HETA 94-0151-2475
NOVEMBER 1994
GENERAL ELECTRIC AIRCRAFT ENGINES
MADISONVILLE, KENTUCKY

NIOSH INVESTIGATORS:
Max Kiefer, CIH
Doug Trout, MD, MHS
John Decker
Stan Salisbury, CIH

SUMMARY

On March 4, 1994, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation (HHE) at the General Electric Aircraft Engines (GEAE) facility in Madisonville, Kentucky. The requestors were concerned that exposure to contaminants generated during the manufacture of turbine engine blades and vanes may present a health hazard. A variety of health concerns were noted in the request.

On May 10, 1994, a NIOSH investigator conducted an initial site visit at the GEAE facility to review manufacturing processes, and on September 7-9, 1994, NIOSH investigators conducted a followup visit at the GEAE facility. During the September 7-9, 1994, site visit, air samples were collected to assess worker exposures to: metal fumes and dusts during grinding and welding, various solvents in the Braze Prep and Co-Dep areas, and ethanolamine and triethanolamine components of cutting fluids used in plant milling machines.

Surface sampling was conducted in two employee breakrooms to assess the potential for metal contamination in areas where food and beverage consumption occurs. Area samples using special sorbent tubes (multimedia thermal desorption tubes) were also collected at the Electronic Discharge Machine (EDM) process to qualitatively identify possible breakdown products generated during the interaction of electrical current and mineral oil. Ventilation assessments were conducted to evaluate the efficiency of local exhaust ventilation systems at the sampled welding and grinding stations, and in the slurry mix room. A NIOSH medical officer conducted confidential employee interviews, reviewed medical records, and met with the GEAE Occupational Health staff.

All solvent concentrations detected during the monitoring period were well below the applicable NIOSH Recommended Exposure Limit (REL) (where established). No monoethanolamine was detected. Triethanolamine was detected (0.04 parts per million [ppm]) in one area sample collected adjacent a radial grinder.

With the exception of one sample for nickel, all personal exposures to metal dust or fume were below the applicable NIOSH REL. The overexposure to nickel, 20 micrograms per cubic meter (ug/m3) was found on a 426 minute sample from the Co-Dep operator; the NIOSH REL is 15 $\mu g/m^3$. The highest cobalt concentration (20 $\mu g/m^3$) was from a 383 minute sample obtained from the 404B Welding Operator. The NIOSH REL for cobalt is 50 µg/m3; the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for cobalt is 20 $\mu g/m^3$. One sample collected at a grinding station had a cadmium concentration of 1.9 $\mu g/m^3$. NIOSH considers cadmium to be a potential occupational carcinogen, and recommends controlling exposure to the lowest feasible limit. Other substances detected at the welding and grinding stations monitored were iron, magnesium, chromium, zinc oxide, and

titanium. All concentrations of these metals were below the applicable RELs. With the exception of zinc, only very low levels of metal residues (nickel, cobalt, chromium) were found in surface samples collected in the two breakrooms. The levels of zinc found were 2 to 45 times higher than the other metals detected. Standards regarding surface contamination have not been established, and exposure can not be estimated from these results.

Qualitative air monitoring to identify compounds potentially generated during the EDM process did not identify any unusual contaminants of concern. A limited assessment of the local ventilation systems at the stations sampled indicate that most of these systems were operating effectively.

The NIOSH medical officer interviewed 21 employees. Among the 10 employees reporting health problems, the most prevalant were upper respiratory irritation and skin rashes. There was no apparent pattern that would suggest a common cause. Review of the Occupational Safety and Health Administration (OSHA) 200 logs revealed primarily musculoskeletal injuries, lacerations, and contusions.

Industrial hygiene monitoring showed that, with one exception, personal breathing zone exposure to the contaminants sampled were below applicable limits during the monitoring period. A potential health hazard from nickel was identified at the Co-Dep operation. One cobalt sample was below the NIOSH REL but equal to the AC exposure GIH TLV. A limited assessment of the local ventilation systems indicated that most systems were operating effectively. Qualitative air monitoring to identify compounds potentially generated during the EDM process did not identify any contaminants of concern. Recommendations to eliminate smoking, improve housekeeping and ventilation, and evaluate alternatives to compressed air for cleaning purposes are contained in the Recommendation section of this report.

KEYWORDS: SIC 3724 (Aircraft Engines and Engine Parts), monoethanolamine, triethanolamine, nickel, cobalt, chromium, welding fume, acetone, MEK, MIBK, toluene, xylene, surface sampling, local exhaust ventilation, grinding.

INTRODUCTION

NIOSH received a confidential employee request on March 24, 1994, to evaluate worker exposure to contaminants generated during the manufacture of blades and vanes for turbine engines at the General Electric Aircraft Engine Facility (GEAE) in Madisonville, Kentucky. Specific health concerns noted in the request included lung cancer and brain tumors, bronchitis, heart and pulmonary disease, dermatitis, depression, and central nervous system disorders. The request noted several areas of concern throughout the manufacturing portion of the facility, including insufficient ventilation for contaminant control, as well as concerns with exposure to specific compounds (metals, solvents, acids).

On May 10, and September 7-9, 1994, NIOSH conducted site visits to inspect the GEAE facility, review work practices, interview workers and the medical staff, review appropriate GEAE safety and health programs, collect environmental samples, and assess local exhaust systems used to control contaminants.

On September 29, 1994, an interim report was sent to GEAE representatives, the confidential requestor, and the employee union. The report provided a summary of actions taken by NIOSH, preliminary findings, and preliminary recommendations.

BACKGROUND

Facility and Process Description

The GE facility in Madisonville, Kentucky, employs approximately 800 workers and manufactures the blade and vane components of turbine engines. The 300,000 ft^2 facility started operation in 1970 as a fluorescent light/ballast manufacturing plant and was converted to turbine engine component production in 1980. The facility operates 24 hours/day with 3 work shifts. Employees are represented by the International Union of Electrical Workers, Local 701.

Raw material consists of high nickel content bar stock steel, which is processed by milling, lathing, grinding (automated and manual), and welding (argon shielded TIG). Three types of cutting fluids are used. Brazing is conducted in 12 large vacuum furnaces, and aluminum is deposited on some of the parts using a furnace deposition and vapor-phase deposition process (Co-Dep). Powders containing aluminum and other metals are used to pack parts prior to the deposition process. Various cleaning solvents are used during brazing preparation, and 1,1,1-trichloroethane is used in vapor degreasers. Small-diameter holes are machined through airfoil castings using high power lasers (class IV ND:YAG embedded in a class I system), electrostreaming with nitric acid, or by electronic discharge (parts in a dielectric fluid are machined using an electric charge). Chemical cleaning, using a variety of acids (including HF) is conducted, and there is a nickel electro-plating (nickel strike) line. Molten zinc metal in a dye process (EnCap) is used to encapsulate parts. Many processes are equipped with local exhaust ventilation, although most of these systems (except for the plating and chem clean lines) entail recirculation back into the facility after filtering. The facility is air-conditioned, and there are two separate break rooms for food and beverage consumption.

