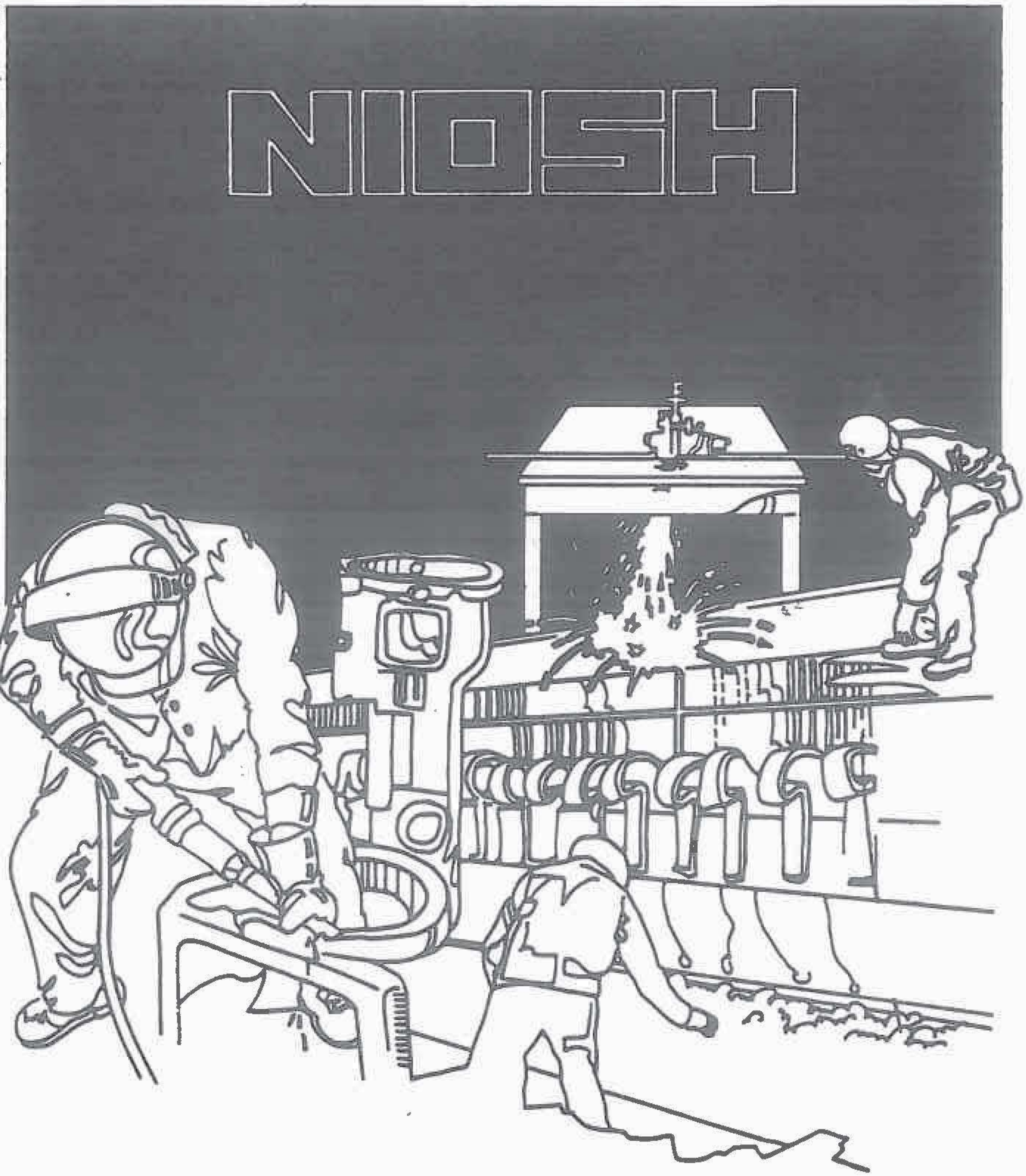
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health



Health Hazard Evaluation Report

HETA 85-254-1722
UNITED TECHNOLOGIES DIESEL SYSTEMS
SPRINGFIELD, MASSACHUSETTS

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) 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.

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UNITED TECHNOLOGIES DIESEL SYSTEMS
SPRINGFIELD, MASSACHUSETTS

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I. SUMMARY

In March 1985, the National Institute for Occupational Safety and Health (NIOSH) received a request from Local 206 of the International Union of Electrical, Radio and Machine Workers, to evaluate respiratory effects of metal dusts generated during the sharpening and repair of carbon steel and tungsten carbide tools in Department 480 (Tool and Cutter Grinder Area) at United Technologies Diesel Systems, Springfield, Massachusetts.

A comprehensive environmental and medical survey was completed February 10-18, 1986. Personal air samples for cobalt, tungsten (soluble and insoluble forms), and total and respirable dust were obtained on 5 of 8 potentially exposed machinists in Department 480. Cobalt exposures ranged from not detectable (ND) to 0.24 milligrams per cubic meter (mg/m^3). The American Conference of Governmental Industrial Hygienists (ACGIH) proposed threshold limit value (TLV®) for cobalt is 0.05 mg/m^3. The Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for cobalt is 0.1 mg/m^3. Both of these limits are TWAs based on an eight-hour exposure. There is no NIOSH recommended exposure limit (REL) for cobalt. Urinary cobalt excretion ranged from non-detectable (ND) to 61.8 micrograms per gram of creatinine (ug/gm.) and was directly related to the measured level of airborne cobalt.

