NIOSH HEALTH HAZARD EVALUATION REPORT:

HETA #2001-0303-2893
TRW Automotive
Mt. Vernon, Ohio

October 2002

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (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 (OSHA) 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.

HETAB also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Douglas Trout, MD, MHS, and Joshua Harney, MS, of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by the Industrial Hygiene Section of HETAB. Desktop publishing was performed by Pat McGraw. Review and preparation for printing were performed by Penny Arthur.

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

Highlights of NIOSH Health Hazard Evaluation

Evaluation of Evaluation of Respiratory Illnesses (Hypersensitivity pneumonitis and occupational asthma)

This Health Hazard Evaluation was requested by the union and management at Mt. Vernon to try to find ways to stop illnesses from occurring among employees in the machining areas.

What NIOSH Did

- We met with management and union representatives.
- We examined medical records.
- We asked employees to fill out a questionnaire about their health.
- We checked the air for the level of coolant, and the coolant for bacteria and fungi.
- We checked the cleaning procedures used in the machining areas.

What NIOSH Found

- Many employees have been diagnosed with asthma or hypersensitivity pneumonitis (HP) related to work, and some are still restricted from work because of the illnesses.
- No new symptoms related to asthma or HP have been reported to doctors since May 2001.
- Employees have reported symptoms that are likely related to irritation caused by the coolant.
- The coolant used to contain a bacterium called *Mycobacteria immunogenum,* but the coolant has been changed and no longer contains living *Mycobacteria*.
- Most levels of coolant in air were below NIOSH guidelines, but in some areas air levels were above our guidelines.
- Many improvements have been made at Mt. Vernon to decrease the level of coolant mist in the air and to improve management of coolant.
- No exposures at the plant were identified which were related to the tremor some employees experienced.

What TRW Automotive Managers Can Do

- Maintain a safety and health program for employees working in the machining areas.
- Use ongoing measurement of coolant mist levels to help determine where more controls, such as enclosing and ventilating machines, may be needed.
- Use a medical monitoring program to keep track of employee symptoms to identify areas where exposure to coolant might be causing symptoms.
- Monitor the use of biocide closely and continue to check the fluid for bacteria.
- Continue to communicate with employees and the union about health and safety issues.
- Follow appropriate precautions when cleaning the machines and central systems.

What the TRW Automotive Employees Can Do

- Attend all training sessions given by the union and management.
- Follow instructions on use and maintenance of machines and coolant.
- Report all health problems that might be related to work to the plant medical department.

What To Do For More Information:

We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #2001-0303-2893

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SUMMARY

On May 11, 2001, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Automobile, Aerospace, and Agricultural Implement Workers of America (UAW) Local 1939 and management at the TRW Automotive plant in Mt. Vernon, Ohio, to conduct a health hazard evaluation (HHE). The request concerned respiratory problems, including hypersensitivity pneumonitis (HP), thought to be associated with occupational exposures to metalworking fluids (MWFs). Prior to receipt of the request, on May 9, 2001, a meeting had been held at NIOSH Hamilton Laboratories in Cincinnati, Ohio, with representatives of NIOSH, TRW, and UAW Local 1939 and UAW Health and Safety. At that meeting, respiratory symptoms and illnesses among workers were discussed. It was reported that symptoms began in approximately October 2000, and that five workers had subsequently been diagnosed by their personal physicians with HP. Subsequent evaluations and actions taken by TRW responses were also discussed. Among the industrial hygiene and medical issues discussed at the meeting, it was noted that atypical mycobacteria (*Mycobacterium chelonae*) had been cultured from the MWF (along with other bacteria) and that several of the workers first diagnosed with HP had been found to have antibodies to the *M. chelonae* on precipitin testing.

Subsequent to the meeting and the HHE request, multiple site visits were made to the Mt. Vernon plant. Environmental evaluations conducted by NIOSH investigators occurred in June and December 2001. The industrial hygiene evaluations included records reviews, personal breathing zone (PBZ) and area air sampling during usual operations as well as during cleaning operations, and bulk sampling of MWF. Medical evaluation included medical record review, discussions with employees' private physicians, and a questionnaire survey.

Initial microbial culture data collected by TRW, and confirmed by subsequent NIOSH sampling, revealed that the central MWF systems were contaminated with up to 10^7 colony forming units per milliliter (CFU/ml) total bacteria and 10^5 CFU/ml *Mycobacterium* species. In May 2001, the acid fast bacteria (AFB) pellet stain (used to assess the quantity of dead and living *Mycobacteria*) revealed 'very high' and 'high' concentrations in two of the four systems. By mid-August, about six weeks after TRW began using a new biocide (para-chloro, meta-cresol [PCMC]), no fungal or bacterial growth was found from process MWF samples. Repeated AFB pellet stains revealed a slow downward trend in the concentration of *Mycobacteria* levels over the course of the HHE.

Air sampling data (a mixture of area and PBZ samples) collected by TRW from June 2001 to February 2002 were reviewed. The mean concentrations of total particulate for these groups of samples by department ranged from 0.14 to 0.68 mg/m^3. Sixteen PBZ MWF aerosol samples for thoracic fraction of MWF aerosol taken by NIOSH representatives during normal production on June 29, 2001, ranged from below the limit of detection to 0.37 mg/m^3 (mean concentration was 0.23 mg/m^3). All samples contained a large percentage of extractable material, indicating that the exposures were primarily MWF aerosol. Aerosol sampling conducted during cleanup operations beginning the night of June 29, 2001, revealed airborne thoracic particulate concentrations inside the containment area ranging from 0.13 mg/m^3 to 0.51 mg/m^3 (mean: 0.41 mg/m^3). Concentrations outside the containment area ranged from 0.03 mg/m^3 to 0.2 mg/m^3 (mean: 0.1 mg/m^3). PBZ sampling for MWF aerosol on December 18, 2001, after air-conditioning had been added to the machining areas, revealed concentrations ranging from 0.14 mg/m^3 to 0.69 mg/m^3. Five exposures were above the NIOSH REL for thoracic particulate (0.4 mg/m^3); all five were from operators who worked on a particular horizontal broach machine as a part of their job rotation.

On May 21-22, 2001, a questionnaire was administered to all employees at the plant. Three hundred five (91%) of 335 employees completed the questionnaire, which included questions concerning respiratory and systemic symptoms occurring within the year prior to the survey. All symptoms included in the questionnaire were reported more frequently among those employees exposed to MWF compared to those who were not exposed, with prevalence ratios for symptoms ranging from 1.2 - 2.2. All but one of the 95% confidence intervals (CI) for the prevalence ratios excluded 1, suggesting that these differences were not due to chance. Twenty (77 %) of the 26 persons meeting the case definitions for HP or occupational asthma (OA) in the November 2001 medical record review (see below) participated in the questionnaire survey. Both HP and OA were more common among the exposed group compared to the unexposed group, although the CI for both illnesses included 1.

Records reviewed in November 2001 revealed that 107 workers had been placed on work restriction due to respiratory conditions in the previous 11 months. Among these 107, 70 (65%) had returned to work as of November 2001; 37 (35%) of the total 107 remained on medical leave of absence. Medical records were reviewed for 32 (86%) of the 37 workers. Among these 32 workers, 25 (78%) had primary work duties in the machining areas of the plant, although all 32 reported intermittent work duties in the machining side of the plant. Date of onset of symptoms for these workers ranged from October 2000 to April 2001, with the majority of persons reporting onset of respiratory symptoms in December 2000 and January 2001. Among the 32 workers, 14 (44%) met a case definition for OA and 12 (38%) a definition for HP. TRW records from March 2002 revealed that 35 workers were on medical leave of absence; most of these workers had remained on medical leave of absence since November 2001. Continuing review of records and discussions with the primary treating physicians in April 2002 revealed clinical diagnoses of HP and/or OA among 41 workers, with onset of symptoms prior to May 2001.

Concerns related to tremor occurring among some workers were raised during the course of the HHE. Review of medical records for seven employees seen by a private neurologist and review of the toxicity of the materials and substances used by these workers did not reveal a neurotoxic agent to which workers may be exposed at TRW. Specifically concerning PCMC (which has not been identified in the medical literature as an agent causing tremor in the workplace), four of the seven workers for whom the date of onset of tremor was reported had onset of tremor prior to the first use of PCMC at TRW.

Many TRW Mt. Vernon employees have experienced a spectrum of work-related respiratory illness, with onset of symptoms occurring between the fall of 2000 and April 2001. No employees with onset of respiratory symptoms after that time have been identified. The majority of air samples revealed concentrations of MWF aerosol in the machining areas of the plant to be below the NIOSH REL, but NIOSH air sampling revealed several instances where PBZ exposures exceeded the NIOSH REL during normal operations. Air sampling during cleanup operations indicated exposures to MWF aerosol at concentrations above the NIOSH REL.

Although the exact cause of employees' symptoms and illnesses has not been determined, evidence from similar outbreaks of illnesses at other workplaces suggests that contamination of the MWF with *Mycobacteria sp.* is playing a role. Multiple interventions were put in place over time at TRW and we are not able to identify one specific control measure which has been primarily effective in eliminating the source of the illnesses. Recommendations are provided in this report to assist TRW, the union, and workers at TRW in addressing occupational exposures in the machining areas and work-related illnesses and symptoms.

KEYWORDS: SIC 3714 (Motor vehicle parts and accessories): hypersensitivity pneumonitis, HP, occupational asthma, metalworking fluids, MWF, machining, *Mycobacterium chelonae*, *Mycobacterium immunogenum*.

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INTRODUCTION

On May 11, 2001, the National Institute for Occupational Safety and Health (NIOSH) received a request from the United Automobile, Aerospace, and Agricultural Implement Workers of America (UAW) Local 1939 and management at the TRW Automotive plant in Mt. Vernon, Ohio, to conduct a health hazard evaluation (HHE). The request concerned respiratory problems and hypersensitivity pneumonitis (HP) thought to be associated with occupational exposures to metalworking fluids (MWFs).

Prior to receipt of the request, on May 9, 2001, a meeting had been held at NIOSH Hamilton Laboratories in Cincinnati, Ohio, among representatives of NIOSH, TRW, and UAW Local 1939 and UAW Health and Safety. Subsequent to the meeting and the HHE request, multiple site visits were made to the Mt. Vernon plant. Environmental evaluations conducted by NIOSH investigators occurred in June and December 2001. A questionnaire survey was performed in May 2001. The NIOSH medical officer held group informational meetings with all employees at the TRW facility in June 2001. Multiple interim letters, dated June, October, and December, 2001, and January 2002, have been sent to the requestors summarizing NIOSH activities and interim recommendations. Results of medical record review and other information distributed in the interim letters were briefly summarized in a Centers for Disease Control and Prevention publication.[1] This final report will include a summary of the interim letters and provide final conclusions and recommendations for this HHE.

BACKGROUND

Approximately 350 production workers (including approximately 150 machinists) were employed at the TRW Mt. Vernon plant at the time of the HHE request. The plant manufactures automotive brake calipers and drums in a 200,000-square foot facility that is approximately 25 years old. A floor-to-ceiling wall divides the facility approximately in half between assembly and machining areas. The two areas have separate ventilation systems; at the time of the HHE request the assembly areas had air-conditioning, while the machining areas did not. There are four primary central MWF systems, with central reservoirs ranging in size from 4,500 (one system) to 20,000 (three systems) gallons. These systems are referred to as the Large, Henry, Small, and Mann Hummel systems. The plant also has many 'stand-alone' machines which receive their MWF from smaller, individual sumps. At the time of the HHE request, the primary MWF in use was a semisynthetic fluid (United Chemical Solutions, UCS 4900-SS). A triazine-based biocide was used on a regular basis, with intermittent additions of an isothiazolinone-based biocide (generally for levels of bacteria greater than 10^5 colony-forming units per milliliter [CFU/ml] in MWF). The MWF monitoring program included daily testing for dilution, percent free oil and solids contamination, pH, and total dissolved solids, as well as every other day testing for microbial contamination.