The GEAE Madisonville plant has an Environmental, Safety and Health Manager, an industrial hygienist, a safety specialist, and a laser safety officer. There are also 3 safety trainers, two full-time nurses (the off-shift [12 a.m.-7 a.m.] has no nursing coverage), and a contract plant physician. The facility contracts with a consulting industrial hygiene firm for periodic exposure monitoring.

EVALUATION PROCEDURES

Industrial Hygiene Evaluation

Processes selected for personal breathing zone (PBZ) or area air monitoring were based on an assessment of the chemicals in use, employee work practices, and controls utilized. Activities of concern noted by the HHE requestors were also targeted for sampling. The monitoring was conducted utilizing established analytical protocols (NIOSH analytical methods).[1] Calibrated air sampling pumps were attached to selected workers and connected, via tubing, to sample-collection media placed in the employees' breathing zone. Monitoring was conducted throughout the employees' work-shift, or during the length of the activity of interest. Manufacturing activity at the facility was considered to be normal during the monitoring. After sample collection, the pumps were post-calibrated and the samples submitted to the NIOSH laboratory or contract laboratory (Data Chem, Salt Lake City, Utah) for analysis. Field blanks were submitted with the samples. Specific sampling and analytical methods used during this survey were as follows:

Qualitative Air Sampling

The purpose of this monitoring was to help determine if any compounds may be generated during the electronic discharge machine (EDM) process that warrant further evaluation. Area air samples were obtained utilizing reusable Carbotrap® 300 multibed thermal desorption (TD) tubes as the collection media. These stainless steel tubes contain three beds of sorbent materials - a front layer of Carbotrap C, a middle layer of Carbotrap, and a back section of Carboxen. This technique is designed to trap a wide range of organic compounds for subsequent qualitative analysis via thermal desorption and gas chromatography/mass spectrometry (GC/MS).

The samples were collected using constant-volume SKC model 222 low-flow sampling pumps. The samples were collected at flow rates of 20-100 cubic centimeters per minute (cc/min). The pumps are equipped with a pump stroke counter and the number of strokes necessary to pull a known volume of air was determined. This information was used to calculate the pump's cc's of air per pump-stroke "K" factor. The pump-stroke count was recorded before and after sampling and the difference used to calculate the total volume of air sampled.

After first collecting a background sample to check humidity, two short-term (2-3 minute) samples were obtained by sampling directly from the generated plume at the EDM. A control sample was collected in an office in the facility, and another sample was collected at the outlet of the pollution control device (centrifugal and filter demister) on the EDM machine.

At the NIOSH laboratory, each sample was analyzed separately by directly inserting the tube into a thermal desorber unit with no other sample preparation. A desorption time of 10 minutes at 300°C was used. Reconstructed total ion chromatograms were obtained for each sample, and all were scaled the same for comparison. Each peak in the chromatogram was identified.

Solvent Sampling

Integrated PBZ air samples for acetone, 2-butanone (MEK), toluene, xylene, methyl isobutyl ketone, and 1,3-dioxacyclopentane were obtained using Supelco ORBO-90 sorbent tubes as the collection medium. The samples were collected using constant volume SKC model 222 low-flow sampling pumps at flow rates of 50-200 cc/min. The samples were analyzed by gas chromatography with flame ionization detection according to NIOSH methods 1300, 1501, and 2500.

Metal Fume and Dust Sampling

Integrated PBZ air sampling for metal fume and dust was conducted using Gilian HFS 513A sampling pumps with a flow rate of approximately 2 liters per minute (LPM). The samples were collected during welding, zinc encapsulating, and grinding operations. The samples were collected on 0.8 μm pore-size, mixed cellulose-ester (MCE) filters, and analyzed according to NIOSH method 7300. This element-specific analysis is capable of differentiating and quantifying 29 different metal species.

Cutting Fluids

Integrated area air samples were collected for monoethanolamine and triethanolamine at grinding machines using cutting fluids containing these compounds. The samples were collected with calibrated DuPont P-2500 constant-flow air sampling pumps. Nominal flow rates of 0.7 to 1.0 LPM were used to collect the samples. Sampling and analyses were conducted according to NIOSH method 3509. Midget impingers containing 15 milliliters (ml) of 2mM hexanesulfonic acid were used to collect the samples. After sampling, deionized water was added to adjust the collection media volume back to 15 ml. The samples were transferred to polyethylene scintillation vials and shipped to the NIOSH contract laboratory for analysis by ion chromatography.

Surface Sampling

Surface wipe samples were collected to determine the extent of metal dust surface contamination in both employee breakrooms. These samples were collected with commercially available pre-moistened Wash & Dri® towlettes. One hundred square centimeters (100 cm^2) of surface area were wiped with each towlette. The samples were collected according to the surface sampling protocol described in the Occupational Safety and Health Administration (OSHA) Industrial Hygiene Technical Manual, and NIOSH Method 0700, Lead in Surface Wipe Samples.[2] The samples were sent to the NIOSH contract laboratory for analysis.

Bulk Samples

Bulk samples of process powders from the Co-Dep area were obtained and submitted to the NIOSH contract analytical laboratory to compare compounds detected in the air samples with the composition of these materials.

Ventilation

A limited ventilation assessment was conducted for those processes monitored that used local exhaust ventilation (LEV) for controlling worker exposure to contaminants. A comprehensive characterization of the facility ventilation system was not conducted. The ventilation assessment consisted of measuring the air velocity at exhaust hood openings (face velocity). Critical dimensions were measured (hood size, distance from hood opening to point of contaminant generation). Employee work practices were observed when these systems were being used.

Air velocity was measured using a TSI VelociCalc® 8360 anemometer. This instrument measures air velocity in feet-per-minute (fpm). Multiple measurements were obtained and the results averaged to obtain the mean velocity. The hood area was measured and the total exhaust volume in cubic feet per minute (CFM) was determined.

Medical Evaluation

During the September 1994 visit, the NIOSH medical officer conducted confidential interviews with all first and second shift employees who wished to discuss work-related health concerns. In addition, randomly chosen employees working on the first shift were also interviewed. During this site visit, discussions were held with the contract occupational physician as well as with the occupational health staff at the plant. The first-aid logs for 1993 and 1994 (to date) and the OSHA Injury and Illness logs (Form 200) for 1992-1994 (to date) were reviewed by the NIOSH medical officer.