Respirable dust exposures ranged from 0.04 to 0.72 mg/m^3. These levels were below the OSHA PEL and ACGIH TLV®-TWA for respirable nuisance dust of 5.0 mg/m^3. Total nuisance dust levels ranged from 0.24 to 5.3 mg/m^3, below the applicable ACGIH TLV®-TWA and OSHA PEL of 10 and 15 mg/m^3, respectively. It should be noted, however, that nuisance dust exposure limits are not the most appropriate criteria to use in this evaluation since other contaminants, with lower exposure limits (most notably cobalt), were identified in the dust samples.

Personal air samples contained no detectable soluble or insoluble forms of tungsten (limit of detection was 1.0 micrograms/filter). The NIOSH REL's for insoluble and soluble tungsten are 5 mg/m^3 and 1 mg/m^3, respectively (TWA based on exposures up to 10 hours).

Concentrations of nickel and iron (as iron dust) were also detected in several samples in amounts which could be reliably quantitated. Concentrations of nickel ranged from ND to 5.0 micrograms/m^3 (TWA

over the period sampled). NIOSH considers inorganic nickel to be a carcinogen and recommends exposures be kept below 15.0 micrograms/m^3 for a 10-hour TWA. Iron dust levels ranged from ND to 0.79 mg/m^3 (TWA over the period sampled). The OSHA PEL for iron (as iron oxide fume) is 10 mg/m^3.

A self-administered questionnaire given to 5 workers in Department 480 identified only non-specific respiratory complaints. Pulmonary function testing identified one worker with mild to moderate restrictive lung disease. A reduction in the forced expiratory volume in one second (FEV_1) post-shift compared to pre-shift was demonstrated in three of four workers; two workers had a 10% or more reduction. Chest x-rays were normal in all workers except one which showed an elevation of the left hemidiaphragm.

Blood tests for thyroid function, serum creatinine, and complete blood count were considered normal in all workers tested. The blood urea nitrogen in one worker was slightly elevated. The mean blood cobalt level was 4.25 micrograms per deciliter (ug/dl), with a range of 3.8-5.0 ug/dl. These are higher than levels reported in the literature among workers with similar exposures.

Based on these results, it has been determined that a potential health hazard from airborne exposure to cobalt exists among workers in Department 480. A reduction in FEV_1 post-shift compared to pre-shift was demonstrated in three of four workers. Furthermore, the urinary excretion of cobalt appears to be directly related to the airborne concentrations, and thus provides a good indicator of exposure. Recommendations to reduce exposures are included in Section VIII of this report.

Key Words: SIC 3541 (Machine Tools, Metal Cutting Types), tungsten carbide, metal dust, cobalt, respiratory effects, nickel, iron

II. INTRODUCTION

On March 12, 1985, the National Institute for Occupational Safety and Health received a request for a Health Hazard Evaluation from American Bosh, Local 206, affiliated with the International Union of Electrical, Radio and Machine Workers, AFL-CIO, to investigate respiratory complaints of workers in Department 480 (Tool and Cutter Grinder Area) at United Technologies Diesel Systems, in Springfield, Massachusetts. NIOSH was asked to evaluate the possible health hazard of respirable metal dusts generated in the sharpening and repair of tools, particularly those tools containing tungsten carbide.

An initial site visit was conducted on May 6, 1985. It was believed that significant potential for exposure to metal dust existed and that further evaluation was warranted. A follow-up site visit was made on December 4, 1985 and our activities included a comprehensive site evaluation, interviews with employees from Department 480, and a review of environmental and medical records. NIOSH investigators returned on February 10-18, 1986, for a comprehensive medical and environmental survey. This consisted of a self-administered symptom questionnaire, biologic monitoring for blood cobalt, thyroid function tests, creatinine, blood urea nitrogen (BUN), complete blood count (CBC), pre-shift and post-shift urinary cobalt, chest x-rays, pulmonary function tests, and personal air sampling for cobalt, tungsten (soluble and insoluble), and respirable and total dust fractions.

III. BACKGROUND

United Technologies Diesel Systems fabricates fuel injection systems for the trucking industry, agricultural vehicles and military equipment. The original facility, which includes Department 480 (Tool and Cutter Grinder Area), was built in 1910. The production facility was taken over by United Technologies from Ambac Industries, Inc., in 1979 and at the time of the initial site visit United Technologies employed approximately 1,200 people. In February 1986, the company announced that it would be closing operations at the facility by August 1986. As a result of this announcement there was a plant-wide slowdown that was reflected in a reduced number of work orders in Department 480 at the time of the February survey.

Department 480 was previously located in a third floor area of the main building and was moved to its present location 3 years ago. At the time of the February, 1986, survey, Department 480 employed 8 machinists over 3 shifts, 5 on first shift, 2 on second shift, and 1 on third shift. Carbon steel and tungsten carbide steel drill bits, gun drills, reamers, face cutters and other cutting tools are brought from other areas in the plant and are sharpened or repaired on any of approximately 20 machines in the area. The majority of the retooling is done in dry grinding operations with local exhaust ventilation (LEV) available on most machines in this department. Eight self-contained dust filtering and air recirculating systems (manufacturers: AAF Arrestall, Torit) supplied point-of-generation exhaust ventilation. Both flexible and solid ductwork, ranging in size from four to eight inches in diameter, connected the machines to these dust collectors. NIOSH investigators observed that these LEV systems were not routinely used by the machinists.