At the May 9 meeting, it was reported that initial respiratory symptoms and illnesses among workers had begun in approximately October 2000; subsequently, five workers were diagnosed by their personal physicians with HP between December 2000 and April 2001; several of the workers had been hospitalized at the time of diagnosis. It was further reported that, beginning in December 2000 and continuing to the time of the HHE request, TRW had responded to the illnesses primarily by: 1) performing cleaning operations (along with recharging with new MWF) on some of the central systems and individual machines; 2) cleaning, re-charging, and adding MWF circulation pumps to some of the stand-alone machines; 3) maximizing existing general ventilation in the machining areas; 4) reviewing and improving MWF maintenance procedures; 5) increasing industrial hygiene evaluations in the machining areas; and 6) providing screening medical examinations to workers. Among the industrial hygiene and

medical findings, it was noted that atypical mycobacteria (*Mycobacterium chelonae*) had been cultured from the MWF (along with other bacteria) and that several of the workers first diagnosed with HP had been found to have antibodies to the *M. chelonae* on precipitin testing.

At the initial meeting it was reported that employees diagnosed with HP (and other respiratory illness) included employees from multiple departments. Review of information (such as job locations and job tasks) collected by TRW and their consultants provided no indication that one specific MWF system, machine, or portion of the machining area was associated with the illnesses. Around the time of the HHE request, and in the weeks afterward, many other TRW employees reported respiratory and other symptoms and were evaluated at one or more medical facilities. In response to the reported symptoms and illnesses and evidence of continued microbial contamination of the MWF in the various systems at the plant, in June 2001, NIOSH representatives made a series of recommendations to the plant to decrease health effects related to exposures at the plant. Subsequently, among the major actions taken by TRW related to both qualitative (primarily thought to involve microbial contaminants) and quantitative (aerosol concentration) aspects of the MWF aerosol were: 1) discarding all old MWF, cleaning all central systems again (some had been cleaned several times), and re-charging the systems with fresh MWF–these actions were completed in July 2001; 2) installing a new biocide (para-chloro meta-cresol [4-chloro-3-methyl phenol, PCMC]) known to be effective against *Mycobacteria*–July/August 2001; 3) installing new general ventilation (air-conditioning) in the machining side of the plant – August/September 2001; and 4) adding mist collectors for many of the machines (particularly those identified as producing higher MWF aerosol concentrations) supplied by the central systems–December 2001/January 2002. Additionally, TRW enclosed and ventilated parts washers, and took some steps to shroud (partially enclose) the Barnes transfer line heads (which contribute to MWF aerosol levels on the machining side of the plant).

METHODS

Industrial Hygiene

Record Review

During the course of the HHE, interim recommendations from NIOSH representatives to TRW were guided in part by ongoing review of industrial hygiene data collected by both TRW and NIOSH. Only representative data from among those collected by TRW will be reviewed in this report. One of the primary tests used to assess microbiologic contamination of the MWF at TRW is the 'Acid-fast bacteria (AFB) pellet stain.'[2] This test has been performed for TRW by a contract laboratory. To perform the AFB pellet stain, 5 milliliters (ml) of MWF is centrifuged and the resulting pellet is smeared to a microscope slide. The slide is then stained to differentiate *Mycobacteria* (which may be either alive or dead), and those cells are counted and reported using the following key:

Negative - $< 10^4$ cells per ml MWF
Very Low - 1-5 cells/slide
Low - 1-10 cells/slide
Low to Moderate - 1-5 cells/microscope field
Moderate - 5-50 cells/field
Moderate to High - 50-100 cells/field
High - >100 cells/field
Very High - Almost confluent, impractical to count

June 2001 Site Visit

During a site visit in June 2001, NIOSH staff assessed occupational exposures in the machining areas. The NIOSH site visit occurred during a weekend in which TRW was conducting a series of cleaning operations involving the machines supplied by the Large system, as well as other machines in that general area. The effectiveness

of the containment system was evaluated both qualitatively and quantitatively to determine whether workers outside the containment area were at risk of exposure from airborne contaminants generated during the vigorous cleanup activities within the containment area. A real-time aerosol monitor was used inside and outside the containment area before and during cleanup operations to give an immediate indication of the containment's effectiveness.

The plastic containment curtain was observed before, during, and after negative pressure was created in the containment area. Openings in the contained area, for example, adjacent doorways to the assembly side of the plant and openings in the curtain itself, were challenged with smoke to determine whether gross airflow moved into or out of the containment area.

Air Sampling Methods – Both general area and personal breathing zone (PBZ) air samples were collected during this site visit. Air samples for MWF aerosol were collected on a 37 millimeter (mm) closed-face cassette containing a tared 2 micrometer (µm) pore-size polytetrafluoroethylene (PTFE) filter. A thoracic cyclone was attached to the sampling cassette so that only the thoracic fraction of the aerosol would be collected. The thoracic portion of an aerosol is the portion that will penetrate past the nasopharynx, i.e., those particles with an aerodynamic diameter of 10 µm or less.[3] Tygon® tubing connecting the sampler and a personal sampling pump allowed air to be drawn through the sampling train at a flow rate of 1.6 liters per minute (Lpm).[4] The cassettes containing the filters and back-up pads for each sample were placed into a desiccator for at least 16 hours for equilibration before analysis.

The particulate mass for each sample was determined by measuring the gross weight of each filter on an electro balance and subtracting the previously determined tare weight of the filter. The filters for each sample were then extracted using a 1:1:1 blend of dichloromethane, methanol, and toluene. After drying in a vacuum oven for at least two hours, the filters were allowed to re-equilibrate to balance room conditions for at least two hours. The filters were then reweighed on the same electro balance. The extractable mass was calculated by subtracting the post-extraction filter weight from the pre-extraction filter weight. If the collected aerosol was largely extractable, then it was presumably MWF.

A bulk sample of process MWF was submitted with the air samples to make sure it was soluble in the trisolvent extraction fluid mentioned above. This solubility test indicated that the MWF used at TRW was indeed soluble in the trisolvent, and therefore suitable for analysis by this methodology.

The limit of detection (LOD) and limit of quantification (LOQ) for particulate mass analysis were determined by using the standard deviation of the mass of five media blanks. The LOD is three times the standard deviation of the media blanks, and the LOQ is ten times the standard deviation of the media blanks. The MWF samples were analyzed in two separate batches having unique analytical limits. For samples numbered MWF 1 through MWF 15, the LOD for particulate mass was 0.05 milligram/sample, which equates to a minimum detectable concentration (MDC) of 0.07 milligrams per cubic meter of air (mg/m^3) based on an average sample air volume of 681 L. The LOQ was 0.2 mg/sample, yielding a minimum quantifiable concentration (MQC) of 0.29 mg/m^3 based on an average sample air volume of 681 L. For MWF 16-30, the LOD was 0.004 mg/sample, yielding an MDC of 0.006 mg/m^3 based on a sample air volume of 627 L, the average sample volume for this sample set. The MQC for MWF 16-30 was 0.013 mg/m^3, based on the same average sample air volume.

Air sampling was also conducted using a portable, real-time, hand-held aerosol monitor (HAM Model 1055, PPM Inc., Knoxville, Tennessee). The HAM was used three separate times during June 29-30, 2001: during normal production, immediately before cleanup operations began after production in the Large system machining area

ceased, and during cleanup operations. The HAM gives the user aerosol mass concentration information based on the light scattering properties of particulate passing through the instrument. Therefore, if any two particles have the same physical dimensions, but have different light scattering properties, they will 'look' different to the HAM. The HAM was initially calibrated by the manufacturer using Arizona road dust, a solid particulate with an uneven surface texture. It is unknown how closely the light scattering properties of the calibration dust are to those of the MWF aerosol at TRW, primarily a liquid particulate with presumably smoother surface texture than the Arizona road dust. This being the case, and because during this study the HAM was not calibrated using a side-by-side gravimetric method, data gathered with the HAM should be regarded as qualitative in nature.

December 2001 Site Visit

NIOSH industrial hygienists performed a second environmental evaluation on December 18-19, 2001. Personal exposure monitoring for MWF aerosol was conducted during the second shift on December 18, 2001, and the third shift on December 19, 2001. Twenty PBZ samples were collected each day, following the methods described above.

The MWF samples were analyzed in two separate batches having different analytical limits. For samples A1 through A23, the LOD for particulate mass was 0.007 mg/sample, which equates to an MDC of 0.009 mg/m^3 based on an average sample air volume of 796 L. The LOQ was 0.02 mg/sample, yielding an MQC of 0.025 mg/m^3 based on an average sample air volume of 796 L. For samples A26-46, the LOD was 0.006 mg/sample, yielding an MDC of 0.009 mg/m^3 based on a sample air volume of 646 L, the average sample volume for this sample set. The MQC for A26-46 was 0.031 mg/m^3, based on the same average sample air volume.

Medical

Medical Record Review

Beginning at the time of the HHE request, the NIOSH medical officer reviewed numerous records including: 1) TRW personnel records concerning employee illnesses; and 2) medical records from personal physicians of employees reporting symptoms or illness. Records were reviewed periodically during the course of the HHE with two primary purposes.

One purpose for the review of physicians' records was to examine the physicians' diagnoses of illness. A physician diagnosis of an individual illness is based on 'clinical' knowledge and judgement and may not take into account certain criteria called for in epidemiologic case definitions for that illness. The other purpose for the review was to review records using epidemiologic case definitions for HP and occupational asthma (OA). In November 2001, a review of company personnel records and medical records was performed using the following case definitions. HP was defined as the presence, within the previous year, of one or more work-related respiratory symptoms (cough, dyspnea, wheezing, or chest tightness) and one or more systemic signs or symptoms (fever, chills, extreme fatigue, myalgia, or night sweats); and an infiltrate seen on chest X-ray (CXR) or high resolution computed tomography (HRCT) scan; and abnormal spirometry (either an obstructive or restrictive pattern). OA was defined as one or more work-related respiratory symptoms (cough, dyspnea, wheezing, or chest tightness) and the absence of systemic signs or symptoms; no infiltrate seen on CXR or HRCT scan; and spirometry consistent with reversible airway obstruction (an obstructive pattern with $\geq$20% improvement in forced expiratory volume at one second after administration of inhaled bronchodilators).

Questionnaire

On May 21-22, 2001, a questionnaire was administered to all employees at the plant. Three hundred five (91%) out of 335 employees

completed the questionnaire. The 335 employees to whom the questionnaire was distributed included employees at work on the days of the survey, as well as those employees who were on medical leave of absence and who could be reached by union representatives. The goal of the survey was to obtain further information concerning the nature of respiratory problems among employees at the plant. The questionnaire included questions concerning job duties, current symptoms, and medical history. Questions about symptoms asked about symptoms experienced in the year prior to the survey, and possible responses included "usually," "sometimes," or "never." The responses to the symptom questions were combined to create a positive response ("usually" or "sometimes") and negative response ("never"). Those persons reporting MWF use in their job were considered to be 'exposed' to MWF, and those not reporting MWF to be 'unexposed.' A second exposure variable was also used in evaluating symptoms, 'high' and 'low' exposure areas, with the 'high/low' distinction based on total particulate concentrations in air (Table 1). In creating this variable, Department W03 was excluded because: 1) although the exposures were similar to those in the 'high' exposure group, the median for the department was less than the median for all the departments; and 2) there was a relatively small number of observations in this department.