EVALUATION CRITERIA

General

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff use established environmental criteria for the assessment of a number of chemical and physical agents. These criteria 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 should be noted, however, that not all workers will be protected from adverse health effects if their exposures are below the applicable limit. A small percentage may experience adverse health effects due to individual susceptibility, pre-existing medical conditions, and/or hypersensitivity (allergy).

Some hazardous substances or physical agents may act in combination with other workplace exposures or the general environment to produce health effects even if the occupational exposures are controlled at the applicable limit. Due to recognition of these factors, and as new information on toxic effects of an agent becomes available, these evaluation criteria may change.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Criteria Documents and recommendations, (2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and (3) the U.S. Department of Labor OSHA standards.[3-5] Often, NIOSH recommenda-tions and ACGIH TLVs may be different than the corresponding OSHA standard. Both NIOSH recommendations and ACGIH TLVs are usually based on more recent information than OSHA standards due to the lengthy process involved with promul-gating federal regulations. OSHA standards also may be required to consider the feasibility of controlling exposures in various industries where the hazardous agents are found; the NIOSH recommended exposure limits (RELs), by contrast, are based primarily on concerns relating to the prevention of occupational disease.

Environmental

Organic Solvents

Exposure to organic solvents can occur through inhalation of the vapors, skin contact with the liquid, or ingestion. As many organic solvents have relatively high vapor pressures and readily evaporate, inhalation of vapors is considered a primary route of exposure. Overexposure to many organic solvents can result in respiratory irritation, central nervous system depression, headache, nausea, and possible effects on the liver, kidney or other organs.[(6-8)] Many industrial solvents are primary skin irritants, and can cause defatting of the skin and dermatitis. Solvents are among the leading causes of occupational skin disease.[7] Solvent toxicity can range from relatively low (e.g. some freons) to high (e.g. carbon tetrachloride). Some solvents are carcinogenic (e.g. benzene).[8] The ability to detect the presence of a solvent by the sense of smell will vary widely depending on the specific substance, and individual sensitivity. Substances are considered to have good warning properties if an average person with normal sensory perception can detect the presence of the chemical at a level below the REL. The following table summarizes the principle health effects associated with the solvents evaluated and lists their NIOSH RELs and odor detection thresholds.

Chemical	**NIOSH REL[6]**	**Odor Threshold & Description[10]**	**Principle Health Effects[(9,11)]**
methyl-isobutyl ketone	50 TWA 75 ppm STEL	2.1 ppm: sweet/sharp	Headache, loss of appetite, nausea, eye irritation
methyl-ethyl ketone (2-butanone)	200 TWA 300 ppm STEL	17 ppm: sweet, sharp	Headache, dizziness, numbness of extremities. Skin and eye irritation.
toluene	100 TWA 150 ppm STEL	1.6 ppm: sour, burnt	Eye/respiratory irritation, fatigue, headache, central nervous system (CNS) depression
xylene	100 TWA 150 ppm STEL	20 ppm: sweet	Eye/respiratory irritation, CNS depression, headache, dermal effects
acetone	250 ppm TWA	62 ppm: sweet, fruity	Eye irritation, nausea, headache, central nervous system depression.

Note: TWA = time-weighted average concentration for up to 10 hours/day
C = ceiling limit not to be exceeded
STEL= short-term exposure limit - 15 minute average
PPM = parts of gas or vapor per million parts air

Note that many solvents have similar toxic effects. In this case, their combined effect should be evaluated. Unless there is scientific evidence to the contrary, the effects are considered to be additive (as opposed to potentiating, synergistic or antagonistic), and are calculated according to the ACGIH formula as follows:

$$Combined \quad REL = \frac{C_1}{REL_1} + \frac{C_2}{REL_2} + \ldots \frac{C_n}{REL_n}$$

Where: C = measured atmospheric concentration
REL = corresponding recommended exposure limit

If the sum of the above fractions exceed unity, the combined REL is considered to be exceeded.

Welding Fume/Metals

The composition of welding fume will vary considerably depending on the alloy being welded, the process, and the electrodes used.[(4,12)] Many welding processes also produce other hazards, including toxic gases such as ozone or nitrogen oxides, and physical hazards such as intense ultraviolet radiation. Of particular concern are welding processes involving stainless steel, cadmium or lead coated steel, and metals such as nickel, chrome, zinc and copper. Fumes from these metals are considerably more toxic than those encountered during welding of iron or mild steel. Epidemio-logical studies and case reports of workers exposed to welding emissions have shown an excessive incidence of acute and chronic respiratory diseases.[12] These illnesses include metal fume fever, pneumonitis, and pulmonary edema. The major concern, however, is the excessive incidence of lung cancer among welders. Epidemiological evidence indicates that welders generally have a 40% increased risk of developing lung cancer.[12] Because of the variable composition of welding emissions, and epidemiological evidence showing an increased risk of lung cancer, NIOSH recommends that exposures to all chemical and physical agents associated with welding or brazing be controlled to the lowest feasible concentration. Exposure limits for each chemical or physical agent should be considered upper boundaries of exposure. The ACGIH TLV and OSHA PEL for total welding fume, which applies only to manual metal-arc or oxy-acetylene welding of iron, mild steel, or aluminum, is 5 mg/m^3, as an 8-hour time-weighted average.[(4,5)]

The potential health effects and NIOSH RELs for elements of toxicological importance that were detected in the environmental samples are shown in the following table. These metals may be present when grinding, deburring, or welding various alloys.

Element	NIOSH REL (mg/m^3)	Principle Health Effects[9,13]
Cadmium	LFC*	Pulmonary edema, emphysema, pneumonitis, headache, muscle ache, nausea, vomiting, renal injury, cancer
Nickel	0.015	Dermatitis, pneumoconiosis, nasal irritation, nasal and lung cancer
Chromium	0.5**	Skin and mucous membrane irritation, possible lung cancer
Iron	5	Benign pneumoconiosis (siderosis)
Manganese	1 TWA, 3 STEL	Central nervous system effects, manganese pneumonitis, headaches
Cobalt	0.05 (TWA)***	Dermatitis, potential for pulmonary fibrosis, pneumonitis, respiratory sensitization
Copper	0.1 (fume) 1 (dust/mist) TWA	Upper respiratory irritation, metal fume fever
Aluminum	10 (TWA), total dust	long term overexposure may lead to dyspnea, cough, and weakness
Magnesium oxide	15 (TWA)****	Metal fume fever, muscular pain
Zinc	5 TWA 10 STEL	Metal fume fever, dry or irritated throat, metallic taste

* NIOSH considers cadmium to be a potential human carcinogen and recommends controlling exposure to the lowest feasible concentration (LFC).