Respiratory complaints among workers in Department 480 date back several years. One former employee was reported by local occupational medical specialists to have developed, within 2 years of employment, an intersitial lung disease. This type of lung disease, a diffuse interstitial fibrotic process, is characteristic of "hard metal disease", so-called because it is believed to be secondary to cobalt exposure in dust generated while grinding tungsten carbide. NIOSH investigators reviewed the medical records of this employee and agreed with the impression that an intersitial lung disease was present. Also, these worker complaints prompted an Occupational Safety and Health Administration (OSHA) site visit in October 1984. A return visit by OSHA, in January 1985, found air levels (measured in the breathing zones of two workers) for total dust, cobalt, nickel, chromium, titanium, and molybdenum within the OSHA permissible exposure limits (PEL's).

IV. EVALUATION DESIGN

A. Environmental

The environmental assessment of employees working in Department 480, performed on February 10 to 14, 1986, was designed to determine the correlation (if any) of employee pre- and post-shift urinary cobalt concentrations (discussed in the following section) with corresponding total and respirable cobalt air exposures measured by personal sampling during the same shift. Personal air samples, measuring both soluble and insoluble tungsten, were also collected over this same time period.

Full-shift personal air samples were collected, over all three shifts, on five of eight potentially exposed machinists in Department 480. Participants were monitored, as a minimum, for total dust, cobalt, and tungsten on each day of the study. On alternating days (February 10, 12, and 14, 1986) personal samples were also collected for respirable dust and cobalt. NIOSH investigators did not observe machinists in Department 480 wearing respirators at any time during this evaluation.

Total and respirable dust samples were collected using tared, 37-millimeter (mm), 5.0 micron-pore-size polyvinyl chloride (PVC) filters connected to high volume personal air sampling pumps. For determining the respirable dust fraction, NIOSH Method 600 was employed using standard 10 mm nylon cyclones with a flowrate of 1.7 liters per minute (lpm)(1). This sampling rate provides optimum collection efficiency of dust particles smaller than 10 microns in diameter. Full-shift total dust sampling, using NIOSH Method 500, used flowrates ranging from 0.8 to 2.0 lpm (1).

Soluble and insoluble tungsten samples were collected on 37 mm, 0.8 micron mixed-cellulose-ester filters at flowrates ranging from 1.0 to 1.3 lpm. The samples were analyzed for soluble and insoluble tungsten and cobalt by flame atomic absorption spectroscopy according to NIOSH Method 7074.(1)

A quantitative determination of trace metals, using the tared PVC filters from the respirable and total dusts samples, was made by inductively coupled plasma-atomic emission spectrometry (ICP-AES) according to NIOSH Method 7300 (1). The PVC filters were ashed in a low-temperature oxygen plasma asher (LTA) for one hour at 200 watts to remove the filter material. Five milliliters (ml) of concentrated nitric acid (HNO_3) and one-half ml of 70 percent (%) perchloric acid ($HClO_4$) were added to each sample and then taken to dryness. The residues were redissolved with 10 ml of 4% HNO_3/1% $HClO_4$ and then analyzed for trace metals content by ICP-AES.

B. Medical

A study protocol to evaluate worker exposure to metal dust was submitted to and approved by the Human Subjects Review Board at NIOSH. All machinists in Department 480 (Tool Cutter and Grinder Area) were invited to participate. Five of eight eligible workers participated in the study. Two workers refused and another worker was on leave at the time of the study. A self-administered questionnaire was given to each participant. The questionnaire sought basic demographic information, work history, past medical history, active medical problems, current symptoms (especially respiratory complaints), and a detailed history of occupational and non-occupational exposure to cobalt.

A venous blood specimen was collected and analyzed for blood cobalt, thyroid function tests, serum creatinine, blood urea nitrogen, and a complete blood count with differential and morphology. The blood cobalt analysis was done using standard methods at ESA laboratories in Medford, Massachusetts. All other blood testing was done using standard methods by MetPath Laboratories, Teterboro, New Jersey.

Pre-shift and post-shift spot urine collections for cobalt and creatinine were obtained daily during the study period. Urine specimens were collected after handwashing and in a manner to minimize specimen contamination (see Appendix). Laboratory and field blanks were collected daily and processed using identical methods to the urine samples. All urines were processed within 2 to 4 hours and frozen until analyzed at the Centers for Disease Control, Center for Environmental Health, Division of Environmental Health Laboratory Sciences. Analyses were adapted from a previously published method (2).

Pre-shift pulmonary function tests (on the first day of the workweek) and post-shift pulmonary function tests (on the fourth day of the workweek) were obtained. Three valid pre-shift and post-shift spirometric curves were obtained from each participant. Forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were measured with an Ohio Medical Model 822 dry rolling seal spirometer. Equipment and test procedures conformed to the American Thoracic Society's criteria for screening spirometry (3). Predicted values for FEV_1 and FVC were calculated using the equations of Knudson (4). For the determination of FEV_1, FVC, and FEV_1/FVC%, the largest FEV_1 and FVC from each set of 4 valid spirograms were used, regardless of the curve(s) on which they occurred. A series of symptom questions was asked before each pulmonary function test (PFT) session. These included whether cough, shortness of breath, chest tightness or wheezing were currently experienced, as well as time of last medication, cigarette, meal, and respiratory infection.

A posterior-anterior and a lateral chest x-ray was done at a local hospital and all x-rays were read by two radiologists (certified B readers) using the standard method and classification of occupational lung diseases (pneumoconiosis)(5).