The magnitude of the relationships between exposure and symptoms or illness was assessed by the prevalence ratio (PR); a 95 percent confidence interval (95 percent CI) which excluded 1.0, or a significance level of $p \leq 0.05$, was considered to indicate a statistically significant finding. The PR represents the prevalence of the symptom in one group ("exposed") relative to the prevalence in the comparison group ("unexposed"). For example, a PR of one means there is no association between the symptom/illness and "exposure." A PR of greater than one indicates that there is evidence of an association. A PR of two would mean that a person in the "exposed" group may be two times more likely to have reported the symptom than a person in the "unexposed" group. Further analysis of some aspects of the questionnaire data related to respiratory illness is presented in the Appendix.

EVALUATION CRITERIA

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 criteria. 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 increases 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®),[3] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[6] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever is the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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

Metalworking Fluids

MWF Aerosol

NIOSH recommends that occupational exposures to MWF aerosols be limited to 0.4 mg/m^3 of thoracic particulate mass as a TWA concentration for up to 10 hours (hrs)/day during a 40-hr work week, measured according to NIOSH Method 0500.[7] The 0.4 mg/m^3 concentration thoracic particulate mass corresponds to approximately 0.5 mg/m^3 total particulate mass. Both of these REL values will be referred to in this report because both types of sampling were done.

This REL is intended to reduce the respiratory disorders associated with MWF exposures in the workplace. However, concentrations of MWF aerosols should be kept below the REL where possible because some workers have developed HP/OA, or other adverse respiratory effects when exposed to MWFs at lower concentrations.[7] Limiting exposure to MWF aerosols is also prudent because certain MWF exposures have been associated with various cancers. In addition, limiting dermal (skin) exposures is critical to preventing allergic and irritant skin disorders related to MWF exposure. In most metalworking operations, it is technologically feasible to limit MWF aerosol exposures to 0.4 mg/m^3 or less.

Microorganisms

Historically, microbial contamination of MWF has been a problem primarily because of the microbial growth effects on fluid quality and performance. Fluid degredation from microorganisms may result in changes in fluid viscosity, and the acid products of fermentation may lower the pH of the fluids, causing corrosion of machined parts. Anaerobic bacteria, specifically the sulfate reducers, may produce hydrogen sulfide and other toxic gases. Excessive microbial growth may result in clogged filters and ports and may interfere with the machining operations.

Water-based MWFs are excellent nutritional sources for many kinds of bacteria and fungi. The predominant species routinely recovered from MWFs are virtually identical to those routinely recovered from natural water systems. Many species that grow in MWFs secrete waste products that serve as a nutritional substrate for organisms with more restrictive nutritional needs. Well-maintained MWFs should have bacterial concentrations below 10^6 colony forming units per mL (CFU/mL) of fluid.[8]

Some individuals manifest increased immunologic responses to microorganisms, or their metabolites, in the environment. Although microbial contamination of MWFs poses a potential occupational hazard, there are insufficient data to determine acceptable levels of microbial contamination in the air. In addition, allergic or hypersensitivity reactions can occur even with relatively low air concentrations of allergens, and individuals differ with respect to immunologic susceptibilities. Although some pathogenic organisms have been identified in oil emulsion MWFs in the past,[9,10] most pathogens do not persist well in most MWFs.[11,12,13,14]

MWF Aerosol and Respiratory Illness

Studies summarized in the NIOSH Criteria Document provide evidence that occupational exposure to MWF aerosols causes symptoms consistent with airways irritation, chronic bronchitis, asthma, and HP. HP has been described as occurring at facilities performing a variety of machining operations;[15,16] in general those facilities have used water-based MWF.[17] In many cases, the specific agent(s) responsible for HP and other illnesses is (are) not known. HP (also called extrinsic allergic alveolitis) is a spectrum of granulomatous, interstitial lung diseases which occur after repeated inhalation and sensitization to a wide variety of microbial agents (bacteria, fungi, amoebae), animal proteins, and low-molecular weight chemical antigens. The presence of *Mycobacteria* has been associated with many of the reported outbreaks of HP in machining environments.[17,18] The *Mycobacteria* isolated from TRW (as discussed above and in Results) was initially identified as *M. chelonae*, a mycobacteria that has been found as a contaminant in other machining plants where there have been outbreaks of HP. Recently *M. immunogenum* has been identified as new species of the *M. abscessus/M. chelonae* group.[19] Samples from TRW (and other machining environments), previously identified as *M. chelonae*, have been re-examined and found to be *M. immunogenum*.

In general, the time of onset of HP after initial exposure to an antigen may range from a period of weeks to years. HP is marked by a pneumonitis, which is reversible if exposure to the antigen is stopped; continued exposure can lead to a chronic interstitial fibrosis or scarring of the lungs. In general, HP is marked by nonspecific symptoms. Acute HP begins in the first 12 hours after exposure with cough, dyspnea (shortness of breath), chest tightness, fevers, chills, malaise, and myalgias (muscle aches). The symptoms of the subacute and chronic forms of HP include cough, dyspnea, wheezing, loss of appetite, and weight loss. The diagnosis should be considered in anyone with recurrent "pneumonia" or recurrent or persistent unexplained respiratory symptoms; suggestions for uniform criteria for the diagnosis of HP have been published.[20,21]

RESULTS

Industrial Hygiene

Initial Record Review and Interim Recommendations

Microbial culture data were among the first data reviewed for this HHE. Cultures collected on April 19, 2001 (prior to the HHE request but after cleaning and maintenance changes had been initiated at the plant), revealed that bulk samples of MWF taken from the Large system had 40 CFU/ml bacteria (no genus or species identified) and 400 endotoxin units/ml (EU/ml), and a sample from the Small system had 1.3×10^7 CFU/ml total bacteria and 40,000 EU/ml. On May 7-8, 2001, two bulk samples of MWF taken from the Small system after the first cleaning of that system contained 10^5 CFU/ml *Mycobacterium* species. Other samples from all four central MWF systems, taken prior to the HHE request (not reported here) also contained *Mycobacterium sp.* Bulk samples taken on May 25, 2001, from the four central MWF systems indicated that viable (alive) bacterial, fungal, and *Mycobacteria* counts were below the limit that could be detected (< 1 CFU/ml for bacteria, and < 10 CFU/ml for fungi) for all four systems. The bulk samples also were analyzed using the AFB pellet stain to assess the quantity of dead and alive *Mycobacteria*. The testing on that date revealed the following: Henry system - 'very high;' Large system - 'high;' Small system - 'very low;' and Mann Hummel system - 'very low.' These results indicated that at that time the Large system and the Henry system had concentrations of dead *Mycobacteria* much greater than those found in the other two central systems. It should be noted that the Small system (which previously had relatively high concentrations of

microorganisms) had been cleaned twice in the five weeks prior to the May 25 testing.

Results of bulk MWF sampling after August 2001 consistently revealed that most bulk samples had viable (alive) bacterial and fungal counts below the limit that could be detected. A summary of AFB pellet stain results is presented in Figure 1. TRW had been collecting AFB pellet stain information on a frequent basis (during that time period, every several days for much of the time). The data in Figure 1 include representative bimonthly sample results from the four central systems, and show a downward trend over the period from May 2001 through August 2002. The Large system is the only system that has had fairly consistent negative results on the AFB pellet stains recently; the other systems have had negative test results alternating with test results of very low or low.

Record Review of Ongoing Air Sampling Performed by TRW

Air sampling data collected over the period of June 2001 to February 2002 were reviewed. These data represented a mixture of area and PBZ samples taken by TRW and consultants in multiple departments over many different dates. The results are summarized briefly in Table 1 by department. Some of the air concentrations were reported as less than the MDC; in those cases, for the purpose of this review, the average MDC value for the department over the time period of the sampling was substituted as the concentration. As Table 1 shows, the median concentrations for these groups of samples were below the NIOSH REL for total particulate of 0.5 mg/m^3, although all departments except one had one or more samples above the NIOSH REL. Based on the information in Table 1, machining departments can be divided into 'high' exposure departments (Departments 1, 2, 4, and 6) and 'low' exposure departments (Departments 7, 17, and 57). Reported symptoms and illnesses were compared between these 'high' and 'low' exposure areas, as mentioned in Methods.

In many cases, the extractable portion of the total particulate was analyzed in the samples collected by TRW or consultants. Review of these data reveals that the percentage of extractable material (representing MWF) was variable, ranging from near zero to 100%. This in part reflects that fact that these sampling data included sampling from a wide variety of locations in the plant.

June Site Visit

Results from PBZ MWF aerosol sampling conducted by NIOSH during normal production on June 29, 2001, are listed in Table 2. Four samples were collected on the assembly side of the plant (samples numbered MWF 7, 10, 12, 16); thoracic particulate concentrations from those samples ranged from 'not detected' (nd) to 0.07 mg/m^3. Sixteen samples were collected from personnel working on the machining side of the plant. Full-shift exposures ranged from nd (collected from a Kirby operator whose machine was offline most of the shift) to 0.37 mg/m^3 for the Honsberg operator. One partial-shift exposure (PHN131 anchor broach) exceeded 0.4 mg/m^3, indicating the potential for over exposure associated with that operation. The mean exposure for those working on the machining side (excluding the Kirby operators) was 0.23 mg/m^3. All samples contained a large percentage of extractable material, indicating that the exposures were primarily MWF aerosol.

Table 3 details results of the aerosol sampling conducted during cleanup operations beginning the night of June 29, 2001. One PBZ sample was collected from a steam cleaning assistant; the rest of the samples were area samples. Airborne thoracic particulate concentrations inside the containment area ranged from 0.13 mg/m^3 to 0.51 mg/m^3 (mean = 0.41 mg/m^3). Concentrations outside the containment area on the machining side ranged from 0.03 mg/m^3 to 0.2 mg/m^3 (mean = 0.1 mg/m^3). These samples were also largely comprised of extractable material.

As shown in Table 4, based on HAM data, the outdoor concentrations of airborne particulate were 0.07 mg/m^3, and concentrations in the assembly side of the plant were consistently less than 0.1 mg/m^3 on June 29. During this same time, concentrations on the machining side of the plant ranged from 0.2 mg/m^3 in the aisle along the north wall of the building to 0.5 mg/m^3 by the PHN131 horizontal broach, with higher readings obtained near certain work stations such as the Barnes transfer machine. Particulate concentrations at the Barnes transfer stations #11 and #15 were 0.3 mg/m^3 and 0.8 mg/m^3, respectively. Stations #5 and #7 were 1.2 mg/m^3 and 1.5 mg/m^3, respectively. Because of the qualitative nature of these HAM values, they merely illustrate a general increase in aerosol concentrations from the northern end to the southern end of the areas monitored.

Table 5 compares HAM aerosol concentrations immediately preceding and during cleanup operations at seven locations, both inside and outside the containment. The measurements taken during cleanup were all within 10% of those taken preceding cleanup operations. The exception occurred at the north-south aisle on the west side of the plant, where the concentration during cleanup was about 80% of that measured prior to cleanup.

Cleaning Process Description– In preparation for cleaning of the Large system, the utility boxes and motors on each machine were covered with plastic to prevent damage from the steam cleaners. Next, a degreaser and machine tool cleaner were sprayed on those machine surfaces that had MWF contact. Following this, steam cleaning and a visual inspection were done. If MWF residue was still visible, more steam cleaning was done until the machines were visibly clean. All the runoff was channeled through the floor flumes back to the central sump. After the machines were cleaned in this manner, a high-pressure 'snake hose' was drawn through the floor flumes to clean the flumes and underside of the flume cover-plates. Then the flumes were flushed for one hour with water and machine tool cleaner. After this flushing, a mixture of water, 2.5% MWF and 2000 parts per million (ppm) PCMC (biocide) was run through the system for about 2 hours. Next, a mixture of 5% coolant, 2000 ppm PCMC, and a defoamer agent was run through the system. This prepared the system to be recharged with virgin MWF and the required mixture of biocide, defoamer, and other additives before production resumed.