** Chromium can occur in various oxidation states. Certain hexavalent chromium compounds (chromic acid and chromates) have been shown to be carcinogenic. NIOSH recommends controlling exposure to the LFC for these compounds. Chromium associated with grinding stainless steel would not be expected to be hexavalent. Hexavalent chromium compounds have been detected in certain welding processes (shielded metal arc, gas tungsten arc).[12]

*** The ACGIH Threshold Limit Value (TLV) for cobalt is 0.02 milligrams per cubic meter

**** The OSHA PEL for magnesium oxide fume is 15 milligrams per cubic meter. NIOSH did not adopt an REL for this substance, and has concluded that adverse health effects could occur at a proposed OSHA PEL of 10 milligrams per cubic meter.

mg/m^3 = milligrams of contaminant per cubic meter of air.

Cutting Fluids

Skin exposure to cutting fluids or coolants can result in contact dermatitis or other skin problems caused by the fluids themselves, dissolved or suspended metals, or certain additives, some of which are designed to suppress bacterial growth and inhibit corrosion of metals. Some additives used in these fluids may be primary irritants or sensitizers.[(14-16)]

Cutting fluids tend to be alkaline (pH >9) and act very much like strong soap upon the skin, removing surface oils and fats and causing the skin to become dry, cracked, and susceptible to infections. Metals can be liberated during grinding and reach significant levels in the cutting fluid over time. Exposures to certain metals, such as nickel, chromium, and cobalt, can cause allergic contact dermatitis in machinists and grinders.[15] Additionally, suspended particles or shavings in the cutting fluids may have an abrasive action on the skin, causing cuts or scratches. Harmful bacteria could then enter the tissues and cause infection.

Petroleum oils (non-water soluble) can result in irritant contact dermatitis. Oils can remove the protective film present on normal skin, disturb the water-holding quality of the skin, and injure the membranous structure of skin cells. Generally, the lower boiling-point solvents and oils tend to be more irritating.[16]

Monoethanolamine, Triethanolamine

Ethanolamine, or monoethanolamine, is a colorless, viscous liquid with an unpleasant, fishy, ammonia-like odor that can be detected at about 2-3 parts per million (ppm).[17] Ethanolamine is a pulmonary irritant in animals, and it is expected that severe exposure will cause the same effect in humans.[9] The liquid applied to human skin for 1.5 hours caused marked erythema.[9] The NIOSH REL for ethanolamine is 3 ppm as a 10-hour time-weighted average (TWA) and 6 ppm as a 15-minute short-term exposure limit (STEL).[3] These recommended exposure levels are based on skin, eye, and respiratory tract irritation and central nervous system effects.[3]

Triethanolamine is also a clear, colorless liquid with an ammonia-like odor. Triethanolamine is moderately irritating to the eyes and skin.[9] NIOSH has not established a REL for triethanolamine. In 1993, the ACGIH adopted a Threshold Limit Value of 5 mg/m^3 for triethanolamine.[4]

Surface Contamination

Occupational exposure standards defining "acceptable" levels of surface contamination have not been established. However, wipe samples can provide information regarding the effectiveness of housekeeping practices, the potential for exposure to contaminants from other exposure routes (e.g., surface contamination on a table that is also used for food consumption), the potential for contamination of worker clothing and subsequent transport of the contaminant, and the potential for non-process related activities to generate airborne contaminants (e.g., custodial sweeping).

Local Exhaust Ventilation

Local exhaust ventilation (LEV) is commonly used to control contaminants at the point of generation to reduce the potential for employee exposure. Ventilation assess-ments, in conjunction with exposure monitoring results, help determine the adequacy of controls at a workstation. This information also assists with deciding if additional controls, or modifications of existing controls, are warranted. A principle design parameter for LEV systems is capture velocity. Capture velocity is the velocity necessary to overcome opposing air currents and capture contaminated air by causing it to flow into the exhaust hood. Recommended capture velocities will vary depending on the contaminant's toxicity and volatility, the manner in which the material is used (e.g., heated, agitated), and room conditions (e.g., air currents). Criteria commonly used for evaluating LEV systems are from the American Conference of Governmental Industrial Hygienists (ACGIH) *Industrial Ventilation Manual*.[18] According to the ACGIH manual, the minimum capture velocity for contaminants released at high initial velocity, as in grinding, is 500 fpm. However, in addition to those noted above, factors such as the extent of use, total air volume exhausted, direction of throw, and the contaminant generating potential of the process (e.g., buffing vs. heavy grinding) should be considered when determining the proper capture velocity.

RESULTS AND DISCUSSION

Environmental Monitoring

Monoethanolamine/Triethanolamine

The results of the area monitoring for monoethanolamine and triethanolamine are shown in Table 1. Samples were collected adjacent to grinding machines using one of the two water-based cutting fluids containing these components used at the GEAE facility. All concentrations of monoethanolamine were below the analytical limit of detection. Triethanolamine was detected (0.26 mg/m^3) in one area sample collected adjacent Radial Grinder #1300, using Cim-cool 400 coolant.

Solvents

The personal air sampling results from the solvent monitoring conducted in the Braze Prep and Co-Dep area are shown in Table 2. Solvents are primarily encountered as carriers in fluxes and pastes used to prepare parts for brazing, for cleaning of small parts (acetone), and in the Co-Dep area during the preparation of slurry (acetone). All solvent concentrations detected during the monitoring period were well below the respective NIOSH REL. The highest acetone concentration detected (14.5 ppm) was in a 105 minute sample obtained from the Co-Dep operator. Analytical efforts to detect and quantify 1,3-dioxacyclopentane, a component present in Nicrobraz Cement 520, used in the Co-Dep and Braze Prep area were unsuccessful, and no results are available for this compound. 1,3-Dioxacyclopentane is a water-white liquid solvent with a vapor pressure of 70 mm Hg. Exposure can occur by inhalation or skin contact and may cause central nervous system depression (narcotic-like effect).[17] No exposure standards or guidelines have been developed for 1,3-dioxaxcyclopentane.

Metal Dust and Fume

The PBZ air monitoring results to assess exposure to metal dust and fume are shown in Table 3. With the exception of one sample for nickel, all exposures were below the applicable NIOSH REL for the activities monitored. In general, at most of the stations, only low concentrations of the various elements were detected. The highest nickel exposure (20 $\mu g/m^3$) was on a 426 minute sample from the Co-Dep operator. This exceeded the NIOSH REL of 15 $\mu g/m^3$ for nickel. The highest aluminum concentration (40 $\mu g/m^3$) was also detected on the sample taken from the Co-Dep operator. The NIOSH REL for aluminum is 10,000 $\mu g/m^3$ (total dust). Note that the results in Table 3 are listed in micrograms of contaminant per cubic meter of air ($\mu g/m^3$), and not mg/m^3 (there are 1000 micrograms in one milligram).

