. A systematic review and evaluation of maintenance activities in the Blohm area to identify tasks that may contribute to elevated concentrations of MWF should be conducted. Examples of potential aerosol-generating activities include nozzle adjustments, use of compressed air, or breaking into MWF containing piping/tubing. As noted, the specific activity(s) of the maintenance worker that resulted in an exposure exceeding the NIOSH REL were not identified during this survey.

Implement controls to reduce the potential for exposure for the identified maintenance tasks. Engineering controls (e.g., containment, eliminate use of compressed air, depressurization, etc.) or work practice changes should be a first consideration. If engineering or other controls are not feasible, or prior to the implementation of controls, workers conducting tasks where exposures could exceed the NIOSH REL should utilize respiratory protection. Because measured exposures were less than 10 times the REL, a particulate respirator, with an assigned protection factor (APF) of 10 will provide sufficient protection. A P-series (oil-proof) filter certified under 42 CFR Part 84 should be used; the minimally protective filter would be designated P-95. Respirators should only be used within the constraints of a comprehensive respiratory protection program (29 CFR Part 1910.134). Users must be medically cleared, trained, and fit-tested for their assigned respirator.

7. Because 50% of the Machine Operator exposures exceeded one-half of the NIOSH REL, additional sampling to evaluate worker exposures in the Blohm area should be conducted every 6 months.[9] The sampling strategy should focus on workers that are expected to have the highest exposures (high production areas, etc.). Area sampling can help augment the personal exposure monitoring. The objectives of an environmental monitoring program are to evaluate the effectiveness of work practices and engineering controls, ensure that exposures are below the REL, and identify areas where further reduction in exposures is possible.

8. Employees should be encouraged to report all potential work-related health symptoms to appropriate health care personnel. Pratt & Whitney should monitor reported health problems in a systematic manner designed to identify particular job duties, work materials (such as particular MWFs), machines, or areas of the plant which may be associated with particular health effects. A complete discussion of an occupational safety and health program pertaining to MWF, including medical monitoring, fluid maintenance, engineering controls, and environmental surveillance, is contained in the recently published NIOSH Criteria Document "Occupational Exposure to Metalworking Fluids."[9]

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Table 1 Pratt & Whitney TAPC, Blohm Grinding Line Personal Air Samples for Metalworking Fluids HETA 98-0030 April 1, 1998 - Second Shift					
Sample # Job Description	Machine #	Sample Time (min)	Total Particulate (mg/m^3)	Extracted- MWF (mg/m^3)	Percent - EMWF
98-198 Machine Repair	Entire Blohm Line	16:18-23:12 (414)	0.15	0.10	67%
98-197 Machine Operator	Blohm 10A/B	16:18-18:36 19:19-23:08 (367)	0.12	0.09	75%
98-193 Machine Operator	Blohm 8A/B	16:21-18:37 19:21-23:09 (364)	0.15	0.09	60%
98-188 Machine Repair	Entire Blohm Line	16:23-19:41 20:28-23:06 (356)	0.10	0.05	50%
98-165 Machine Operator	Blohm #2	16:25-23:12 (407)	0.26	0.19	73%
98-183 Machine Operator	Blohm #5	16:24-18:39 19:12-23:11 (374)	0.36	0.19	53%
98-200 Machine Repair	Electronics Maintenance	16:26-18:34 19:35-23:05 (338)	0.12	0.09	75%
98-140 Machine Operator	Blohm 1-4	16:26-23:08 (402)	0.15	0.11	73%
98-182 Inspector	Blohm Lines 9-12	16:29-22:58 (389)	0.09	0.06	67%
NIOSH Recommended Exposure Limit			***0.5***		

mg/m^3= milligrams of contaminant per cubic meter of air sampled
All samples corrected to the average of 4 blanks
Percent - EMWF = the percentage of the total particulate concentration attributed to extracted-MWF