Workers involved with cleanup procedures wore various personal protective equipment (PPE). Those directly conducting steam cleaning wore full-facepiece respirators with P100 cartridges, while their assistants used P95 filtering facepieces. All workers, including those taping off the motors and utility boxes on the machining centers, wore Tyvek™ outer garments and nitrile gloves.

Containment effectiveness evaluation – When the plastic sheeting separating the Large system machining areas from the rest of the plant was installed, it was initially observed to billow out away from the Large machining area. This indicated that that area was under positive pressure relative to the adjacent areas. After production in this area was halted, the rooftop make-up fan was shut off and the rooftop exhaust fan was on. Other large fans were used to exhaust air from this space. As a result, the plastic sheeting billowed into the Large system machining area, indicating that during cleanup operations this area was under negative pressure relative to the adjacent areas of the building.

Under these conditions, smoke tubes were used to help visualize the effectiveness of the containment system. Smoke was introduced near openings in the plastic in the following areas: eastern-most aisle running north-south on the machining side, western-most aisle running north-south, basket assembly/pallet pass-through in wall between machining and assembly, and at several seams in the plastic along the aisle separating the Large machining area from the Henry machining area. In all cases, smoke was drawn into the containment area, confirming that it was under negative pressure relative to adjacent areas.

Bulk MWF microbial analyses – Table 6 shows the results of microbial analysis of bulk MWF collected from the June site visit, as well as from two other days. With the exception of *M. chelonae*,[*,22] the other organisms found are fairly typical of water-based MWFs. While Large system and Henry system samples from May 2001 included several species of culturable bacteria in addition to *M. chelonae*, in June 2001 *M. chelonae* was the dominant organism in the MWF of these central systems. During this same period, the Small system contained only *M. chelonae*, which increased in concentration to levels matching those of the Large and Henry systems, approximately 10^6 CFU/mL. The Mann-Hummel system, though it was not at the time being used for normal production, also yielded only *M. chelonae* on May and June 2001 cultures. The MWF from the PHN131 broach had several other types of bacteria present in addition to the *Mycobacteria*. *M. chelonae* was also found in the ZJ parts washer in June, along with very high levels of Gram-negative bacteria. By mid-August, about six weeks after TRW began using PCMC biocide, no fungal or bacterial growth was obtainable from process MWF samples collected at the locations listed in Table 6. At the time of each NIOSH sample collection, endotoxin levels were generally lower than is usually found in other water-containing MWF systems where Gram-negative organisms typically predominate.[23]

December Site Visit

PBZ results from MWF aerosol sampling conducted during second shift on December 18, 2001, are listed in Table 7. Most samples contained a large percentage of extractable material, indicating that the exposures were primarily MWF aerosol. The exceptions were the tool and die operator (sample #A15), who did not use any machinery with MWF during this shift, an OTS operator in WO2 (sample #A9), and one of the Kirby operators in WO7 (sample #A5). The concentrations from these three samples were below 0.2 mg/m^3. The rest of the concentrations ranged from 0.23 mg/m^3 to 0.69 mg/m^3 (mean = 0.37 mg/m^3). Five exposures were above the NIOSH REL (0.4 mg/m^3); all five were from operators who worked on a horizontal broach machine as a part of their job rotation.

Table 8 details results of the aerosol sampling conducted during third shift operations beginning the afternoon of December 19, 2001. These samples were all largely comprised of extractable material. The concentrations ranged from 0.14 mg/m^3 to 0.4 mg/m^3 (mean = 0.27 mg/m^3).

During the December 2001 site visit engineering controls were observed. At the Barnes transfer line, parts rotate past stationary machining stations (called 'heads') that have cutting actions that retract from the cutting zone while the transfer line moves a new part into place to be machined. Five of six heads on the north Barnes line are splash-guarded on three sides. On the south Barnes transfer line, three of seven heads are splash-guarded on three sides, while the remaining four heads are splash-guarded only in the front, or in the front and one side. Both the north and south sides of the Barnes transfer line have several heads where the cutting tool remains on, rotating quickly, and the MWF is forcibly expelled into the cutting zone even while there is no part within the zone. This creates large amounts of aerosol due both to the impaction of the fluid on the surface opposite its injection point, and to the spinning action of the cutting tools bathed in MWF. Two heads were observed during third shift operations on December 19, 2001. Head #9 operated with a cutting time of roughly 11 seconds per part, and a non-cutting time of roughly 12 seconds between parts. Head #8 had cutting times averaging roughly 8 seconds, and non-cutting times averaging 15 seconds between parts. In both

[*] The identification of mycobacteria present in MWF is an active field of investigation. It appears that some mycobacteria previously identified as *M. chelonae* is now more accurately identified as *M. immunogenum*. Future work will help clarify the types of mycobacteria present as contaminants in MWF.

cases, non-cutting times occasionally increased up to over one minute.

Medical

Medical Record Review

One of the primary purposes of the medical record review during the early stages of the HHE was to determine whether workers were becoming newly symptomatic during the time TRW was taking measures to eliminate (or minimize) the cause(s) of the respiratory illnesses which were occurring among employees. During June and July of 2001 many employees were being evaluated for respiratory symptoms and other concerns by several different healthcare providers. Although it could not be formally documented during that time because of the large number of workers continuing to present for evaluations, discussions with the two primary healthcare providers for TRW employees indicated that many of the workers presenting for evaluation had been symptomatic for many weeks or months.

TRW records reviewed in November 2001 revealed that 107 workers had been placed on work restriction due to respiratory conditions in the previous 11 months. Among these 107, 70 (65%) had returned to work as of November 2001. Nineteen (27%) of those 70 workers were medically restricted by their treating physician from exposure to MWF – (medical restriction included either use of respiratory protection or restrictions from working in the machining areas of the plant). Fifty-one (73%) of the 70 had medical restrictions prior to November 2001 which had subsequently been removed by their treating physician. Thirty-seven (35%) of the total 107 remained on medical leave of absence as of November 2001. Medical records were reviewed for 32 (86%) of the 37 workers. Among these 32 workers, 25 (78%) had primary work duties in the machining areas of the plant, although all 32 reported intermittent work duties in the machining side of the plant. The median length of time working at TRW for these 32 workers was 18 years. Date of onset of symptoms for these workers ranged from October 2000 to April 2001, with the majority of persons reporting onset of respiratory symptoms in December 2000 and January 2001. Among the 32 workers, 14 (44%) met the definition (defined in Methods) for OA and 12 (38%) the definition for HP. Six (19%) of the 32 had illnesses characterized primarily by respiratory or upper respiratory symptoms but did not meet the definitions for OA or HP; these persons had symptoms consistent with work-related bronchitis or rhinosinusitis.

The date of onset of symptoms refers to the date employees reported that they first had symptoms related to their illness. In most cases this date is different (often by several months or more) from the date employees first saw a health care provider. The difference between these dates is likely due to several factors, including employees not considering their symptoms serious enough to require medical care as well as other issues related to access to medical care.

TRW records from March 2002 revealed that 35 workers were on medical leave of absence due to respiratory conditions. Of the 35, 30 of the workers had been on medical leave of absence as of the November 2001 record review and had remained off work. Three of the 35 had not been medically restricted in November 2001, and 2 of the 35 had been medically restricted (work in the non-machining areas) as of November 2001. Twenty-one workers were medically restricted as of the March 2002 record review. Of the 21, 16 had been similarly restricted in November 2001, 3 had not been medically restricted as of November 2001, and 2 had previously been on medical leave of absence.

Several issues were discussed in a meeting with one of the primary treating pulmonologists in April 2002. Regarding the possibility of newly symptomatic workers (the recognition of newly symptomatic employees could be used as an indicator of the effectiveness of control measures at the plant), the physician reported that no TRW workers hired to replace workers out on medical

disability had been seen for respiratory illness; the physician agreed with the findings of symptom onset reported in the record review above. The physician's own summaries of illness among TRW workers at that time included: 18 persons diagnosed with HP, 10 with OA, 13 with a mixed HP/OA illness, 5 with other respiratory diagnoses, and 7 not categorized. The physician noted that a primary symptom which had persisted among many of the ill workers, and which was a primary reason for inability to return to work, was a profound fatigue (in many cases, occurring in the setting of normal pulmonary function tests).

Neurologic Issues

In the course of the HHE, concerns related to neurologic symptoms among some workers were raised. The exact number of workers reporting these symptoms was not determined precisely, however union representatives reported that approximately 10-20 workers may have reported these symptoms. Specifically, workers had reported to healthcare providers that they were experiencing tremors, and they were concerned that the tremors were related to occupational exposures at the TRW facility. Some of the employees reporting these symptoms were referred to a neurologist. In April 2002, the NIOSH medical officer reviewed seven medical records from the consulting neurologist and interviewed an eighth worker with tremor (but who had not yet seen a neurologist). Of those eight persons, seven worked primarily in the machining areas, and the other worked primarily in assembly but performed overtime work in the machining areas. The records of six workers had some information on physical findings, and each demonstrated abnormal findings on the neurologic examination; most commonly the workers were noted to have fine postural tremor with some intention tremor as well. One person had a history of head tremor. In several cases, the records noted "mild" or "minimal" evidence of cogwheel rigidity (which is among the findings consistent with Parkinson's Disease). The onset of tremor (for all seven workers for which this information was available) was noted to be January 2001 (two persons), May 2001 (two persons), July 2001 (one person), 'fall' 2001 (one person), and Febraury 2002 (one person). The consulting neurologist performed a medical evaluation for tremor (including blood tests and magnetic resonance imaging of the brain in most cases) and could not identify a specific cause or underlying reason for the observed clinical findings. Conclusions from the neurologist for each of the seven persons included concerns about possible work-related "chemical" or "toxic" exposures; no specific chemicals or toxins were described in the records as possible agents causing the observed findings.

Material safety data sheets for all of the agents used in manufacturing processes in the machining portion of the plant around January 2001 were reviewed, and none of the materials contained substances that have been found to be associated with parkinsonism or tremor. A thorough review of agents (chemicals or toxins) known to be associated with movement disorders (such as parkinsonism and tremor) did not reveal any such substances to be in use (or produced) at TRW.[24]

Questionnaire

Among the 305 persons completing the questionnaire, 168 (57%) were from 1st shift (day), 107 (36%) from 2nd shift (afternoon), and 22 (7%) from 3rd shift (nights). Descriptive statistics of participants are included in Table 9, grouped by self-reported exposure to MWF in their job.

The questionnaire was used to try to identify specific machines, systems, or areas that might be associated with an increase of reported symptoms or illnesses. Sixty-one (21%) workers reported that they usually work on one machine; this is consistent with the frequent job rotation which had been reported by management and employee representatives. Among the 270 persons who reported at least one respiratory or systemic symptom in the year prior to the survey, only 76 (28%) reported that the symptoms were related to a specific work activity or job task. A summary of the work activities or job tasks associated by these 76 persons with symptoms, categorized by self-

reported work with MWF in their usual job, is presented in Table 10. Among the 76 persons, 44 (58%) identified exposure to MWF (or some task related to using MWF) as being related to their symptoms, but very few individual specific areas, systems, or machines were identified as being related to symptoms.

All symptoms included in the questionnaire were reported more frequently among those employees exposed to MWF (Table 11), with prevalence ratios for symptoms ranging from 1.2 - 2.2. CI for the prevalence ratio for one of the symptoms ("ache all over") included 1; all other CI were greater than 1. Twenty (77 %) of the 26 persons meeting the case definitions for HP or OA in the medical record review (discussed above) participated in the questionnaire survey. Both HP and OA were more commonly observed among the exposed group compared to the unexposed group, although the difference between the two groups was not statistically significant. Of the five persons with HP or OA unexposed to MWF, four worked in Department W21 (a department in which machining with MWF occurred). One of the five worked in W08 (assembly, no MWF used routinely), but did report (in the medical record) daily presence in machining areas.