During the hand-packing of the blades in boxes with the metal containing powder, the Co-Dep operator wore a single-use dust respirator (3M 8710, NIOSH TC-21C-132), a hair net, and disposable coveralls. This type of respirator is not approved for protection against dusts or mists with a TWA exposure limit of less than 50 $\mu g/m^3$ (such as nickel).[19] A lateral draft slot hood was available in this area, but it was used only during the first portion of the packing activity. Prior to packing the bottom section of the boxes, the operator moved the cart holding the boxes to an open area several feet away from the exhaust hood.

The highest cobalt concentration detected was on a 383 minute sample obtained from the 404B Welding Operator. A concentration of 20 $\mu g/m^3$ cobalt was detected on this sample. The NIOSH REL for cobalt is 50 $\mu g/m^3$. The ACGIH TLV for cobalt, however, is 20 $\mu g/m^3$. Approximately 70% of this worker's time was spent welding, with the remainder spent grinding parts. A nickel concentration of 12.5 $\mu g/m^3$ and a chromium concentration of 18.6 $\mu g/m^3$ was also detected on this sample. There is a newly installed LEV system at the 404B station. However, at the welding stations monitored, the LEV is not used except during grinding, as the LEV tends to collect the argon shield gas and disrupt the weld.

One PBZ sample collected at a grinding station (404 CFM Bench Grinding Station) found a cadmium concentration of 1.9 µg/m^3. NIOSH considers cadmium to be a potential occupational carcinogen, and recommends controlling exposure to the lowest feasible limit.[3] In September 1992, OSHA promulgated a comprehensive standard for cadmium, that established a new PEL of 5 µg/m^3, and an "action level" of 2.5 µg/m^3.[20] The source of the cadmium was not determined (cadmium is not a standard process metal used at GEAE). One possible source may be brazing compounds that were subsequently released during grinding.

Other elements detected at the welding and grinding stations monitored were iron, magnesium, chromium, and titanium. All concentrations of these metals were below the applicable REL. Low concentrations of zinc oxide were found in all samples at concentrations between the analytical limit of detection (LOD) and the limit of quantification (LOQ). With the exception of the previously described Co-Dep operation, respiratory protection was not worn by any of the monitored workers.

Bulk Samples

Bulk samples of two process packing powders from the Co-Dep area were collected and analyzed for metals. The results of this analysis were as follows:

1. Co-dep Alloy Powder Class B. Turbochrome Ltd. Chromalloy Geo Turbine Corp. Lot # 362-94

Metals Detected	Concentration
Aluminum	2.4 mg/gm (0.2%)
Cobalt	0.8 mg/gm (0.08%)
Nickel	50 mg/gm (5%)
Copper	0.017 mg/gm
Iron	0.06 mg/gm

2. T-Block 1 Maskant Powder. Turbochrome Ltd. Lot # 253-93

Metals Detected	Concentration
Aluminum	190 mg/gm (19%)
Iron	0.46 mg/gm (0.046%)
Copper	0.075 mg/gm
Titanium	5.6 mg/gm (0.56%)
Zinc	0.026 mg/gm

Surface Sampling

The results of the surface sampling (Table 4) indicate the presence of various metal residues. With the exception of zinc, only very low levels of metal residues (nickel, cobalt, chromium) were found in the two breakrooms. The highest concentration of zinc detected was from a 100 square centimeter (cm^2) sample collected from the top of the microwave in the main breakroom. A concentration of 450 $\mu g/100\ cm^2$ was detected on this sample. Lower concentrations of zinc were found on a table in the main cafeteria (51 $\mu g/100\ cm^2$) and on a table in the mezzanine level breakroom (110 $\mu g/100\ cm^2$). Although standards regarding surface contamination have not been established, and exposure can not be estimated from these results, the levels suggest that additional attention to surface cleaning in the breakrooms may be prudent. Employee attention to handwashing prior to entering the breakroom should be emphasized.

Qualitative Air Sampling

Qualitative air samples were collected at various locations adjacent to EDM #3057, which was using Mineral Seal #38 oil in the reservoir during the monitoring period. Similar compounds were detected on all samples, even the control sample collected in the mezzanine level office area. Major compounds detected were 1,1,1-trichloroethane, C_4 aliphatic hydrocarbons, methyl ethyl ketone, tetrahydrofuran, 1,3-dioxolane, various C_{10} - C_{16} saturated and unsaturated aliphatic hydrocarbons, limonene, and toluene. Other compounds detected included methylene chloride, dichloroethylene, acetone, p-dioxane, xylene, cyclohexanone, butyl cellosolve, and ethanol. Comparison of samples obtained at the exhaust inlet at the oil bath with the sample collected at the outlet of the pollution control device did not indicate any appreciable differences in compounds identified or their relative response. It is possible that many of the compounds identified were not generated at the EDM machine, but from other processes and materials (e.g., paint) in the facility.

Safety and Health Program Management

The Madisonville GEAE facility has a well-established and functional safety management program. Program elements include written policies and procedures, safety committees, and worker safety and health training. The facility industrial hygienist conducts investigative (complaint) exposure monitoring, but most exposure assessments are conducted by the contract industrial hygiene firm. Considerable industrial hygiene monitoring data, both personal and area air sampling, is available for various processes and activities at the facility. Material Safety Data Sheets (MSDSs) were available for all materials in use at the facility. However, the MSDSs for two materials in the Co-Dep department did not identify the hazardous ingredients present. The plant contract physician reviews workers compensation report and consults with the nursing staff. Annual audiograms are provided for all workers. Medical surveillance (pulmonary function testing) is provided for workers who wear respirators and a respiratory protection program has been established. Safety glasses are required in all production areas.

GEAE management has an ongoing ergonomics initiative to evaluate and modify workstations to improve posture, decrease manual lifting loads, and eliminate unnecessary motion. Several of these modified workstations (bag lifting in Co-Dep, Electrostreaming, X-Ray, etc.) were reviewed, and these innovative enhancements appear to have significantly reduced potential ergonomic hazards at these processes.

Procedural/Housekeeping

Housekeeping was, for the most part, excellent throughout the facility. Aisles were clear and workstations were kept free of clutter. In the blender area of the Co-Dep department, however, considerable buildup of spilled Maskant powder was noted.

Compressed air was being used for workstation clean-up and to "dust-off" workers clothing. A principle hazard of concern is exposure to metal dusts or fumes. Compressed air use at metal grinding and welding workstations can cause settled fumes and dust to become airborne, potentially creating or exacerbating an inhalation hazard.

Smoking is allowed in the manufacturing areas and is not restricted except for areas where there is a potential safety (fire/explosion) hazard.

Ventilation

GEAE has recently installed LEV systems designed to capture and remove process emissions at numerous workstations and processes. These include various manual grinding, deburring, and polishing stations, EDM machines, and milling/grinding machines using cutting fluids. Some of the LEV systems were installed because industrial hygiene monitoring data indicated that worker exposure to cobalt and nickel fume or dust exceeded the applicable limit or guideline at some welding and grinding stations (NIOSH REL, OSHA PEL, or ACGIH TLV). At other stations, LEV systems were installed to control oil mists or cutting fluids. Most of these systems were designed to recirculate the exhaust air back into the work area after filtration.

