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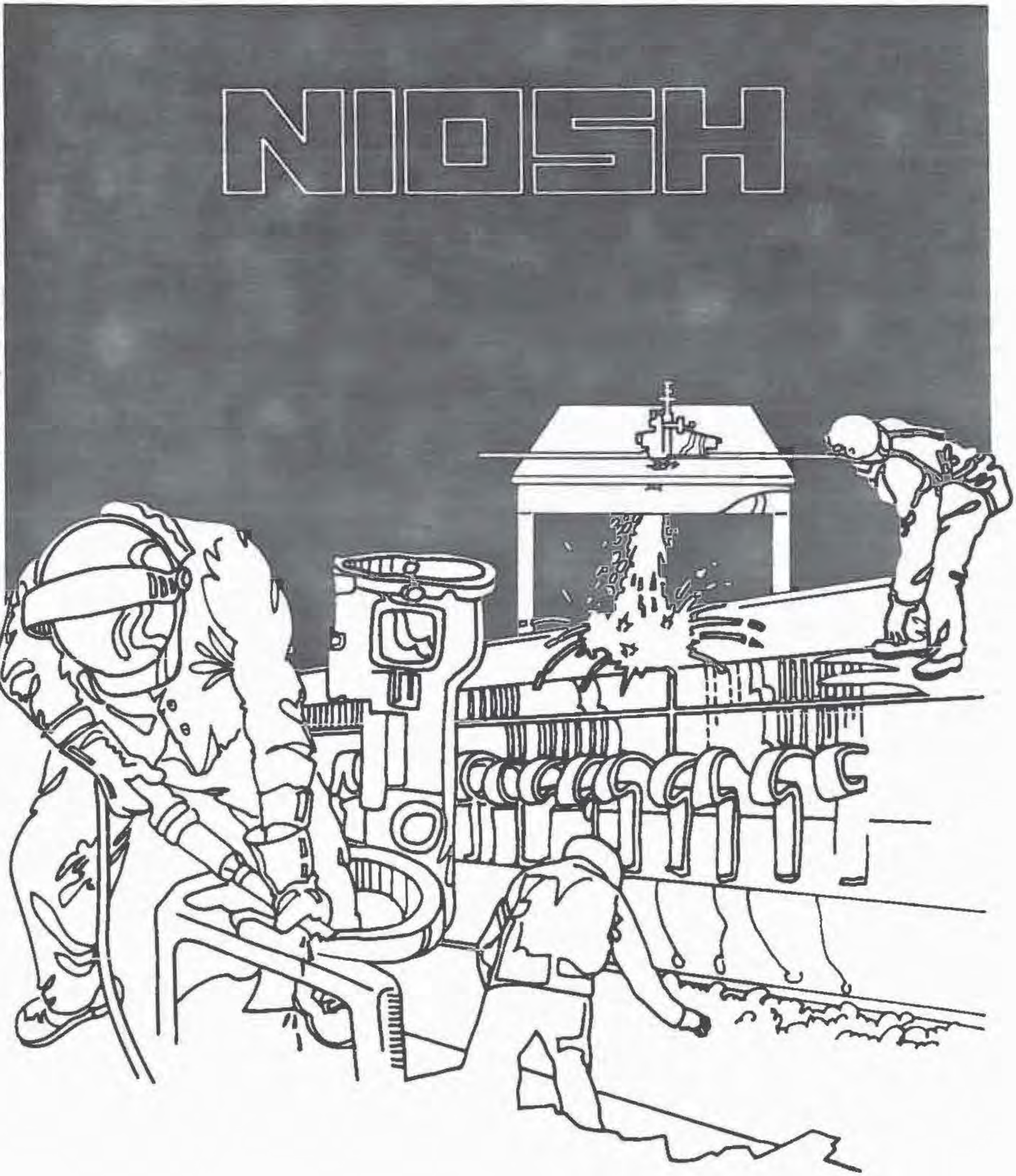

Health Hazard Evaluation Report

HETA 85-295-1907
GENERAL ELECTRIC
CARBOLOY SYSTEMS
DETROIT, MICHIGAN

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.