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for 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 exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects, even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH criteria documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV's)(6), and 3) the U.S. Department of Labor (OSHA) general industry standards (7). Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended exposure limits, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in the report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Although not applicable in this evaluation, some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA, where there are recognized toxic effects from high short-term exposures.

Cobalt

The ACGIH has proposed adoption of a recommended TLV-TWA for cobalt of 0.05 mg/m^3. The OSHA permissible exposure limit (PEL) for cobalt is 0.1 mg/m^3. Although NIOSH does not have a recommended exposure limit specifically for cobalt, NIOSH does recommend an action level of 0.05 mg/m^3 for cemented carbide dust which contains more than two percent cobalt (8).

The process of repairing or re-sharpening carbon steel and tungsten carbide tools creates exposures to a number of different metal dusts including iron, cobalt, nickel, chromium, molybdemum, and titanium.

Cemented tungsten carbide is a unique metal commonly used in drills, saw blades, and other cutting tools because of its strength, rigidity, and resistance to extreme heat. Carbide tools, for example, retain their sharpness at not only ordinary cutting temperatures (1,700° to 2,000°F) but even at temperatures approaching 3,000°F (a level existing at the interface between the carbide cutting tip and the metal being cut). The production of tungsten carbide requires the techniques of powdered metallurgy. Finely divided (mean diameter 1.5 micron) tungsten and carbon powders are blended and then heated (in an inert atmosphere) to form tungsen carbide. Cobalt (Co) is added in varying amounts (3% to 25%) to the tungsten carbide powder as a binding agent (8). Depending on the desired properties of the final product, other metal powders such as titanium carbide, tantalum carbide, chromium carbide, and nickel may be added (8). Exposures to cobalt and other metal constituents may occur during grinding, milling, and cutting of new tools, or during the re-sharpening and repair of old tungsten carbide tools.

Cobalt is a naturally occurring element in the environment. It forms an integral part of the cyanocobalamin molecule (vitamin B 12) (9). This vitamin is essential to the human diet to prevent the development of pernicious anemia (low red blood cell count) (10). The average U.S. daily cobalt intake from food, water and community air have been estimated to be 0.3 mg (milligrams), 0.006, mg and 0.0001 mg respectively (11).

While cobalt is an essential element, in high concentrations it is known to have adverse effects on the lungs, heart, thyroid, skin, and blood producing system. Fibrotic lung changes have been observed in workers exposed to airborne cobalt concentrations of 0.1 to 0.2 mg/m^3 (12-18). A common pattern of illness is described in these reports. The worker may first develop a cough, followed by labored breathing on exertion. This may be followed by substantial weight loss, as the individual goes on to develop a progressive interstitial pulmonary fibrosis (scar tissue in the lung). This may be accompanied by cor pulmonale (hypertension in the lungs), leading ultimately to cardiorespiratory collapse and death (10). The reported latency period from exposure to disease varies from a few years to 20 years (10). It is unclear whether this variable latency is related to individual susceptibility, or varying levels of exposure among affected workers. The association between inhaled cobalt metal and the development of lung fibrosis is supported in studies conducted in swine (19).

A series of reports (16-18) describe lung function test results among 155 Swedish cemented carbide workers and 74 controls matched for sex, age and smoking history. Persons exposed to an average of 0.06 mg/m^3 airborne cobalt showed changes on pulmonary function tests, suggestive of obstructive disease; these changes did not regress over the weekend. Smokers were more affected than non-smokers.

Several investigators have suggested evidence of bronchitis among hard metal workers (14-28). Asthma has been reported (14-15,30-31) as early as one month after initial exposure (20). The development of asthma seems to be a true sensitization to cobalt. The occurrence of allergic lung sensitization has heightened plausibility in view of the occurrence of documented cobalt allergic dermititis that has been reported among workers using cobalt-containing materials (31,32). Sjogren et al (33) has reported three, non-smoking, hard metal workers, having symptoms and signs compatible with allergic alveolitis. The symptoms, signs and chest x-ray findings cleared following removal from the work environment, but upon re-exposure the symptoms and chest X-ray findings recurred. All three workers had eczematous skin changes and were sensitive to cobalt on skin patch testing.

Other physiological effects associated with cobalt include cardiomyopathy (enlargement and dilation of the heart). This was first reported in the 1960's and was associated with heavy beer consumption (2 to 6 liters per day). Cobalt sulfate or cobalt chloride was commonly used in beer at that time as a foam stabilizer (34-39). The signs and symptoms of affected individuals included abdominal pain, shortness of breath, lowered blood pressure, heart enlargement, pericardial effusion, tachycardia and electrocardiographic (ECG) abnormalities. The amount of cobalt ingested daily by a 6-liter-per-day drinker was estimated to be about 5-10 mg.

Therapeutically, cobalt has been used in the treatment of anemias (low red blood cell counts). It has been shown to increase hemoglobin and hematocrit levels in humans (40-48). Hypothyroidism and goiter has been associated with daily oral doses of 2-10 mg/kg of cobalt chloride administered over a 2-4 month period in a small percentage of people (10). Additional effects, reported in humans but for which there is limited information available, include disturbed kidney function, hyperglycemia, mild to moderate changes in liver function tests and impaired sense of smell (10).

The NIOSH Criteria for Controlling Occupational Exposure to Cobalt holds the following position concerning the possible carcinogenicity of cobalt (10):

> "Information on cobalt is inadequate to conclude that cobalt is a carcinogen. The information is also inadequate to conclude that cobalt is non-carcinogenic. In fact, limited data provide suggestive evidence that at least some cobalt containing compounds may prove carcinogenic (49-51) when subjected to long-term testing by currently accepted protocols. Until such testing is performed, no definitive guidelines can be given. Tumor induction at the injection site, however, would argue for the need to adequately clean any wound contaminated with cobalt."