LEV filter replacement is conducted by contract personnel. Monitoring data that assessed worker exposure to contaminants during filter maintenance was not available.

1. T-700 Blades: Radii & Deburr Belt Grinder

At this station, a rectangular hood (hood area = 0.285 square feet [ft^2]) with a punched grille (grille correction factor = 0.88) attached to a flexible duct was positioned approximately 1.5 feet from the point of contaminant generation. An average of 8 measurements showed a hood face velocity of 800 fpm (exhaust volume = 200 CFM). Only a negligible calculated capture velocity is provided with the hood positioned at this distance (1.5 feet) from the belt grinder.

2. 404-B Welding Station (ventilation only used during grinding)

At this station, a rectangular hood (hood area = 0.288 ft^2) with a punched grille is positioned on a table 3"-5" from the grinding area (hand held grinder). An average of 9 measurements showed a hood face velocity of 1340 fpm (exhaust volume = 340 CFM). This equates to a calculated capture velocity of 300 fpm (at 5" from hood opening) to 566 fpm (at 3" from hood opening).

3. 80-C Weld Station 6008 (ventilation only used during grinding)

A rectangular hood (hood area = 0.285 ft^2) with a punched grille is positioned on a table 3"-5" from the grinding area (hand held grinder). An average of 8 measurements showed a hood face velocity of 2310 fpm (exhaust volume = 579 CFM), and a calculated capture velocity of 970 fpm (at 3" from hood opening) to 500 fpm (at 5" from hood opening).

4. 80-C Weld Station 6007 (ventilation only used during grinding)

This rectangular open hood (hood area = 0.285 ft^2) is also positioned on a table about 3"-5" from the hand held grinder. An average of 8 measurements showed a hood face velocity of 2180 fpm (exhaust volume = 621 CFM), and a calculated capture velocity of 1039 fpm (at 3" from hood opening) to 538 fpm (at 5" from hood opening).

5. Slurry Room Ventilation Hood

Ventilation measurements were taken at this hood to determine if door position affected hood performance. It was felt that with the door closed only minimal make-up air was provided, which could potentially result in a decrease in the exhaust hood's ventilation rate. Velocity measurements (average face velocity = 121 fpm) and exhaust volume calculations (1815 CFM), however, showed that door position had no significant effect on hood performance.

Medical Evaluation

The NIOSH medical officer interviewed 21 employees. This included 10 persons who requested an interview (including 2 union representatives) and 11 persons who were chosen at random from areas where industrial hygiene sampling was taking place. All departments of the plant in which industrial hygiene sampling was conducted were represented among the employees interviewed. Nine of the 11 employees who reported no work-related health problems were from the randomly chosen group. Among the 10 other interviewed employees, 5 noted intermittent upper respiratory symptoms, including eye and throat irritation and sinus congestion. Two employees reported intermittent rashes on the upper extremities. Other symptoms reported included one person with upper extremity discomfort and one person with various systemic symptoms. There was no apparent pattern to the reported symptoms that would suggest a common cause.

Review of the OSHA 200 logs revealed that 132 entries were made in 1992, 88 in 1993, and 34 in 1994 (up to the date of our site visit). The majority of these entries were for injuries, including musculoskeletal problems, lacerations, and contusions. In 1992 there were three entries for skin problems, one for upper respiratory irritation, and one for a "reaction" to paint fumes. In 1993 there were five entries for skin problems (including one case of potential nickel sensitization), two for upper respiratory irritation, and one for an undefined allergic response. In 1994 (to date) there was one entry each for occupational asthma and skin rash. Review of the medical department logs did not reveal any pertinent information in addition to the above.

Most interviewed employees felt that significant improvement in plant ventilation had occurred over the previous few years. Several employees were concerned that proper procedures for the use of the coolant fluids were not being followed in terms of the addition of biocide and the frequency of changes.

CONCLUSIONS

Industrial hygiene monitoring showed that, with two exceptions, PBZ exposures to the contaminants sampled were below applicable limits during the monitoring period. The two exceptions were nickel exposure (exceeded the NIOSH REL at the Co-Dep operation) and cobalt exposure (equaled the ACGIH TLV during welding and grinding at the 404 B Vane Weld station). Overall, the contaminant concentrations detected were lower than those found in previous industrial hygiene surveys conducted by the GEAE consultant. The recent installation of LEV for contaminant control at many of the workstations may be responsible for the lower concentrations. A limited assessment of the ventilation systems at the stations sampled indicated that most of these systems were operating effectively. Qualitative air monitoring to identify compounds potentially generated during the EDM process did not identify any unusual contaminants of concern.

Management attention to safety and health appears to be at a high level. A comprehensive and functional safety and health program has been established at the facility, and efforts to improve safety were noted (e.g., ventilation modifications, ergonomic enhancements). Housekeeping was good in most areas of the facility. Although the measured surface sampling did not indicate an unusual housekeeping problem, additional attention to cleaning in the employee breakrooms is warranted. Employee attention to handwashing prior to entering the breakroom should be emphasized.

RECOMMENDATIONS

1. Improve housekeeping in the Blender area of the Co-Dep department. Spills of Maskant or other materials should be promptly cleaned up. Routine cleaning in this area may need to be on a more frequent basis than in other areas of the facility because of the materials (large quantities of powder) and process. A Co-Dep materials transfer conduit was also leaking and is in need of repair.

2. Evaluate alternatives to compressed air use at the Zinc EnCap and Co-Dep stations, and as a cleaning tool at workstations. Properly filtered (HEPA) vacuum cleaners may be one alternative that could be considered.

3. Contact the chemical supplier for the materials that have incomplete MSDSs (T-Block 1 Maskant Powder, Nicrobraz White Stop-Off Powder) and identify the contents.

4. Evaluate exposures of workers conducting local exhaust ventilation air-filter replacement (air monitoring during filter maintenance), and implement precautions if necessary to ensure exposures are controlled during these activities. Inform contract maintenance personnel of the potential exposures during their work at GEAE.

5. Eliminate tobacco use at the GEAE facility. NIOSH considers environmental tobacco smoke (ETS) to be a potential occupational carcinogen and recommends that workers not be involuntarily exposed.[21] Until smoking at the workplace can be completely eliminated, nonsmokers should be protected from exposure to ETS by isolating smokers. This can be accomplished by restricting smoking to separately ventilated (60 CFM/person) enclosed areas not used for other purposes. The air from these areas should be exhausted directly to the outside at a location where re-entrainment of ETS will not present a problem.