Reported symptoms were also analyzed by 'high' and 'low' exposure status. Based on summary data presented in Table 1, Departments 1, 2, 4, and 6 were categorized as 'high' exposure areas; 53 participants from the questionnaire survey worked primarily in those departments. Departments 7, 17, and 57 (toolroom) were grouped as 'low' exposure areas; 21 participants from the questionnaire survey worked primarily in those departments. Table 12 shows there were no statistically significant differences in symptoms or illnesses between these two groups. In general, systemic symptoms (fever, aches, and chills) had the highest PR between the groups, while several respiratory symptoms (cough, shortness of breath, and chest tightness) were reported by similar percentages in both groups. Although the small numbers make detecting statistically significant comparisons difficult, similar percentages of workers with the two illnesses (HP and OA) were found among both the 'high' and 'low' exposure groups.

DISCUSSION AND CONCLUSIONS

Our evaluation documented that many TRW Mt. Vernon employees have experienced work-related respiratory illness, with first reported onset of symptoms in the fall of 2000. As has been observed in other outbreaks of respiratory illness among workers exposed to MWF in machine shops,[16] a spectrum of illness was observed among TRW workers. Record review concerning workers on medical leave of absence in November 2001 found that 12 and 14 workers, respectively, met case definitions for HP and OA. Ongoing record review in April 2002 revealed that the primary treating pulmonologist had diagnosed at least 41 persons with HP, OA, or some combination of these two illnesses. The larger number of clinically-defined cases of illness relative to the epidemiologically-defined cases is not unexpected, and likely involves a number of factors. In many cases, clinicians will (appropriately) make a diagnosis of illness (such as OA or HP) and begin treatment based on history and physical findings. Testing, often included as necessary components of epidemiologic case definitions, may not be performed in all clinical cases (or the test results may not be available when the record review is performed). Additionally, the record review performed for this HHE in November 2001 included only workers off work due to respiratory illness. Although, in most cases, persons diagnosed with HP or OA in 2001 had been removed from work and had not returned to work prior to the November 2001 record review, it is possible that a small number of workers who had been sick had returned to restricted duty, and would therefore not have been included in the record review. It is also likely that the actual number of workers with diagnosed illness is greater than that reported above from either record

review because: 1) the review of clinicians' records for this HHE included review of records of the two primary treating physicians, and some TRW employees likely sought medical care from other physicians from whom records were not reveiwed; and 2) due to the ongoing nature of the medical evaluations of the primary physicians, a review by NIOSH representatives at any point in time could have been incomplete.

In addition to diagnosed illnesses, our questionnaire survey and medical record reviews confirmed that a substantial percentage of TRW employees have been symptomatic with respiratory and/or systemic symptoms (not necessarily meeting the criteria for diagnosis of HP or OA). Some of these symptomatic workers have been diagnosed with a variety of other conditions (such as rhinosinusitis and bronchitis). Workers exposed to MWF are known to experience respiratory and upper respiratory symptoms more commonly than comparison groups of workers.[25,26] It is not known whether such symptoms represent milder forms of the illnesses that have been diagnosed, irritant effects of the aerosol in the machining areas not related to the observed illnesses, or some other effect.

Although the exact cause of employees' symptoms and illnesses has not been determined, evidence from similar outbreaks of illnesses at other workplaces suggests that contamination of the MWF with *Mycobacteria sp.* is playing a role. Multiple interventions (control measures) were put in place over time at TRW. During the course of the HHE, it was sometimes difficult to distinguish between new onset of symptoms and newly diagnosed illnesses. It was several months until the records were available to document that new diagnoses of respiratory illness were being made among workers who had onset of symptoms quite a bit earlier (many months in some instances). Our review found that no workers had onset of symptoms after May 2001; however, we are not able to identify one specific control measure which has been primarily effective in eliminating the source of the illnesses. Actions taken by TRW to eliminate (or minimize) the source of work-related illnesses prior to May 2001 included primarily improvement in MWF maintenance procedures, cleaning machines and central systems, and recharging the systems with fresh MWF. Many other control measures were instituted after May 2001, and it is not clear whether or not new illnesses would have continued to occur (or if pre-existing symptoms would have worsened) in the absence of any specific control(s). The assessment of the effectiveness of controls to prevent new illnesses may be particularly difficult in situations in which some workers may have been "sensitized" to a substance (or antigen) in the plant, and who may still may be symptomatic from exposure to much decreased levels of that substance (antigen).

Industrial Hygiene Issues

Review of air sampling data collected over June 2001 - February 2002 confirmed that some machining departments had higher air concentrations of MWF aerosol than others. PBZ air monitoring conducted by NIOSH during normal production in June 2001 revealed no exposures above the NIOSH REL for MWF aerosol. Five exposures exceeded the NIOSH REL during the December 2001 site visit, which occurred after the general ventilation improvements in the machining areas (August/September 2001) but prior to installation of mist collectors on a number of the machines (December 2001/January 2002). The mean exposure for the samples taken on December 18, 2001, was 0.37 mg/m^3, compared to a mean of 0.23 mg/m^3 for the samples taken on June 29, 2001. The increase in number of exposures above the REL, and the increase in the mean exposure for the sample sets, may have resulted from the greater percentage of samples collected from operators who work on machines that were expected to produce more MWF aerosol than other machines. These "high-exposure" jobs were a point of focus so that after mist collectors were installed a repeated exposure assessment (not performed as part of this HHE) could document the effects of improved engineering controls. Therefore air sampling performed by NIOSH is

not suitable to determine the effectiveness of increased general ventilation in lowering MWF aerosol concentrations.

Observations from several site visits indicated that it may be feasible to further reduce the amount of MWF aerosol produced by some of the larger machining centers which may be more difficult to enclose and/or ventilate. Regarding the Barnes transfer line, one possible approach is to optimize the flow of MWF and tool rotation speeds so that MWF is applied to the work area only when parts are machined, not during non-production cycle time. In general, when a part is not being machined by a head, reducing or stopping the MWF flow and tool rotation would be expected to produce decreased levels of MWF aerosol.

Air sampling done during cleanup operations indicates that the potential for exposures to MWF aerosol above the NIOSH REL exists during such work. Because of this, and the potential for significant bioaerosol exposure during such cleaning operations, PPE should be used by cleanup personnel (as it was at TRW during the June 2001 cleaning operations). Based on qualitative observations of the containment system and aerosol measurements, isolation of the Large system area during cleanup was effective with one possible exception. One area sample (numbered MWF28 – south across the aisle from the 9 station anchor dial, see Table 2) was collected outside the containment area and had a higher concentration than other similar area samples. We could not determine whether that higher concentration originated from cleaning operations inside the containment area or from some operation outside the containment area in close proximity to MWF 28.

Total concentrations of culturable bacteria measured during this HHE have not been above levels typically seen at similar facilities. However, the relatively high concentrations of *Mycobacteria* in May and June 2001 (compared to the concentrations of more common Gram-negative bacteria) does represent a potentially important qualitative difference in the bacterial contamination of the MWF compared to that of similar facilities. Since the steam cleaning procedures, the improvements in MWF maintenance, and the change in biocide in late July/August 2001, microbial growth in the MWF has been minimal. Repeated AFB pellet stains used to detect total (alive and dead) *Mycobacteria* has revealed a downward trend over the course of the HHE. The fact that the pellet stain concentrations decreased slowly probably indicates that these organisms have existed in areas within the MWF systems that are inaccessible to cleaning methods (sometimes referred to as existing in a "biofilm"). It seems reasonable that as the "biofilm" deteriorates it will slough dead cells into the MWF.[27]

Medical/Epidemiologic Issues

The PRs for symptoms reported among workers exposed to MWF (compared to those unexposed) are similar to those PRs found among workers in other HHEs at other machining shops with and without diagnosed cases of HP and/or OA.[25,26] However, in comparison to other machine shops where we have performed similar surveys, the absolute numbers (and percentages) of workers at TRW reporting symptoms was higher in both the exposed and the unexposed groups. The reason(s) for this are not clear. MWF aerosol concentrations were not substantially higher at TRW relative to other machine shops in which NIOSH has conducted HHEs. It is possible that the great concern over illnesses among TRW employees around the time of the HHE was one factor leading to increased reporting of symptoms in the questionnaire survey.

The analyses of symptoms and PRs between 'high' and 'low' exposure groups consisted of a smaller number of persons compared to the similar analyses among 'exposed' and 'unexposed.' The smaller numbers make it harder to draw conclusions about statistical differences between groups; however, it appears that both respiratory symptoms and illnesses were reported approximately equally between the 'high' and 'low' exposure groups. One possible conclusion

from this comparison is that exposure to MWF aerosol at concentrations observed in both the 'high' and 'low' exposure areas is sufficient to cause respiratory effects. There are several limitations in this type of comparison. For example, many of the air concentrations used to determine the 'high' and 'low' groups were area samples, and may not be representative of actual exposures. Also, TRW workers rotated jobs frequently, and our questionnaire did not determine how much time an employee reporting a usual job in any given department actually spends in that department (versus another department). And finally, it is likely that MWF aerosol exposures may vary widely within any given department. Further data are needed before any conclusions could be drawn from these data concerning the level of MWF aerosol associated with respiratory symptoms and illnesses.

Neurologic Issues (Tremor)

Review of the medical records involving employees with tremor, as well as review of information concerning substances used in the machining areas of the plant relative to possible neurologic effects, did not reveal any substances or chemical compounds associated with neurotoxicity to which workers may be exposed at TRW. The most common finding in the medical records which were reviewed was of postural tremor. Postural tremor is a tremor which is greatest when the limb (arm or leg) is actively maintained against gravity. Acute onset of postural tremor has been thought to be related to specific toxic exposures, metabolic factors (such as those related to systemic illness) or stress.[28] One person's tremor appeared, by history, to be more consistent with essential tremor (tremor of uncertain cause, thought to be familial). Although the consulting neurologist could not identify a single source for the reported symptoms and observed abnormalities, several issues were mentioned in the records that may be playing a role. These issues include co-morbidity (other illness, such as respiratory illness, that could be contributing to tremor) and medication use. For example, among the three workers who had the most severe clinical illness with HP, all reported tremor, and two of the three reported tremor starting around the same time as their pulmonary illness. Among the workers for whom records were reviewed, several reported use of medications to treat pulmonary symptoms, and it is possible that some of those medications (such as inhaled beta-agonists) could have been contributing to the observed tremor. In one case, one person had a history of use of a medication known to cause tremor as an adverse effect.

When we considered potential occupational exposures at TRW related to tremor, it was noted that the onset of the reported tremors ranged from January 2001 to February 2002. Over that time period, the MWF and biocides in use at the plant changed, and substantial changes were also made in ventilation in the machining areas of the plant. Specifically concerning PCMC (the phenol biocide which was first used in the plant in July/August 2001), four of the seven workers for whom the date of onset of tremor was reported had onset of tremor prior to the first use of PCMC at TRW. These facts make it unlikely that the MWFs, or additives to the MWFs, were related to the observed tremors. Continued clinical follow-up for workers experiencing tremor would be appropriate in addressing continued concerns related to these symptoms and to further examine other potential causes.