Iron Oxide Fume or Dust (52)

Inhalation of iron oxide fume or dust causes an apparently benign pneumoconiosis termed siderosis. Iron oxide alone does not cause fibrosis in the lungs of animals, and the same probably applies to humans. Exposures of six to ten years are usually required before changes recognizable on chest x-ray can occur. The retained dust produces chest x-ray shadows that may be indistinguishable from fibrotic pneumoconiosis. In one study, eight of 25 welders exposed chiefly to iron oxide for an average of 18.7 (range 3 to 32) years had reticunodular shadows on chest x-ray consistent weith siderosis but with no reduction in pulmonary function; exposure levels ranged from 0.65 to 47 mg/m^3. In another study, 16 welders with an average exposure of 17.1 (range 7 to 30) years also had x-ray finding suggestive of siderosis and spirograms which were normal; however the static and functional compliance of the lungs was reduced. Some of the welders were smokers. The welder with the lowest compliance complained of dyspnea.

ACGIH recommends an 8-hour TLV of 5.0 mg/m^3 for iron oxide fume (6). The OSHA PEL for iron oxide fume is an 8-hour TWA of 10 mg/m^3 (7).

Nickel (53)

Metallic nickel and certain soluble nickel compounds as dust or fume can cause hypersensitivity dermatitis. Nickel compounds have been associated with cancer of the paranasal sinuses and lung. Nickel fume in high concentrations is a respiratory irritant. Severe but transient pneumonitis in two workers resulted from exposure to nickel fume; in one case, exposure lasted six hours, and post nickel sampling found a level of 0.26 mg/m^3. "Nickel itch" is a dermatitis resulting from sensitization to nickel. The first symptom is usually itching, which occurs up to seven days before skin eruption appears. The primary skin eruption is erythematous or follicular; it may be followed by superficial discrete ulcers, which discharge and become crusted or eczematous. In the chronic stages, depigmented plaques may be formed. Nickel hypersensitivity, once acquired, apparently is not lost. Recovery from the dermatitis usually occurs within seven days of exposure, but may take several weeks. One worker who developed cutaneous sensitization also developed asthma from inhalation of nickel sulfate. Immunologic studies showed circulating antibodies to the salt, and controlled exposure to a solution of nickel sulfate resulted in decreased pulmonary function and progressive dyspnea. The possibility of developing hypersensitivity pneumonitis could not be excluded.

In animals, finely divided metallic nickel was carcinogenic when introduced into the pleural cavity, muscle tissue, and subcutaneous tissue; rat and guinea pigs exposed to a concentration of 15 mg/m^3 of powered metallic nickel developed malignant neoplasms. Several epidemiologic studies have shown an increased incidence of cancer of the paranasal sinuses and lungs among nickel exposed workers. Carcinogenicity is believed related to respirable particles of nickel subsulfide, nickel oxide, and nickel carbonyl vapor.

The NIOSH recommended exposure limit for nickel is 15 micrograms per cubic meter as a 10-hour TWA (49). The ACGIH TLV and the OSHA standard for nickel metal is an 8-hour TWA of 1.0 mg/m^3 (6, 15).

VI. RESULTS AND DISCUSSION

A. Environmental

Thirty full-shift personal air samples were collected on five machinists in Department 480 between February 10 and 14, 1986. Table I presents these sample results, expressed as TWA's over the period sampled, for total dust, respirable dust, and cobalt.

Personal exposures to airborne cobalt ranged from not detectable (ND) to 0.24 mg/m^3. The limit of quantitation (LOQ) for cobalt and other trace metals from this sample set was 1.0 microgram per filter. Two employees monitored had airborne cobalt exposures equal to or exceeding the ACGIH proposed TLV-TWA of 0.05 mg/m^3 on three of the five study days. One of these two individuals had a TWA personal exposure of 0.24 mg/m^3, a concentration approximately five times the ACGIH recommended level and over twice the OSHA PEL for cobalt.

A close correlation was obtained by comparing the amount of tungsten carbide work performed by the individual machinists over each sampling period, as noted by NIOSH investigators, to their respective airborne cobalt exposures. These airborne cobolt levels also correlated closely with the urinary excretion levels of cobalt (discussed in the following section).

Respirable dust exposures ranged from 0.04 to 0.72 mg/m^3, levels well below the OSHA PEL and for the ACGIH TLV*-TWA respirable nuisance dust of 5.0 mg/m^3. Total dust exposures ranged from 0.24 to 5.3 mg/m^3, also well below the applicable OSHA PEL and the ACGIH TLV*-TWA of 15 and 10 mg/m^3 for nuisance dust. It should be noted, however, that nuisance dust exposure limits are not the most appropriate criteria to use in this evaluation since other contaminants, with lower exposure limits (most notably cobalt), were identified in these dust samples.

Personal air samples for insoluble and soluble forms of tungsten ranged from ND to levels below their limits of reliable quantitation. None exceeded the NIOSH REL's for insoluble and soluble tungsten of 5 mg/m^3 and 1 mg/m^3, respectively.