6. Modify the LEV hood at the T-700 Blades Radii & Deburr belt grinder to ensure the exhaust hood is positioned closer (within a few inches) of the point of contaminant generation. A new hood configuration may be necessary at this station. This hood currently provides only negligible contaminant control for the belt grinding operation. Review plant processes to determine if there are other similarly configured ventilation systems that should

be modified. The ventilation configuration at the 404B Weld Station should be reassessed and modified if necessary to control exposure during grinding and welding.

7. Ensure that the Co-Dep operator cleans the packed boxes under the local exhaust hood, and re-monitor this activity. If respiratory protection is still necessary to control exposure to nickel, a respirator equipped with high efficiency particulate (HEPA) filters should be used.

REFERENCES

1. NIOSH [1984]. NIOSH manual of analytical methods, 3rd rev. ed. Vol.1/2 (supplements 1985, 1987, 1989). Eller, RM, ed. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 84-100.

2. U.S. Department of Labor, OSHA [1990]. OSHA Industrial Hygiene Technical Manual. Chapter 2 -- Sampling for surface contamination. OSHA Instruction CPL 2-2.20B.

3. NIOSH [1992]. NIOSH 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; National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 92-100.

4. ACGIH [1994]. Threshold limit values and biological exposure indices for 1994-1995. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists.

5. Code of Federal Regulations [1989]. OSHA Table Z-1. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

6. Axelson O, Hogstedt, C [1988]. On the health effects of solvents. In: Zenz C, ed. Occupational medicine, principles and practical applications. 2nd ed. Chicago, IL: Year Book Medical Publishers, Inc. p. 775.

7. Cone JE [1986]. Health hazards of solvents. In: State of the art reviews: occupational medicine. 1(1):69-87.

8. Doull J, Klaassen C, Amdur MO, eds. [1980]. Casarett and Doull's toxicology: the basic science of poisons, 2nd Ed. New York, NY: Macmillan Publishing Company, Inc.

9. Proctor NH, Hughes JP, Fischman MF [1988]. Chemical hazards of the workplace, 2nd. Ed. Philadelphia: J.B. Lippincott Company.

10. AIHA [1989]. Odor thresholds for chemicals with established occupational health standards: American Industrial Hygiene Association.

11. NIOSH [1981]. NIOSH/OSHA occupational health guidelines for chemical hazards. Cincinnati, OH: U.S. Department of Health, and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 81-123.

12. NIOSH [1988]. Criteria for a recommended standard: occupational exposure to welding, brazing and thermal cutting. Cincinnati, Ohio: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control; National Institute for Occupational Safety and Health DHHS (NIOSH) Publication No. 88-110.

13. 54 Fed. Reg. 2513 [1989]. Occupational Safety and Health Administration: air contaminants; final rule. (Codified at 29 CFR 1910)

14. Zugerman C [1986]. Cutting fluids: their use and effects on the skin. Occupational Medicine: State of the Art Reviews. 1(2):245-258

15. Fischer AA [1990]. Contact urticaria due to occupational exposures. Chapter 6. In: Adams RM, ed. Occupational Skin Disease. Philadelphia, PA: WB Saunders Company, p. 113.

16. Zenz C [1988]. Occupational medicine: principles and practical applications, 2nd. ed. Chicago, IL: Year Book Medical Publishers. p. 141.

17. HSDB [1991]. Hazardous substance data bank, U.S. National Library of Medicine. Silver Platter (CHEM-BANK, May 1991), Boston, USA.

18. ACGIH Committee on Industrial Ventilation [1992]. ACGIH industrial ventilation: a manual of recommended practice. 21st Ed. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists.

19. NIOSH [1993]. NIOSH certified equipment list. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-104.

20. Code of Federal Regulations [1992]. Occupational exposure to cadmium: final rule. 29 CFR 1910.1027. Washington, DC: U.S. Government Printing Office, Federal Register.

21. NIOSH [1991]. Current intelligence bulletin 54: Environmental tobacco smoke in the workplace: lung cancer and other health effects. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 91-108.

AUTHORSHIP AND ACKNOWLEDGMENTS

Evaluation Conducted and Report Prepared By:	Max Kiefer, CIH Regional Industrial Hygienist NIOSH Regional Office Atlanta, Georgia
	Doug Trout, MD, MHS Medical Officer NIOSH Medical Section Cincinnati, Ohio
	Stan Salisbury, CIH Regional Program Consultant NIOSH Regional Office Atlanta, Georgia
	John Decker Regional Industrial Hygienist NIOSH Regional Office Atlanta, Georgia
Originating Office:	NIOSH Hazard Evaluations and Technical Assistance Branch Division of Surveillance, Hazard Evaluations and Field Studies NIOSH Cincinnati, Ohio
Laboratory Support	Staff Measurements Research Support Branch, NIOSH Cincinnati, Ohio

REPORT DISTRIBUTION AND AVAILABILITY

Copies of this report may be freely reproduced and are not copyrighted. Single copies of this report will be available for a period of 90 days from the date of this report from the NIOSH Publications Office, 4676 Columbia Parkway, Cincinnati, Ohio 45226. To expedite your request, include a self-addressed mailing label along with your written request. After this time, copies may be purchased from the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. GE Aircraft Engines
2. Requester
3. Department of Labor/OSHA Region IV
4. PHS/NIOSH Region 5.
   Kentucky Labor Cabinet

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.

Table 1
Monoethanolamine/Triethanolamine Area Air Sampling
GE Aircraft Engines: HETA 94-0151
Madisonville, KY
September 8, 1994

Sample Location and Description	Time (minutes)	Concentration (ppm)	
		monoethanolamine	triethanolamine
T-700 Green Thompson Grinder #1021. Cim-Cool 400 coolant	**08:03-15:16 (433)**	**ND**	**ND**
Grind-Cell Creep Feed Grinder T-700. Pillsbury 5252 coolant	**07:48-14:32 (404)**	**ND**	**ND**
Radial Grinder #1300 F-404 /T-700 Blades. Cim-cool 400 coolant	**07:27-13:59 (392)**	**ND**	**0.04 (0.26 mg/m^3)**
T-700 Grinder #1145. Cim-cool 400 coolant	**09:07-13:26 (259)**	**ND**	**ND**
Evaluation Criteria	**TWA**	**3 ppm**	**5 mg/m^3**

NOTE: ND = none detected (concentration was below the analytical limit of detection)
The limit of detection for the compounds monitored were as follows:

Triethanolamine = 20 micrograms per sample
Monoethanolamine = 7 micrograms per sample

ppm = parts per million of gas or vapor per million parts air
mg/m^3 = milligrams of contaminant per cubic meter of air

Table 2
Personal Monitoring Results: Solvent Air Sampling
GE Aircraft Engines: HETA 94-0151
Madisonville, KY
September 8, 1994