RECOMMENDATIONS

A comprehensive safety and health program regarding MWFs (including engineering controls, fluid maintenance, environmental surveillance, and medical monitoring) following recommendations published in the NIOSH Criteria Document "Occupational Exposure to Metalworking Fluids" should continue to be implemented to minimize health effects related to MWF exposure in the machining environment.[7] Portions of this type of program have already been put in place at TRW Mt. Vernon. Some of the specific components of this type of program include the following:

1. Evaluations concerning the need for further engineering controls to decrease exposure to MWF aerosol, in addition to the general ventilation and the mist collectors already installed, should be made in an ongoing manner by considering industrial hygiene sampling data and information concerning illnesses and/or symptoms among employees in the affected areas. Enclosure of machining centers, with local exhaust ventilation exhausted outdoors, is the recommended form of control for all machines.

a) Jobs and/or areas which have been identified as being associated with PBZ concentrations of MWF aerosol greater than the NIOSH REL should be a focus of attention. In cases where controls have been put in place in response to observed overexposures to MWF aerosol, follow-up industrial hygiene sampling should be conducted by TRW to determine the effectiveness of the controls.

b) TRW should investigate whether it is possible to lessen the amount of MWF aerosol produced by large machining centers, like the Barnes transfer, KJ/RS, etc., by reducing/halting the MWF application and tool rotation in the cutting-zone while machining is not occurring. If only MWF application or tool rotation can be halted, halting tool rotation may reduce aerosol production more than halting MWF application.

2. Until exposures can be reduced through engineering and/or administrative measures, workers exposed to MWF at concentrations above the REL should have respiratory protection. An air-purifying respirator equipped with an R- or P-series filter would be appropriate. Because respiratory protection is usually the least desirable method of reducing exposures, the use of respiratory protection should not be considered a permanent solution. Respirators should only be used within the constraints of a comprehensive respiratory protection program.[29] Users must be medically cleared, trained, and fit-tested for their assigned respirator.

3. Although our understanding of the relationship between microbiologic contamination of the MWF and employee illness is incomplete, TRW should continue to monitor the MWF periodically to document microbiologic contamination (specifically, contamination with *Mycobacteria sp.*). The monitoring should be used as a guide to assist MWF maintenance procedures in minimizing such contamination. It is reasonable to decrease the frequency of periodic monitoring as concentrations of contaminants become non-detectable or are maintained at low levels.

4. As part of the safety and health program, TRW 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) In work areas where one or more workers have recently developed occupational asthma, HP, or another serious condition apparently related to MWF exposure, NIOSH recommends medical monitoring regardless of exposure concentration. The machining areas of the TRW Mt. Vernon facility is one of these areas. The components of a medical monitoring program are outlined in the NIOSH Criteria Document.[7]

b) Workers with respiratory and/or systemic symptoms must continue to be promptly evaluated by health professionals experienced with occupational and respiratory health issues. Individuals with definite or possible occupational respiratory diseases should be protected from exposures to presumed causes or exacerbators of the disease.

c) If employees are removed or restricted from work by their physician, they must not return to work until cleared by that physician. The physician caring for the individual employees must make the final decision concerning the timing and the nature of individual employees' ability to return to work. A gradual, step-wise approach to return to work should be considered. For example, employees who have been diagnosed

with HP, occupational asthma, or similar illness, when judged able to return to work by their healthcare provider, may benefit from an initial trial of work in areas of the plant physically removed from machining processes (such as the assembly area). Subsequent issues, including return to work in the machining areas, as well as issues concerning potential use of respiratory protection, must then be handled on a case-by-case basis. Close clinical follow-up is required for all employees returning to work after having been restricted due to respiratory or systemic illness. Employees who have developed HP or similar illness related to a substance(s) in the MWF may become symptomatic upon return to specific areas of the facility even after cleaning of the machines and the MWF systems and improvement of ventilation and engineering controls (even if MWF aerosol concentrations are less than the NIOSH REL).

d) In some cases, reassignment to areas where exposure is minimized or nonexistent may be medically advisable. In such cases, the reassigned worker should retain wages, seniority, and other benefits that might otherwise be lost by such a job transfer.

5. TRW and the union should continue to educate all TRW workers concerning occupational health concerns at TRW, and should continue to encourage employees to report health symptoms possibly related to workplace exposures to appropriate health professionals as soon as they occur.

6. The employee(s) in charge of MWF management should be given the authority to ensure that fluids are not tampered with, that additions are made appropriately, and that systems are routinely cleaned. No unauthorized additions should be made.

7. During any future cleaning of the MWF systems and machines with pressurized water or steam, the following are recommended (these steps are similar to the steps for containment that were used during the cleanup of the Large system in June 2001):

a) Management should require work practices and PPE intended to minimize worker skin contact with MWF components or contaminants during the cleaning process.

b) Management should require work practices intended to minimize aerosolization of MWF components or contaminants during the cleaning process.

c) Cleaning of the MWF systems should be done without exposing workers in adjacent plant areas to aerosols produced during the cleaning activity (ideally the cleaning should be done when there are a minimum number of other employees in the areas surrounding the areas involved in cleaning).

d) Management should require that appropriate respiratory protection be used by workers performing the cleaning, and by workers in areas adjacent to the cleaning activities. Use of respiratory protection must follow provisions of the OSHA Respiratory Protection Standard.[29]

8. Although not the focus of this HHE, prevention of skin contact with MWF and MWF additives should be a primary focus of a MWF safety and health program. Skin contact with these substances should be reduced as much as possible by the use of engineering controls and modification of work practices, and lastly, by the use of appropriate personal protective equipment.

REFERENCES

1. Weiss L, Pue C, Rossmoore H, Lewis R, Fink J, Harney J, and Trout D [2002]. Respiratory Illness in Workers Exposed to Metalworking Fluid Contaminated with Nontuberculous Mycobacteria, Ohio, 2001. MMWR 51(16):349-52.

2. Harold Rossmoore, PhD, Biosan Laboratory, personal communication, 2001.

3. ACGIH [2001]. 2001 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

4. NIOSH [1994]. Metalworking fluids (all categories) (DRAFT Method 5524). In: Eller PM, Cassinelli ME, eds. NIOSH manual of analytical methods. 4th ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

5. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

6. CFR [1997]. 29 CFR 1910.1000. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

7. NIOSH [1998a]. Criteria for a recommended standard: occupational exposure to metalworking fluids. Cincinnati, OH: Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. DHHS (NIOSH) publication number 98-102.

8. Rossmore LA, Rossmore HW [1994]. Metalworking fluid microbiology. In: Byers J, ed. Metalworking Fluids. New York, NY: Marcel Dekker, Inc., pp. 247-271.

9. Tant CO, Bennett EO [1956]. The isolation of Pathogenic Bacteria from Used Emulsion Oils. Applied Microbiology. 4:332-338.

10. Holdom, RS [1976]. Microbial spoilage of engineering materials. Part 3: Are infected oil emulsions a health hazard to workers and to the public. Tribology International. December, pp. 271-280.

11. Tant CO, Bennett EO [1958]. The growth of aerobic bacteria in metal-cutting fluids. Applied Microbiology. 6:388-391.

12. Rossmore HW [1967]. Survival of coagulase-positive staphylococci in soluble cutting oils. Health Laboratory Science. 4:160-165.

13. Bennett, EO [1972]. The biology of metal-working fluids. Lubrication Engineering. July, pp. 237-247.

14. Hill EC [1983]. Microbial aspects of health hazards from water-based metal-working fluids. Tribology International. 16(3):136-140.

15. CDC [1996]. Biopsy-confirmed hypersensitivity pneumonitis in automobile production workers exposed to metalworking fluids -- Michigan. MMWR. 45(28): 606-610.

16. Zacharisen MC, et al.[1998]. The spectrum of respiratory disease associated with exposure to metal working fluids. JOEM. 40(7):640-647.

17. Kreiss K, Cox-Ganser J. Metalworking fluid-associated hypersensitivity pneumonitis: a workshop summary. AJIM 1997;32:423-32.

18. Shelton BG, Flanders WD, Morris GK. Mycobacterium sp. as a possible cause of hypersensitivity pneumonitis in machine workers. Emerg Infect Dis. [serial online] 1999 Mar-Apr [cited 2001 Dec 4];5(2). Available at http://www.cdc.gov/ncidod/eid/vol5no2/shelton.htm

19. Wilson RW, Steingrube VA, Bottger EC, et al. *Mycobacterium immunogenum* sp. nov., a novel species related to *Mycobacterium abscessus* and associated with clinical disease, pseudo-outbreaks and contaminated metalworking fluids: an international cooperative study on mycobacterial taxonomy. Int J Systematic and Evolutionary Micro 2001. 51:1751-1764.

20. Terho EO [1986]. Diagnostic criteria for farmer's lung disease. AJIM. 10:329.

21. Fox, J, et al. [1999]. Metal working fluid-associated hypersensitivity pneumonitis: an outbreak investigation and case-control study. AJIM 35:58-67.

22. Wilson RW, Steingrube VA, Bottger EC, et al. [2001]. *Mycobacterium immunogenum* sp. nov., a novel species related to *Mycobacterium abscessus* and associated with clinical disease, pseudo-outbreaks and contaminated metalworking fluids: an international cooperative study on mycobacterial taxonomy. Int J Systematic and Evolutionary Micro. 51:1751-1764.

23. Olenchock S [1997]. Ch. 71: Airborne Endotoxin, in: Manual of Environmental Microbiology, Hurst CJ, ed., ASM Press, Washington, D.C. pp. 661-665.

24. Filley CM and Kelly JP [2001]. Clinical neurotoxicology and neurobehavioral toxicology. In: Sullivan JB and Krieger GR, eds. Clinical Environmental Health and Toxic Exposures, 2nd Edition. Lippincott Williams and Wilkins, Philadelphia, PA, pp. 247-260.

25. NIOSH [1998b]. Hazard Evaluations and Technical Assistance report: Ford Electronics and Refrigeration Corporation, Connersville, IN. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention; NIOSH. HETA 96-0156-2712.

26. NIOSH [1998c]. Hazard Evaluations and Technical Assistance report: Pratt and Whitney, TAPC, North Haven, CT. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention; NIOSH. HETA 98-0030-2697.

27. Donlan RM [2002]. Biofilms: microbial life on surfaces. Emerg Infect Dis [serial online] 2002 Sep [date accessed August 23, 2002];8 Available from: URL: http://www.cdc.gov/ncidod/EID/vol8no9/02-0063.htm

28. Olney RK and Aminoff MJ. [2001]. Weakness, myalgias, disorders of movment and imbalance. In: Braunwald E, et al., eds. Harrison's Principles of Internal Medicine, 15th Edition. McGraw Hill, New York, NY, pp. 124-126.