Concentrations of nickel and iron (as iron dust) were also detected in several of the trace metal samples in amounts which could be reliably quantitated. Concentrations of nickel ranged from ND to 5.0 micrograms/m^3 (TWA over the period sampled). NIOSH considers inorganic nickel to be a carcinogen and recommends exposures be kept below 15.0 micrograms/m^3 for a 10-hour TWA. Iron dust levels ranged from ND to 0.79 mg/m^3 (TWA over the period sampled). The OSHA PEL for iron (as iron oxide fume) is 10 mg/m^3.

B. Medical

Questionnaire Data

Twenty-one people were employed in Department 480. Eight were machinists and were potentially exposed to metal dusts; four were on first shift, two were on second shift, and one was on third shift. One female and four males participated in the survey; all were white. Their mean age was 44 years (range 32 to 53 years). Their mean duration of employment at United Technologies was 9 years and 10 months (range 6 to 20 3/4 years), and their mean duration of employement in Department 480 was 8 years (range 2 1/2 to 20 years). All denied previous work with asbestos, or fibrous glass, sand blasting, in shipyards, or quarries, or where known exposures to beryllium or cadmium existed. One worker reported working one year in a foundry, and two others reported working in a cotton, flax or hemp mill for less than 2 years.

In order to ascertain other potential sources of cobalt, detailed dietary histories were obtained. Four of five workers regularly drank from city water, one from well water. Three ate seafood less than one time per month, while two reported weekly consumption. Two drank no alcoholic beverages, while 3 drank between 6 and 24 beers per week. One worker regularly took vitamin supplements.

All workers were regular cigarette smokers with a mean of 26.8 pack years (range 6.5 to 42.5 pack years). All smoked, ate or drank at their work stations. Two occasionally used, and 3 never used, dust masks during grinding or milling operations.

Respiratory conditions or symptoms reported by the 5 workers are listed below:

	No. (n=5)
Morning cough	4
Daily productive cough	3
Chest wheezing apart from colds	2
Sinusitis	2
Chronic bronchitis	1

While all of these symptoms can be produced or exacerbated by exposure to metal or nuisance dusts, these symptoms are confounded by the long smoking histories in this group of workers. Chest wheezing apart from colds can be considered most specific for an occupationally induced etiology, but this also is confounded by smoking.

Pulmonary Function Test Data

PFT's were done pre-shift on the first day of the work week and post-shift on the fourth day of the work week. This was intended to detect cumulative effects of metal dust on pulmonary function. Results are presented in Table II. Pre-shift PFTs were within the normal range in four of the five workers (FEV_1 and FVC greater than or equal to 80% of predicted). One worker had evidence of mild to moderate restrictive lung disease, with an FVC of 69% of predicted and a normal FEV_1/FVC. This could have been related to a previous chest injury. When pre-shift and post-shift pulmonary function tests were compared, all workers for whom a pre- and post-shift test were available showed a clear trend toward a reduction in the FEV_1 and the FVC (four of five study participants) when the pre-shift tests were compared to the post shift tests. One worker had an 18.9% and and another worker a 10.4% reduction in the FEV_1. This is likely to represent an effect of metal dust exposure. A 10% reduction of the FEV_1 is considered sufficient to document an adverse respiratory health effect (54).

Posterior-anterior and lateral chest x-rays were obtained on five workers and were read by a radiologist certified as a B reader (trained in the recognition of pneumoconiosises). Four were reported normal. One showed an elevation of the left hemidiaphram; this was the same worker noted early to have a reduction in the FVC.

Blood Tests

A blood specimen was obtained on 4 of the 5 study participants. The mean blood cobalt level was 4.25 micrograms per deciliter (ug/dl). The range of blood cobalt levels were 3.8 to 5.0 ug/dl. These levels are three to five times higher than expected on the basis of previous reports. Using a similar method others have reported blood cobalt levels ranging between 0.57 to 0.79 ug/dl in workers exposed to air levels of 0.1 mg/m^3 cobalt (51). Another study found blood cobalt levels of 1.05 ug/dl $\pm$ 1.09 and 0.07 ug/dl $\pm$ 0.02 in workers exposed to air cobalt levels of 0.09 mg/m^3 and 0.01 mg/m^3 respectively (reported in reference 51).

Thyroid function tests, complete blood count and serum creatinine were considered normal in all tested. One worker was found to have an elevated blood urea nitrogen (BUN) of 33 (normal reference range 8-23). The serum creatinine was normal in this worker. The elevation of the BUN was considered a non-specific finding.

Urine Cobalt Measurements

Five lab blanks and five field blanks were collected during the study period. All blanks consisting of deionized water provided by the laboratory were confirmed on repeated analysis to be cobalt free. The limit of detection for cobalt by the lab method was 3.4 ug/dl. Three lab blanks were contaminated with cobalt, Day 1 (4.1 ug/dl), Day 3 (3.8 ug/dl), and Day 9 (4.5 ug/dl). This may reflect the collection, handling or processing of the specimen. Contaminated lab blanks, however, were not processed during the same time that urine specimens obtained from workers exposed to airborne cobalt levels that equaled or exceeded the ACGIH proposed TLV for cobalt, were processed.