Task Monitored	Time (min)	CONCENTRATION (PPM)				
		Acetone	MEK	Toluene	Xylene	MIBK
CFM Vanes - Alloy Stop-off Use, Braze Prep Area.	07:43-15:00 (437)	6.1	0.09	0.28	NA	NA
Braze Prep Area: 404-EPE	07:59-15:03 (440)	3.9	0.07	0.23	0.8	0.06
Braze Prep Area: Alloy Stop-off Use	08:41-15:13 (392)	11.6	0.5	0.88	NA	NA
CO-DEP Operator	13:30-15:15 (105)	14.5	NA	NA	NA	NA
Evaluation Criteria	TWA	250	200	100	100	50

NOTE: PPM = parts of gas or vapor per million parts air

MEK = methyl ethyl ketone, or 2-butanone
MIBK = methyl isobutyl ketone

NA = sample not analyzed for that compound

Table 3
Personal Monitoring Results: Elements
GE Aircraft Engines: HETA 94-0151
Madisonville, KY
September 8, 1994

Task Monitored/Sample Description	Time (min)	Contaminants Detected	Concentration ($\mu g/m^3$)
Braze Prep Area: CFM Vanes, Alloy Stop Off. Area 4229	07:43-15:00 (437)	Iron Magnesium Nickel Chromium Zinc oxide Aluminum Titanium	(10) 23 (2.3) 1 (2.5) (2.2) 2
Braze Prep Area: 404 EPE	07:56-15:05 (429)	Aluminum Zinc oxide Chromium Nickel Iron	(2.4) (2.5) (0.8) (1.1) (6.9)
Co-Dep Operator	08:09-15:15 (426)	Aluminum Chromium Nickel Iron Titanium Zinc oxide	40 (0.7) 20 (0.6) 30 (2.5)
Bench Grinding at Radii/Deburr, 80C-Blades. LEV Operational	09:28-15:02 (335)	Cobalt Chromium Iron Nickel Zinc oxide	(0.9) (1.2) (3.9) (3) (3.9)
Pencil Grinding - Laser Cell, 80C/404 CFM Blades	08:30-10:04 10:30-15:07 (381)	Aluminum Cobalt Chromium Iron Nickel Zinc oxide	(2.6) (1.2) 1.8 (3.9) 6.9 (3.2)
TIG Welding 80C Blades, 36 Parts Welded. Off manufacturing floor 45 min.	07:34-10:56 (198)	Zinc oxide Cobalt Chromium Nickel	(6.2) (1.8) 2.5 7.8
Hand Held grinder at 80C Blades Welding Station, 36 Parts Grinded	11:37-15:04 (187)	Zinc oxide Iron Chromium	(6.6) (8) (1.3)

Table 3
Personal Monitoring Results: Elements
GE Aircraft Engines: HETA 94-0151
Madisonville, KY
September 8, 1994

Task Monitored/Sample Description	Time (min)	Contaminants Detected	Concentration ($\mu g/m^3$)
TIG Welding (70%) and Grinding (30%) 404B Vane Weld. Alloy L-605.	07:50-12:41 13:55-15:07 (383)	Zinc oxide Nickel Manganese Aluminum Iron Copper Chromium Cobalt	(3.4) 12.5 3.5 (4) 45 (0.8) 18.6 20
Table Top and Bench Grinding, T-700 Blade Area (Check & Correct), Radii & Deburr. LEV Operational	08:05-15:01 (416)	Aluminum Cobalt Chromium Nickel Iron Zinc oxide	(2.4) 1.6 1.3 7.3 (3.6) (3.0)
Table Top and Bench Grinding, T-700 Blade Area (Check & Correct), Radii & Deburr. LEV Operational	08:10-15:01 (411)	Zinc oxide Nickel Iron Chromium Cobalt Aluminum	(2.4) 5.8 (4.9) 1.3 1.0 (3.6)
TIG Welding, 80C Blades. 37 Parts Welded. Off Manufacturing Floor 45 minutes	07:38-10:56 (198)	Cobalt Chromium Nickel Zinc oxide	(2.3) 2.8 11.8 (6.2)
Hand Held Grinder at 80C Blades Welding Station. 2 hours of grinding, 37 parts grinded	11:38-15:05 (206)	Aluminum Chromium Iron Nickel Titanium Zinc oxide	(12.1) (1.4) 27 (2.4) 2.9 (6)
Bench Grinder, 80 C Blades, Radii & Deburr. LEV Operational	16:16-17:21 17:35-23:24 (417)	Chromium Nickel Zinc oxide	(0.7) (1) (2.9)
EnCap Operator, EnCap #1 & #2, AWAG Area	15:37-23:12 (484)	Zinc oxide Chromium	(3.2) (0.4)
404 CFM Bench Grinding Station, LEV Operational	16:42-23:21 (400)	Cadmium Zinc oxide	1.9 (2.5)

Table 3
Personal Monitoring Results: Elements
GE Aircraft Engines: HETA 94-0151
Madisonville, KY
September 8, 1994

Task Monitored/Sample Description	Time (min)	Contaminants Detected	Concentration ($\mu g/m^3$)
Grinding/Deburring at Flat Band Turning Center, Between Stations 1406 & 1405. 1.5-2 hrs total grinding time.	16:11-16:33 16:59-23:15 (405)	Zinc oxide Nickel Chromium Aluminum	(2.5) (3.9) (1.2) (2.5)

NOTE: $\mu g/m^3$ = micrograms of contaminant per cubic meter of air sampled.

() = Values in parentheses indicate the detected concentration was between the analytical limit of detection and the limit of quantification.

All samples were field blank corrected.

Table 4
Surface Sampling Results: Metals
GE Aircraft Engines: HETA 94-0151
Madisonville, KY
September 8, 1994

Sample Number	Sample Location	Contaminants Detected	Results ($\mu g/100\ cm^2$)
WS-1	Table, Main Cafeteria	Zinc	51
WS-2	Top of Microwave Oven in Main Cafeteria	Nickel Cobalt Chromium Zinc	11 2.8 6.3 450
WS-3	Table near Microwave Oven in Main Cafeteria	Chromium Zinc	0.7 64
WS-4	Food Counter Near Plastic Utensil Bins in Main Cafeteria	Chromium Zinc	0.52 57
WS-5	Entrance Door Push Plate on Main Cafeteria Door, Right Side	Nickel Chromium Zinc	0.33 0.28 21
WS-6	Counter Top, Mezzanine Level Break Room	Nickel Chromium Zinc	2.0 1.1 74
WS-7	Table Top, Mezzanine Level Break Room	Nickel Cobalt Chromium Zinc	9.9 2.1 2.8 110

NOTE: $\mu g/100\ cm^2$ = micrograms of contaminant per 100 square centimeters of surface area

Standards regarding surface contamination for the metals detected have not been established