Table 2 Pratt & Whitney TAPC, Blohm Grinding Line Area and Control Air Samples for Metalworking Fluids HETA 98-0030 April 1, 1998 - Second Shift					
Sample # Job Description	Location	Sample Time (min)	Total Particulate (mg/m^3)	Extracted-MWF (mg/m^3)	Percent- EMWF
98-192 EDM Operator	Business Unit 264	16:50-18:26 19:15-22:59 (320)	0.04	≤0.001	NA
98-160 EDM Operator	Business Unit 264	16:49-23:01 (372)	0.04	0.02	50%
98-189 Area: Line 8A	Blohm Machine 528155	16:45-22:52 (367)	0.18	0.16	89%
98-164 Area: Line 7B	Front of Blohm 528150	16:53-22:46 (353)	0.21	0.17	81%
98-187 Area: Line 2B	Front of Control Panel: 528142	16:52-22:50 (358)	0.21	0.20	95%
NIOSH Recommended Exposure Limit			***0.5***		

mg/m^3= milligrams of contaminant per cubic meter of air sampled
All samples corrected to the average of 4 blanks
≤= Less than or equal
Percent - EMWF = the percentage of the total particulate concentration attributed to extracted-MWF

Table 3
Pratt & Whitney TAPC, Blohm Grinding Line
Personal Air Samples for Metalworking Fluids
HETA 98-0030
April 2, 1998 - First Shift

Sample # Job Description	Machine #	Sample Time (min)	Total Particulate (mg/m^3)	Extracted- MWF (mg/m^3)	Percent- EMWF
98-184 Inspector	Inspection/QC Area	07:04-07:50 10:13-11:51 12:34-14:44 (260)	0.25	0.13	52%
98-131 Machine Operator	Blohm #6	07:05-11:12 11:50-14:46 (423)	0.26	0.23	88%
98-196 Lead Operator	Blohm #7,8,11,12	07:05-11:45 12:15-14:45 (430)	0.20	0.18	90%
98-126 Machine Operator	Blohm #4	07:07-11:50 12:32-14:46 (417)	0.30	0.24	80%
98-123 Machine Operator	Blohm #3	07:09-14:36 (447)	0.19	0.19	100%
98-195 Inspector	Inspection/QC Area	07:11-14:54 (463)	0.16	0.12	75%
98-121 Machine Repair	Electronic Maintenance	07:13-14:45 (452)	**0.62**	0.57	92%
98-143 Machine Repair	Entire Blohm Line	07:15-11:15 12:11-14:29 (378)	0.23	0.17	74%
98-147 Machine Repair	Entire Blohm Line	07:16-14:33 (437)	0.16	0.12	75%
98-146 Machine Operator	Blohm #8	07:21-12:12 12:55-14:32 (388)	0.28	0.23	82%
98-145 Machine Repair	Entire Blohm Line	07:27-14:40 (433)	0.21	0.16	76%
98-153 Machine Repair	Entire Blohm Line	07:27-11:34 13:01-14:47 (353)	0.21	0.35*	167%
NIOSH Recommended Exposure Limit			***0.5***		

mg/m^3= milligrams of contaminant per cubic meter of air sampled
All samples corrected to the average of 4 blanks
Percent - EMWF = the percentage of the total particulate concentration attributed to extracted-MWF
* Analytical error suspected

Table 4 Pratt & Whitney TAPC, Blohm Grinding Line Area and Control Air Samples for Metalworking Fluids HETA 98-0030 April 2, 1998 - First Shift					
Sample # Job Description	Location	Sample Time (min)	Total Particulate (mg/m^3)	Extracted- MWF (mg/m^3)	Percent- EMWF
98-051 EDM Operator	Business Unit 264 Cell 6	08:07-14:34 (387)	0.03	0.01	33%
98-0150 EDM Operator	Business Unit 264 Cell 8	08:10-14:36 (386)	0.12	0.02	17%
98-158 Area	Machine 528155 On supply tank	07:32-14:20 (408)	0.26	0.24	92%
98-167 Area	Column D-17	07:36-14:21 (405)	0.24	0.22	92%
98-185 Area	Front of Machine 528142	07:39-14:23 (404)	0.28	0.25	89%
98-168 Area	Blohm #9, Top of supply tank adjacent vent at Aercology Unit	07:45-14:25 (400)	**1.83**	**1.76**	**96%**
NIOSH Recommended Exposure Limit			***0.5***		

mg/m^3= milligrams of contaminant per cubic meter of air sampled
All samples corrected to the average of 4 blanks
≤= Less than or equal
Percent - EMWF = the percentage of the total particulate concentration attributed to extracted-MWF