29. OSHA [1998]. 29 CFR 1910.134. Respiratory Protection Standard. Federal Register 63 FR 1152, January 8, 1998.

Table 1
Review of Total Particulate Air Sampling* (in mg/m^3) in Machining Areas Performed by TRW
June 2001 to February 2002
HETA #2001-0303, TRW Automotive, June 29, 2001

Department	N (# samples)	Mean	Median	Minimum	Maximum
W01	80	0.42	0.32	0.059	3.3
W02	121	0.51	0.4	0.1	3.5
W03	25	0.39	0.27	0.06	1.3
W04	139	0.68	0.59	0.1	2.1
W06	131	0.4	0.38	0.067	1.6
W07	65	0.2	0.17	0.067	0.52
W17	32	0.16	0.15	0.069	0.36
Toolroom (W57)	19	0.21	0.14	0.062	0.65
"High" Exposure Areas (W1, W2, W4, W6)	471	0.52	0.42	0.059	3.5
"Low" Exposure Areas (W7, W17, W57)	116	0.19	0.15	0.0069	0.65

* Includes area and PBZ samples

Table 2
Personal breathing zone MWF aerosol sample results from normal production
HETA #2001-0303, TRW Automotive, June 29, 2001

Work location	Sample #	Sample time (min.)	sample volume (L)	Concentration, mg/m^3	% Extractable
Neon caliper assembly line	MWF 12	462	739	nd	n/a
Neon caliper assembly line	MWF 7	373	597	nd	n/a
RS/ KJ assembly	MWF 10	455	728	nd	n/a
RS drum assembly	MWF 16	451	722	0.07	67
8/12 station RS/KJ, operator	MWF 14	442	707	(0.28)	65
OTS operator, WO-4	MWF 1	488	781	(0.26)	70
OTS operator, Barnes washer	MWF 3	487	779	0.32	76
PHN131 anchor broach	MWF 20	293	468	0.41	79
Inspector	MWF 19	481	770	0.27	81
CNC operator Honsberg	MWF 18	473	757	0.37	79
RS/KJ 10 station, WO-2	MWF 17	493	789	0.15	80
PTech., neon w/c assembly	MWF 8	480	768	(0.08)	83
CNC operator LeBlond, WO-1	MWF 6	418	669	(0.11)	71
PHN131 9 station	MWF 11	180	448	(0.22)	90
Supervisor 01, 04, 09	MWF 9	375	600	(0.13)	75
Kirby operator, WO-7	MWF 13	502	803	(0.06)	80
Kirby operator, WO-7	MWF 5	145	232	nd	n/a
PHN131 caliper broach operator, WO-2	MWF 15	492	787	(0.25)	80
PHN131caliper 12 station operator, WO-2	MWF 4	488	781	(0.13)	60
Vertical broach operator, WO-2	MWF 2	496	794	0.33	81
NIOSH REL				**0.4 mg/m^3**	

nd = 'not detected'; mass on filter was less than the LOD
n/a = not applicable
( ) = values in parentheses are between the MDC and the MQC, and should be considered semi-quantitative

Table 3

MWF thoracic aerosol sample results collected during cleanup operations
HETA #2001-0303, TRW Automotive, June 29, 2001

Sample location	Inside/Outside containment area	Sample #	Sample time (min.)	Sample vol. (L)	Concentration, mg/m^3	% Extractable
Steam clean asst.*	Inside	MWF 21	270	432	0.44	79
Between 9-station and P131 anchor broach	Inside	MWF 22	386	618	0.45	86
Center of WO1, North of Barnes Transfer	Inside	MWF 23	388	621	0.13	79
Operator's table near Honsberg	Inside	MWF 24	394	630	0.51	84
WO4, near caliper broach	Inside	MWF 25	391	626	0.5	81
Break room, on top of vending machines on South wall	Outside	MWF 26	403	645	0.03	n/a
KJ/RS machine	Outside	MWF 27	306	490	0.09	85
South across aisle from 9 station anchor	Outside	MWF 28	373	597	0.2	78
Assembly, Southwest corner of WO9	Outside	MWF 29	401	642	0.03	n/a
South across aisle from West end of Barnes Transfer	Outside	MWF 30	374	599	0.06	91
NIOSH REL					**0.4 mg/m^3**	

*PBZ sample; all other samples are area samples.

Table 4
Real-time aerosol measurements during normal production
HETA #2001-0303, TRW Automotive, June 29, 2001

Sample location	Aerosol concentration*, mg/m^3
	Normal production
NE corner of machine side	0.23
Middle of Northmost aisle	0.2
NW corner of machine side	0.25
At Northmost parts washer	0.5
Barnes transfer, station #15	0.8
Barnes transfer, station #11	0.3
Barnes transfer, station #7	1.2
Barnes transfer, station #5	1.5
E. aisle, by N. garage door	0.25
E. aisle, by payphone	0.2
PHN 131 broach	0.5
Near pole B6	0.35
Aisle near RS 10 station	0.25
Aisle N of Mann-Hummel Kirby machines	0.2
Machine shop	0.2
SW corner of machine side	0.2
SE corner of machine side, near open garage door	0.15
Assembly side aisles	0.09
Outside SE corner of machine side	0.07

*During this study the HAM was not calibrated using a side-by-side gravimetric method. Data gathered with the HAM should be regarded as qualitative in nature, and are best used in this case as a means to compare aerosol concentrations within the plant on a relative basis.

Table 5
Real-time aerosol measurements from machining side of plant
HETA #2001-0303, TRW Automotive, June 29-30, 2001

Sample location	Aerosol concentration*, mg/m^3	
	Immediately preceding cleanup operations	During cleanup
NE corner of machining side	0.12	0.12
Middle of E aisle inside containment	0.13	0.12
E-W aisle in front of KJ/RS (machines not running)	0.12	0.12
E-W aisle, outside containment, due S of W end of Barnes Transfer (by seam in plastic)	0.21	0.22
E-W aisle, outside containment, near horizontal broach	0.22	0.2
West-most N-S aisle outside containment, near seam in plastic	0.22	0.18
SW corner of containment, by W wall of bldg. by opening in plastic	0.25	0.25

*During this study the HAM was not calibrated using a side-by-side gravimetric method. Data gathered with the HAM should be regarded as qualitative in nature, and are best used in this case as a means to compare aerosol concentrations within the plant on a relative basis.

Table 6
Microbial analysis of bulk MWF samples
HETA #2001-0303, TRW Automotive

Sample location	Date	Predominant fungal taxa, cfu/mL	Total bacteria, cfu/mL	Predominant bacterial taxa, cfu/mL	Endotoxin, EU/mL
'Large system' central sump	5/10/01	ng	> 3.6 x 10^6	*Mycobacterium chelonae*, >3.6x10^6 *Alcaligenes faecalis*, 220 *Pseudomonas pseudoalcaligenes*, 110	1706
	6/14/01	ng	> 3.6 x 10^6	*Mycobacterium chelonae*, >3.6x10^6	3153
	8/15/01	ng	ng	n/a	n/a
'Henry system' central sump	5/10/01	ng	2.4 x 10^6	*Acinetobacter* non-hemolytic *asacchar*, 110 *Alcaligenes faecalis*, 1210 *Alcaligenes xylosoxidans*, 110 *Brevundimonas diminuta*, 440 *Comamonas testosteroni*, 660 *Mycobacterium chelonae*, 2.4 x 10^6	12500
	6/14/01	ng	> 3.6 x 10^6	*Mycobacterium chelonae*, >3.6x10^6	1859
	8/15/01	ng	ng	n/a	n/a
'Small system'	5/10/01	ng	220	*Mycobacterium chelonae*, 220	2859
	6/14/01	ng	> 3.6 x 10^6	*Mycobacterium chelonae*, >3.6x10^6	4453
	8/15/01	ng	ng	n/a	n/a
'Mann-Hummel' collected at Kirby #2	5/10/01	ng	770	*Mycobacterium chelonae*, 770	240
	6/14/01	ng	2728	*Mycobacterium chelonae*, 2728	75
	8/15/01	ng	ng	n/a	n/a

Table 6 - Continued

Sample location	Date collected	Predominant fungal taxa, cfu/mL	Total bacteria, cfu/mL	Predominant bacterial taxa, cfu/mL	Endotoxin, EU/mL
PHN131 Anchor broach	5/10/01	ng	1.1 x 10^6	*Mycobacterium chelonae*, 1.1 x 10^6	209
	6/14/01	*Acremonium sp.* 2310, *Aureobasidium pululans* 3960, *Fusarium sp.* 1650	1.4 x 10^5	*Alcaligenes faecalis,* 3.3x10^4 *Comamonas testosteroni,* 7.7x10^4 *Gemella morbillorum*, 3.3x10^4 *Mycobacterium chelonae,* 1.1x10^4	5593
	8/15/01	ng	ng	n/a	n/a
CJ parts washer fluid, wash side	6/14/01	*Cylindrocarpon sp.* 440	overloaded	*Mycobacterium chelonae,* 3036 other species represented: *Acinetobacter sp., Alcaligenes faecalis, Comamonas testosteroni, Pseudomonas pseudoalcaligenes*	1.05x10^5
Barnes parts washer, wash side	6/14/01	ng	ng	n/a	8
'Add' water from a Henry system machine	6/14/01	ng	ng	n/a	3
'Clean tank' in MWF recycling tank farm	8/15/01	ng	ng	n/a	n/a
East vertical broach	8/15/01	ng	gram positive rods	unable to speciate, 330	n/a
CNC mill, machine shop	8/15/01	*Acremonium strictum* 110 sterile fungi 550 *Tricliothecium sp* 110 yeasts 110	ng	n/a	n/a
DR bracket broach (Detroit horizontal broach)	8/15/01	ng	ng	n/a	n/a

ng = no growth; n/a - not applicable; EU/mL = 'endotoxin units per milliliter of fluid', 10 EU = 1 nanogram endotoxin;

Table 7

Personal breathing zone thoracic particulate results from 2nd shift
HETA #2001-0303, TRW Automotive, December 18, 2001

Work location	Sample #	Sample time (min.)	sample volume (L)	Concentration, mg/m^3	% Extractable
Honsberg, operator (op.)	A19	571	915	0.27	80
Honsberg op.	A4	569	911.5	0.27	80
PHN 131 broach (adapter line), OTS op.	A17	420	673	0.46	81
9-station, PHN 131 (adapter line), OTS op.	A21	407	652	0.49	72
KJ/RS wash, P-tech	A6	462	740.4	0.27	85
Kirby-knuckle, op.	A11	577	923.9	0.28	89
R&B knuckle dial, op.	A16	575	920.8	0.27	84
Knuckle press, op.	A10	565	905.2	0.23	76.2
Barnes set-up	A13	398	638	0.33	91
Barnes P-tech	A7	558	893.8	0.36	88
Barnes (Detroit) broach - OTS op.	A1	564	902.6	0.55	82
PL (Barnes) broach	A3	551	883	0.69	79
KJ/RS wash	A14	540	864.2	0.28	92
PL (Barnes) broach, OTS op.	A18	473	757.4	0.44	100
Barnes wash, P-tech	A12	463	741.2	0.36	78
12&6-station/broach rotation, WO2, OTS op.	A9	459	735.7	0.19*	trace
Tool & die op.	A15	455	728.4	0.18	trace
Kirby DR line, WO7, CNC op.	A5	451	722.2	0.14	trace
Vertical broach OTS op.	A8	443	709.1	0.31	96
KJ/RS 12&8-station, CNC op.	A2	437	699.2	0.37	69
NIOSH REL				**0.4 mg/m^3**	

* worked on assembly side for 3hrs.