All urine cobalt measurements were spot (that is, untimed) samples, and were corrected using the urine creatinine level measured on the same specimen. Air and urine cobalt sampling results are presented in Table III. Two workers, during 5 sampling periods, had exposures at or above the ACGIH proposed airborne cobalt standard of 0.05 mg/m^3. This exposure was directly reflected in the measured urinary excretion of cobalt during those air sampling periods. Measured urinary cobalt was not detected or reduced in the pre-shift sample in all workers tested (4 of 5) after a weekend. Cobalt excretion by exposure category is presented below:

Total Air Co (mg/m^3)	Mean Change Over Shift in Urinary Co(ug/l)	(Range)
Non-detectable	- 2.3	(-16.0 to 8.1)
> 0 < 0.05	+ 2.5	(- 7.6 to 11.8)
> 0.05	+26.3	(14.1 to 56.0)
Respirable Co (mg/m^3)		
Non-detectable	- 1.6	(- 7.6 to 8.1)
> 0 < 0.05	+11.2	(0.7 to 20.7)

The correlation coefficients for total and respirable cobalt with the change in urinary excretion of cobalt were 0.68 and 0.69 respectively. Based on the data collected in this study, there appears to be a direct correlation between the total and respirable level of airborne cobalt and the level of urinary excretion.

VII. CONCLUSIONS

Based on these results, it has been determined that a potential health hazard from airborne exposure to cobalt exists among workers in Department 480. A reduction in FEV_1 post-shift compared to pre-shift was demonstrated in three of four workers. Furthermore, the urinary excretion of cobalt appears to be directly related to the airborne cobalt concentrations, thus providing a good indicator of exposure and possibly another monitoring technique for the workplace.

VIII. RECOMMENDATIONS

A. Environmental

1. The following recommendations describe modifications to the current local exhaust ventilation system currently in place in Department 480.

   (a) Reconnect the exhaust ventilation hose to machine no. 21281 and relocate the capture hood to beneath the point of work.

   (b) Reconnect the exhaust ventilation hose to machine no. 24155 and repair the associated recirculating air filtering system.

   (c) Reconnect the exhaust ventilation hose to machine no. 23451 and move capture hood nearer the point of work.

   (d) Provide local exhaust ventilation to the Do-All unit (no machine number) and grinder no. 24155.

2. Employee training in Department 480, emphasizing the benefits of local exhaust ventilation in controlling airborne particulate matter, should be provided. This training should include information on the contaminants which may be generated while working with tungsten carbide (such as cobalt, nickel, chromium and tungsten.)

3. General housekeeping was poor throughout Department 480 and should be improved. Dry sweeping of dust should be discouraged.

B. Medical

1. All employees should be advised of the health effects of exposure to metal dusts, particularly cobalt containing tungsten carbide.

2. Yearly pulmonary function testing should be done, including measurement of FEV_1 and FVC.

3. All new employees should have a baseline chest x-ray; routine chest x-rays are not recommended for the asymptomatic employee. All chest x-ray should be read by a B-reader, i.e., who is specially trained in reading chest x-rays for changes indictive of preumoconiosis.

4. Employee medical records should be maintained for at least 30 years.

5. Smoking on the job should be discouraged.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. American Bosh, Local 206
2. United Technologies Diesel Systems
3. The National Institute for Occupational Safety and Health (NIOSH) Region III.
3. The Occupational Safety and Health Administration (OSHA) Region III.

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 I

Personal Air Sampling Results For Total Dust, Respirable Dust, and Cobalt
Department 480 - Tool and Cutter Grinder Area
United Technologies Diesel Systems
Springfield, Massachusettes
HETA 85-254

DATE	SAMPLE NO.	TIME (Min)	FLOWRATE (LPM)[b]	SAMPLE VOL. (LITERS)	CONCENTRATION, milligrams per cubic meter (mg/m^3)[a]	
					TOTAL DUST/COBALT[c]	RESPIRABLE DUST/COBALT[d]
2/10/86	F-05	396	1.0	396	0.78/0.004	
	F-09	468	1.1	515	1.5/0.05*	
	F-38	475	0.8	380	2.2/0.02	
	F-62	463	0.8	322	0.81/0.01	
	F-66	475	1.0	463	2.3/0.05*	
2/10/86	F-47	468	1.7	796		0.28/0.002
	F-51	403	1.7	685		0.20/ND[e]
	F-68	475	1.7	808		0.57/0.002
	F-70	463	1.7	787		0.72/0.03
2/11/86	F-16	441	1.5	662	1.4/0.04	
	F-45	404	1.5	606	2.5/0.01	
	F-65	437	1.5	656	0.85/ND	
	F-67	424	1.5	636	0.38/ND	
2/12/86	F-26	332	1.0	332	0.48/ND	
	F-39	500	1.0	500	0.24/ND	
	F-52	448	1.3	582	1.2/0.05*	
	F-64	507	1.0	507	0.32/ND	
	F-69	282	1.0	282	0.64/0.01	
2/12/86	F-31	546	1.7	928		0.15/ND
	F-49	282	1.7	479		0.19/ND
	F-60	498	1.7	847		0.21/ND
	F-61	506	1.7	860		0.06/ND
	F-63	332	1.7	564		0.18/ND
2/13/86	F-37	80	2.0	160	1.1/ND	
	F-42	438	2.0	876	5.3/0.24*	
	F-56	441	2.0	882	2.0/0.004	
2/14/86	F-58	431	1.0	431	1.4/0.05*	
	F-59	435	1.1	479	0.38/0.01	
2/14/86	F-36	435	1.7	740		0.04/ND
	F-55	431	1.7	733		0.05/0.002
Evaluation Criteria:						
	ACGIH				10.0/0.05 (proposed)	5.0/0.05 (proposed)
	NIOSH				None/f	None/f
	OSHA				15.0/0.1	5.0/0.1

Comments

a All values have been field blank corrected and are expressed as the time-weighted average over the period sampled
b Liters per minute
c Cobalt concentration from total dust samples
d Cobalt concentration from respirable dust samples
e Not detected
f The NIOSH recommended action level for cemented tungsten carbide dust, containing more than two percent cobalt, is 0.05 mg/m^3, ten-hour TWA.