Table 5 Pratt & Whitney TAPC Area Samples for Endotoxin: April 1-2, 1998 HETA 98-0030			
Sample #	Location	Date and Sample Time	Endotoxin Concentration (EU/m^3)
MK8045	Line 7B: Front of Blohm 528150	April 1: 16:53-22:48	66.2
MK8041	Blohm Area, Adjacent Column D-17	April 2: 07:36 - 14:21	126.1
MK8043	Business Unit 264, Control Area, Column N-51	April 1: 16:42-22:02	2.6
MK8042	Business Unit 264, Control Area, Column N-51	April 2: 08:02-14:36	4.3

EU/m^3 = endotoxin units per cubic meter of air sampled

Table 6 Pratt & Whitney TAPC Bulk MWF Samples: April 1, 1998 HETA 98-0030					
Sample #	Location/Description	Bacteria CFU/ml	MB sp. CFU/ml	Endotoxin (EU/ml)	pH
1	Main Tank #2, Clean side of hydroflow vacuum filter, Column G-17	NG	NI	23,828	9
2	Main Tank #2, "Dirty" side of hydroflow vacuum filter, Column G-17	NG	NI	23,437	9
3	Undiluted MWF from bulk tank	NG	NI	ND	ND
4	Runoff Trough, Blohm 6A, Column D-16	NG	NI	22,265	9
5	Supply Tank, Blohm 6A, Column D-16	NG	NI	19,921	9
6	Runoff Trough, Blohm 6B, Column D-13	NG	NI	27,343	10
7	Runoff Trough, Blohm 2B, Column C-13	NG	NI	60,546	9
8	Runoff Trough, Blohm 5B, Column D-9*	NG	NI	33,437	10
9	Supply Tank, Blohm 5B, Column D-9*	NG	NI	33,125	9
10	Runoff Tank, Blohm 1B, Column C-9	NG	NI	37.109	10
11	Runoff Trough, Blohm 4A, Column C-23	NG	NI	62,980	10
12	Runoff Trough, Blohm 3A, Column C-19	NG	NI	75,000	10

NG = no aerobic bacterial growth detected in sample
NI = no *Mycobacterium spp*. isolated
CFU/ml = colony forming units per milliliter of sample
EU/ml = endotoxin units per milliliter of sample
10 EU = 1 nanogram
ND = Not determined. Endotoxin could not be validated and pH could not be determined from the bulk concentrate.
* = Machine 5B had been idle for 16 hours when the bulk samples were collected. All other machines were operational.

TABLE 7 Pratt & Whitney TAPC Reported Symptoms/Illnesses Among Employees Exposed and Unexposed to MWF HETA 98-0030			
Symptom/Illness	**Number of Exposed (% of 77) reporting symptom/illness**	**Number of Unexposed (% of 84) reporting symptom/illness**	**Prevalence Ratio[1] [95% Confidence Interval]**
Tightness in chest	22 (29)	11 (13)	2.18 [1.13 - 4.20]
Sore throat	31 (40)	16 (19)	2.11 [1.26 - 3.55]
Chills	15 (19)	9 (11)	1.82 [0.84 - 3.9]
Ache all over	31 (40)	19 (23)	1.78 [1.1 - 2.88]
Feverish	17 (22)	11 (13)	1.69 [0.84 - 3.37]
Trouble breathing[2]	23 (30)	16 (19)	1.57 [0.9 - 2.74]
Cough ("Usually have cough")	30 (39)	22 (26)	1.49 [0.94 - 2.34]
Wheezing or whistling in chest	23 (30)	17 (20)	1.48 [0.86 - 2.55]
Stuffy, runny, irritated nose	44 (57)	36 (43)	1.35 [0.99 - 1.85]
Irritation of eyes	31 (40)	27 (32)	1.25 [0.83 - 1.89]
Shortness of breath during day	16 (21)	14 (17)	1.25 [0.65 - 2.38]
Rash	28 (36)	27 (32)	1.13 [0.74 - 1.74]
Pneumonia (in the last five years)[3]	6 (8)	3 (4)	2.18 [0.57 - 8.42]
"Asthma attack" in last year	5 (6)	4 (5)	1.36 [0.38 - 4.89]

1 Prevalence ratio for the reporting of the symptom among the MWF-exposed group compared with the MWF-unexposed group. Stratification by current cigarette smoking status does not alter results.

2 Defined as regular trouble with breathing which gets completely better or breathing which is never quite right.

3 Blohm: 4 employees with 1 episode, 1 with 2 episodes, 1 with 3 episodes; BU 264: 2 employees with 1 episode, 1 with 2 episodes.

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