Table 8
Personal breathing zone thoracic particulate results from 3rd shift

Sample location	Sample #	Sample time (min.)	Sample vol. (L)	Concentration, mg/m^3	% Extractable
Assembly, WO9	A40	479	767.1	0.14	66
Ball joint press & Spindle press	A42	438	701.7	0.17	62
Barnes Kirby	A36	469	750.5	0.19	86
Barnes wash, WO4	A34	437	700.6	0.36	88
Barnes load / broach rotation	A32	436	698.5	0.4	86
Barnes set-up	A29	463	741.2	0.35	100
DR broach	A41	332	532.7	0.39	71
DR anchor/6-station rotation	A43	430	688.4	0.33	83
DR anchor/6-station rotation	A27	421	673.8	0.24*	94
Honsberg op.	A28	420	673	0.28	74
RS wash	A39	451	722.4	0.25	94
RS wash	A37	454	726.8	0.26	90
RS 10-station	A33	401	642.5	0.22	100
RS 10-station, OTS op.	A35	397	635.8	0.2	100
Vert. broach op.	A30	432	692	0.22**	93
KJ/RS 12-station	A31	433	693.8	0.33	100
WO2, 12&6 station/broach rotation	A45	423	676.8	0.19	100
Kirby op., WO7	A38	413	661.6	0.14	100
Kirby op., WO7	A46	412	659.7	0.23	64
131 wash	A44	345	552.9	0.18	100
NIOSH REL				**0.4 mg/m^3**	

*worker initially wore pump for ~30 minutes, then set it on shelf near workstation, therefore this sample may not accurately represent his true exposure

**vertical broach not working; worked WO2 12&6 station/broach rotation

Table 9
Description of survey participants
HETA 2001-0303, TRW Automotive, June 29, 2001

	N	# (%) Male	Mean Age (Years), Range	Mean # Years at Plant (years), Range	# (%) Current Cigarette Smokers	# (%) Ever Cigarette Smokers	# (%) Reporting Working on Single Machine
Exposed to MWF	**137**	**113 (82)**	**45, (20-68)**	**14, (1-26)**	**57 (43%)**	**87 (67%)**	**30 (22%)**
Unexposed to MWF	**158**	**112 (71)**	**48, (27-63)**	**14, (1-26)**	**48 (32%)**	**90 (63%)**	**31 (21%)**

Table 10
Work activities or job tasks reported by workers (N=76)* to be related to symptoms reported in the questionnaire
HETA #2001-0303, TRW Automotive

Exposure	Work Activities or Job Tasks
Unexposed (report not using MWF in their usual job) N=29	Nothing specific (14 workers) Exposure to MWF or working in areas where MWF used (8 workers) Riveting or grinding operatins (4 workers) Steam-cleaning machining equipment (3 workers)
Exposed (report using MWF in their usual job) N=47	Being exposed to MWF (coolant) (19 workers) Working on machines or in areas in which MWF was used (14 workers) Working near parts washers (5 workers) Nothing specific (5 workers) Other tasks (4 workers)

* Among 270 persons reporting at least one respiratory or systemic symptom in the questionnaire, 76 (28%) reported that the symptom(s) was related to a specific work activity or task.

Table 11
Reported symptoms/illnesses among employees exposed and unexposed to MWF[1]
HETA 2001-0303, TRW Automotive

Symptom/Illness	Number of Exposed (%) reporting symptom/illness	Number of Unexposed (%) reporting symptom/illness	Prevalence Ratio[2] [95% Confidence Interval]
Fever or sweats	70 (51)	37 (23)	2.2 [1.6 - 3.0]
Rash, dermatitis, or eczema	60 (44)	32 (20)	2.2 [1.5 - 3.1]
Chills or shivering	47 (34)	33 (21)	1.6 [1.1 - 2.4]
Tightness in chest[3]	93 (68)	67 (42)	1.6 [1.3 - 2.0]
Wheezing or whistling in chest[3]	99 (72)	71 (45)	1.6 [1.3 - 2.0]
Unusual shortness of breath[3]	102 (74)	75 (48)	1.6 [1.3 - 1.9]
Ache all over	81 (59)	73 (46)	1.3 [1.0 - 1.6]
Unusual tiredness or fatigue	109 (80)	100 (63)	1.3 [1.1 - 1.5]
Cough[3]	124 (91)	117 (74)	1.2 [1.1 - 1.4]
HP [4]	7 (5)	1 (0.6)	8.1 [1.0-65]
OA[4]	7 (5)	4 (3)	2.0 [0.6 - 6.7]

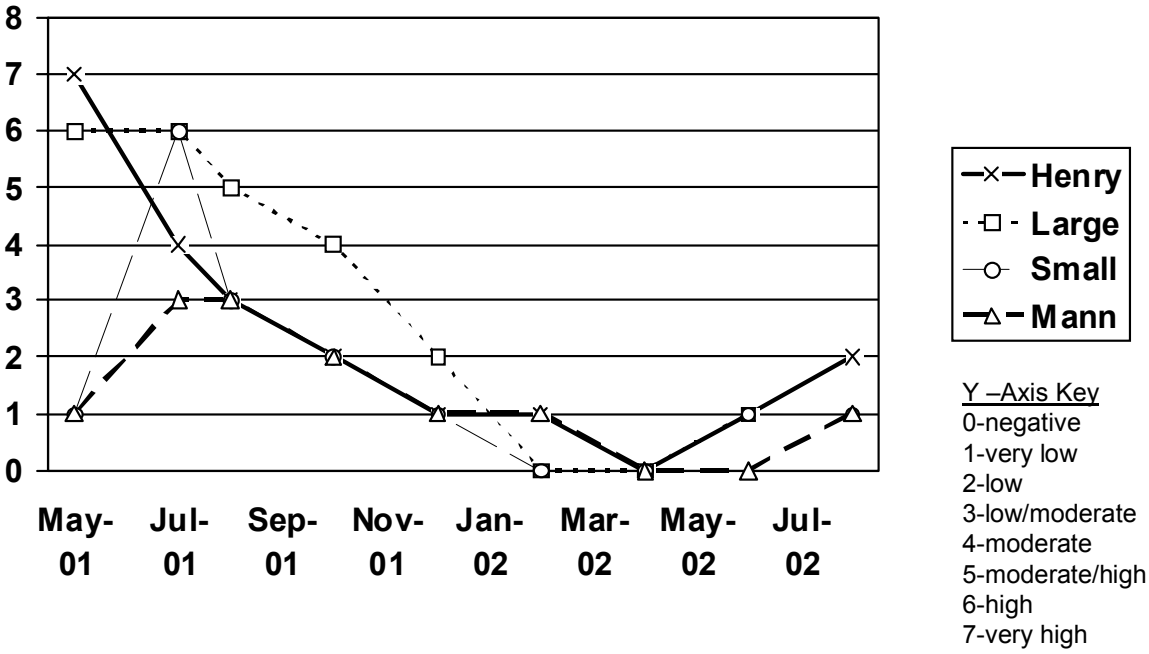
[1] Based on the response to the question "Do you work with metalworking fluid in your job?"
[2] Prevalence ratio for the reporting of the symptom among the MWF-exposed group compared with the MWF-unexposed group.
[3] Unadjusted data presented - PR and CI were similar after adjusting for current cigarette use.
[4] HP, OA - meeting case definition for HP and OA as discussed in Methods.

TABLE 12
Reported Symptoms/Illnesses Among Employees Exposed to 'High' and 'Low' Concentrations of MWF aerosol[1]
HETA 2001-0303, TRW Automotive

Symptom/Illness	Number in "Higher-Exposed" (%) reporting symptom/illness (N=53)	Number in "Lower-Exposed" (%) reporting symptom/illness (N=21)	Prevalence Ratio[2] [95% Confidence Interval]
Fever or sweats	27 (51)	6 (29)	1.8 [0.9 - 3.7]
Ache all over	33 (62)	8 (38)	1.6 [0.9 - 2.9]
Chills or shivering	19 (36)	5 (24)	1.5 [0.6 - 3.5]
Unusual tiredness or fatigue	42 (79)	14 (67)	1.2 [0.9 - 1.7]
Wheezing or whistling in chest	39 (74)	13 (62)	1.2 [0.8 - 1.7]
Rash, dermatitis, or eczema	22 (42)	9 (43)	1.0 [0.5 - 1.7]
Tightness in chest	35 (66)	14 (67)	1.0 [0.7 - 1.4]
Unusual shortness of breath	38 (72)	15 (71)	1.0 [0.7 - 1.4]
Cough	50 (94)	20 (95)	1.0 [0.9 - 1.1]
HP[3]	5 (9)	2 (10)	1.0 [0.2-4.7]
OA[3]	2 (4)	1 (5)	0.8 [0.1 - 8.3]

[1] Participants were grouped based on sampling data presented in Table 1. Those reporting working in Departments 1, 2, 4, and 6 were placed in the "higher" group and those in Departments 7, 17, and 57 (toolroom) were place in the "lower" group.
[2] Prevalence ratio for the reporting of the symptom among the "higher-exposed" group compared with the "lower-exposed" group.
[3] HP, OA - meeting case definition for HP and OA as discussed in Methods.

Figure 1 – Pellet Stain Results, Bimonthly, May 2001 – August 2002
HETA 2001-0303, TRW, Mt. Vernon, Ohio



APPENDIX

In order to learn more about the type of questions that might be useful as components of a screening questionnaire for respiratory health concerns among workers exposed to MWF, a comparison was made of the sensitivity and specificity of some of the questions. These comparisons were made relative to the endpoint of respiratory illness (either occupational asthma [OA] or hypersensitivity pneumonitis [HP]) as defined using the case definitions for the November 2001 record review. Twenty workers who met our case definitions for OA or HP participated in our screening questionnaire – those 20 questionnaires were used in this analysis. Sensitivity is defined as the probability of answering a question positively if the illness is present; specificity is defined as the probability of answering a question negatively if the illness is not present. Two types of "positive" responses to questions about symptoms were evaluated here. Initially, a "positive" response included responses of "usually" or "sometimes" when the respondent was asked whether the symptom was present in the year prior to the survey (and was compared to the negative response of "never"). Comparisons were also made with a "positive" response being defined as "usually" experiencing the symptom (compared to the "negative" response of "sometimes" or "never" experiencing the symptom). Additionally, "work-related" symptoms were also evaluated. A "work-related" symptom was defined as a symptom reported to occur "usually" or "sometimes" within the year prior to the survey which the worker felt was related to work and which either improved or may have improved (response of "yes" or "unsure" when asked if symptoms improved) on days off.

The table summarizes the sensitivity and specificity for selected questions and combination of questions. Several of the questions related to specific symptoms using the broader definition of "positive response" (where "positive" was defined as being a report of "usually" or "sometimes" having a symptom in year prior to the survey) were sensitive but not specific. As the most broadly-defined positive responses were modified, either by restricting the positive response to "usually" experiencing the symptom (versus the negative response of "sometimes" or "never"), linking a work-related component, or by combining symptoms, the sensitivity of the questions decreased while specificity increased.

The NIOSH Criteria Document recommends medical monitoring for workers exposed to MWF; a major objective of that monitoring is the early identification of workers who develop symptoms of MWF-related conditions such as OA or HP. Periodic examinations recommended as part of the medical monitoring program should include a brief questionnaire to determine the presence or absence of respiratory symptoms. The data here support the use of the most broadly-defined questions concerning respiratory symptoms in order that the questionnaire have the greatest sensitivity in detecting potentially affected workers. Follow-up medical examinations (possibly including individual history and physical examination and objective testing such as spirometry or pulmonary function testing) would then be appropriate in characterizing the nature of respiratory symptoms reported among the exposed workers.

Appendix Table
Characteristics of Selected Questions on Questionnaire
Relative to Diagnosis of HP or OA (N=20)
HETA 2001-0303, TRW Automotive

Symptom	Sensitivity	Specificity
Cough - (usually or sometimes)[1]	100%	20%
Cough - (usually)	53%	83%
Cough - work related[2]	47%	82%
Unusual shortness of breath - (usually or sometimes)	95%	42%
Unusual shortness of breath - (usually)	63%	87%
Unusual shortness of breath- work related	74%	86%
Unusual tiredness or fatigue - (usually or sometimes)	95%	30%
Unusual tiredness or fatigue - (usually)	68%	79%
Unusual tiredness or fatigue - work related	32%	84%
Aching all over - (usually or sometimes)	89%	50%
Aching all over - (usually)	42%	92%
Aching all over - work related	26%	87%
Cough, shortness of breath, unusual tiredness, **and** aching all over - (usually or sometimes)	84%	64%
Chest flu (fever, shivering, cough, tired, weak, ache all over) or pneumonia in year prior to survey	76%	48%
Been evaluated by a doctor	60%	73%
Did symptoms cause change in work area	18%	87%
Are symptoms (in general) related to specific work activity or task	59%	70%

[1] Participants were asked to respond to individual symptoms as occurring "usually," "sometimes,"or "never" in the year prior to the survey.
[2] Work-related symptom - worker stated symptom was related to work and replied "unsure" or "yes" when asked if symptom improved on days off.

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