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

HETA 85-295-1907
JUNE 1988
GENERAL ELECTRIC CARBOLOY SYSTEMS
DETROIT, MICHIGAN

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I. SUMMARY

On April 3, 1985, the National Institute for Occupational Safety and Health (NIOSH) received a request from the International Union, United Automobile, Aerospace and Agricultural Implement Workers of America - U.A.W., Local 771, to investigate the exposure to, and the potential health effects of, dusts generated during manufacture of tools and components containing tungsten carbide at the General Electric (GE) Carboloy Systems plant in Warren, Michigan.

During the week of August 25, 1986, an environmental and medical survey was performed of workers in buildings 1, 6, 7, 11, and the Custom Carbide Products Operations (CCPO, buildings 2, 3, 4, and 5). Manufacturing operations at GE Carboloy were in part selected by using historical industrial hygiene data, provided by GE, which indicated the greatest potential for employee exposure to cobalt and other toxic materials. Personal breathing zone air samples for cobalt (Co) and total and respirable dust were obtained on 28 potentially exposed employees in these areas. Time weighted average (TWA) cobalt concentrations from total dust ranged from not detectable (ND) to 145 micrograms per cubic meter (ug/m^3). Cobalt concentrations from respirable dust ranged from ND to 16 ug/m^3. The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV®) for Co is 50 ug/m^3, 8-hour time weighted average (TWA). The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for Co is 100 ug/m^3. While there is no NIOSH recommended exposure limit (REL) for Co, NIOSH does recommend an action level of 50 ug/m^3 for cemented tungsten carbide dust containing more than 2% Co.

Respirable dust concentrations ranged from 0.01 to 0.96 mg/m^3, levels below the OSHA PEL of 5 mg/m^3. Total dust levels ranged from 0.07 to 1.99 mg/m^3, again below the OSHA PEL of 15 mg/m^3. It should be noted, however, that nuisance dust exposure limits (whether total or respirable) are not the most appropriate criteria to use in this evaluation since other contaminants, with lower exposure limits (most notably Co), were identified in the dust samples.

Chromium (Cr) concentrations (no distinction made on its valence state or solubility) ranged from ND to 17 ug/m^3. All values are expressed as TWA's over the period sampled. ACGIH has adopted an 8-hour TLV TWA of 500 ug/m^3 for trivalent (+3) Cr, whereas the OSHA PEL for Cr metal and insoluble salts is 1000 ug/m^3. The NIOSH REL for carcinogenic hexavalent (+6) Cr compounds is 1.0 ug/m^3. NIOSH also recommends a standard of 25 ug/m^3 for non-carcinogenic hexavalent Cr compounds, along with a 15-minute ceiling level of 50 ug/m^3.

A self-administered questionnaire, given to the 23 employees involved in the personal air sampling and biological monitoring portion of this study, identified only non-specific respiratory complaints. Blood tests for thyroid function, serum creatinine, and complete blood count were normal in all 23 workers tested. Participants with cobalt in their blood did not have higher potential airborne exposures (mean concentration 34 ug/m^3) than those without detectable blood cobalt (mean concentration 84 ug/m^3).

The most recent chest x-ray for 54 employees was reviewed by 2 radiologists using the standard international system for identifying pneumoconiosis. None of the films indicated the presence of any occupational pneumoconioses.

A total of 149 urine specimens were collected from 24 participants. At most, seven specimens were collected from each person: pre-shift on August 25 to 28 (Day 1 to Day 4) and post-shift on August 25 to 27, 1986. The limit of detection for Co was 3.4 micrograms per liter (ug/l). Increase in urine Co concentrations over each workshift averaged 7.87 ug/l on Day 1, 8.37 ug/l on Day 2, and 5.46 ug/l on Day 3. The increase in urine concentration over each shift was statistically significant.

The increase in urine Co concentrations over the workshift was correlated with workplace exposures. In this evaluation, the shift change in urine Co concentration, together with the use of a respirator, explained 60% of the variance in the observed airborne cobalt exposures. This suggests that measurements of urine Co concentration can be used as an indicator of daily airborne cobalt exposures, at least within the range of exposures encoumtered.

Based on these environmental and medical results, a hazard from airborne exposure to cobalt exists among workers in Building 6. Furthermore, the urinary excretion of cobalt appears to be directly related to the airborne concentrations. Recommendations pertaining to the respiratory protection program are included in Section IX.