* Indicates concentrations at or above the ACGIH proposed TLV for cobalt of 0.05mg/m^3.

Concentrations of other trace metals with corresponding evaluation criteria.

Nickel: Range measured ND to 5.0 micrograms/m^3. NIOSH considers inorganic nickel to be a carcinogen and recommends exposures be kept below 15.0 micrograms/m^3, 10-hour TWA.
Iron: Range measured ND to 0.79 mg/m^3. OSHA PEL for iron (as iron oxide fume) is 10 mg/m^3.

TABLE II

RESULTS OF PRE-SHIFT AND POST-SHIFT PULMONARY FUNCTION TESTING
IN FIVE WORKERS AT UNITED TECHNOLOGIES DIESEL SYSTEMS
SPRINGFIELD, MASSACHUSETTS

ID	TEST	PRE-SHIFT[a] ACTUAL/PREDICTED	POST-SHIFT[b] ACTUAL/PREDICTED	PERCENT CHANGE[c]
01	FEV_1	2.49/3.47	2.02/3.47	-18.9%
	FVC	2.98/4.35	2.71/4.35	- 9.1%
	FEV_1/FVC	0.84/0.80	0.75/0.80	-11.0%
02	FEV_1	2.22/2.42	2.04/2.42	- 8.1%
	FVC	2.88/2.95	2.64/2.95	- 8.3%
	FEV_1/FVC	0.77/0.82	0.77/0.82	0.0
03	FEV_1	3.79/3.99	3.62/3.99	- 4.5%
	FVC	4.63/4.98	4.61/4.98	- 0.4%
	FEV_1/FVC	0.82/0.80	0.79/0.80	- 3.7
04	FEV_1	3.16/3.77	2.83/3.77	-10.4%
	FVC	3.84/4.76	3.48/4.76	- 9.4%
	FEV_1/FVC	0.82/0.80	0.79/0.80	- 3.7-
05[d]	FEV_1	3.57/3.80	ND	--
	FVC	4.46/4.69	ND	--
	FEV_1/FVC	0.84/0.81	ND	--

a = Pre shift first day of workweek (Feb 10,1986) except for ID = 05
b = Post-shift fourth day of work week (Feb 14, 1986)
c = % Actual change = $\frac{\text{pre-shift - post-shift}}{\text{pre-shift}}$
d = PFT obtained on second day of workweek
ND = Not done

TABLE III

AIR[1] AND URINE[2] COBALT LEVELS IN 5 WORKERS AT UNITED TECHNOLOGIES DIESEL SYSTEMS, SPRINGFIELD, MASSACHUSETTS, FEBRUARY 10-14, 1986

		AIR LEVEL (mg/m3)		URINE LEVEL (mg/l)		
ID NO.	STUDY DAY	TOTAL COBALT	RESPIRABLE COBALT	PRE-SHIFT COBALT	POST-SHIFT COBALT	CHANGE IN URINE COBALT
01	1	ND	0.01	2.8	3.4	+ 0.6
	2	ND	--	3.0	3.4	+ 0.4
	3	ND	ND	3.4	3.4	0.0
	4	--	--	2.7	--	--
	5	--	--	0.0	--	--
02	1	0.004	--	2.1	0.0	- 2.1
	2	0.01	--	4.2	15.9	+11.7
	3	0.01	ND	7.6	0.0	- 7.6
	4	--	--	--	3.8	--
	5	--	--	0.0	0.0	0.0
03	1	0.05*	0.03	8.3	22.7	+14.4
	2	0.04	--	6.3	16.5	+10.2
	3	ND	ND	7.1	0.0	- 7.1
	4	0.24*	--	5.8	61.8	+56.0
	5	0.05*	0.002	28.4	49.1	+20.7
04	1	0.02	0.002	7.7	13.8	+ 6.1
	2	ND	--	20.8	4.8	-16.0
	3	ND	ND	4.9	13.0	+ 8.1
	4	0.004	--	14.0	10.6	- 3.4
	5	0.01	ND	7.6	--	--
05	1	0.05*	0.002	4.4	18.5	+14.1
	2	--	--	--	--	--
	3	0.05*	ND	3.3	--	--
	4	ND	--	54.8	--	--
	5	--	--	--	--	--

* = Equalled or exceeded the ACGIH TLV
1 = Measured using a personal air sampling device
2 = Urine cobalt level is corrected using urine creatinine
ND = Non-detectable level

APPENDIX 1

INSTRUCTIONS FOR URINE COLLECTION

Thank you for participating in the National Institute for Occupational Safety and Health's study of urine cobalt levels at United Technologies Diesel System, Springfield, Massachusetts. The following instructions for urine collection may seem unusual, but they are necessary to prevent dust from getting into the urine sample from work clothes, skin, and hair.

INSTRUCTIONS:

1. Place the paper hat provided for you over your hair. If you have beard an additional paper cover will be given to you.
2. Wash your hands, arms and face thoroughly.
3. In the restroom, remove your shirt or blouse and put on the paper garment provided for you.
4. Lower trousers and undergarments below the level of the collection jar.
5. After doing this, clean hands again with a wipe which will be given to you.
6. Open collection cup without touching the inside of the lid or jar.
7. Collect urine specimen and immediately place the lid on the jar.