Key Words: SIC 3369 (Nonferrous Foundries (Castings)), tungsten carbide, metal dust, cobalt, respiratory effects, hard metals disease, nickel, iron, pulmonary function tests.

II. INTRODUCTION.

On April 3, 1985, NIOSH received a request from the International Union, United Automobile, Aerospace and Agricultural Implement Workers of America - U.A.W., Local 771, to investigate exposures to, and the potential related health effects of, dusts generated during manufacture of tools and components containing tungsten carbide at the General Electric (GE) Carboloy Systems plant in Warren, Michigan.

An initial site visit was conducted by NIOSH on July 1, 1985. A follow-up site visit, made on March 17, 1986, included a comprehensive site inspection, interviews with employees from buildings 1, 6, 7, 11, and the CCPO areas, and a review of environmental and medical records. NIOSH investigators returned on August 24-28, 1986 to conduct 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, and personal air sampling for metals and respirable and total dust fractions.

III. BACKGROUND.

GE Carboloy Systems, a 550,000 square foot facility located near Detroit, Michigan, manufactures 14,000 different tungsten carbide and steel products ranging in size from one gram to 1,000 kilograms (kg). The workforce, at the time of the initial walkthrough, consisted of 450 bargaining unit employees and approximately 200 management employees The 275 day, 125 evening, and 50 night shift hourly workforce work a five-day week and do not rotate shifts.

Tungsten carbide products, which account for approximately 80% of the plant's output, include inserts, dies, bar stock (blanks), tooling products, and speciality components and contain tungsten carbide, Co, titanium carbide, or a combination of these materials. Different carbide grades (recipes), containing from 3 to 25% Co, may be used; the average Co content is 8%. One grade contained nickel (Ni) and Cr but accounted for only 0.1% of total production. All containers, screens, and other handling equipment required cleaning after every grade change to prevent cross contamination.

Extensive industrial hygiene sampling was begun by GE Carboloy in the 1970's, evaluating worker exposures throughout the facility. Personal and area air samples, collected annually, monitored exposures to Co, tungsten, Ni, Cr, total dust, titanium, silver, sodium hydroxide, ethanolamine, and triethanolamine. Approximately 760 personal and area air sample results, dating from 1977 to 1985, were reviewed prior to this evaluation. While there was a reduction in personal cobalt exposures over this time period, several personal samples collected during this period exceeded the ACGIH TLV-TWA for cobalt of 50 ug/m^3. According to GE, each employee received a copy of the annual air sampling results.

This IH data was used by GE Carboloy to establish 17 primary exposure zones. These zones, listed below, cover all plant operations and the potential for exposure to a variety of toxic materials.

ZONE	PRIMARY MATERIALS
1	Cobalt, TWA > 100 ug/m^3.
2	Cobalt, TWA < 100 ug/m^3 but > 50 ug/m^3.
3	Cobalt, TWA < 50 ug/m^3 but > 25 ug/m^3.
4	Cobalt, TWA < 25 ug/m^3 but > 10 ug/m^3.
5	Cobalt, TWA < 10 ug/m^3.
6	Metal particulate, oil mist.
7	Brazing/welding fume and particulates.
8	Solvents.
9	Heat stress and cobalt.
10	Hydrochloric acid.
11	Heat stress, numerous metals, forming sand, wax, ethanol, formaldehyde.
12	Maintenance, building six.
13	Maintenance, building one.
14	Maintenance, plant wide.
15	Laboratories-exposure to numerous materials.
16	Minimal exposures to any materials.
17	No known industrial exposure.

The production of finished tungsten carbide products may involve up to five steps, depending on the specific carbide item being manufactured. The following is a brief description of these five manufacturing stages:

1. Powders. The initial stage, the finely divided tungsten carbide powder, plus any additional ingredients (such as Co, Ni, etc.) are screened (sized), milled, coated with wax (to facilitate initial shaping), dried, granulated, and then pressed into the appropriate shape.

2. Consolidation. Shaped carbide parts receive additional forming (grinding, cut-off, angling) and then are pre-sintered. Pre-sintering removes the wax, leaving the carbide part with a consistency resembling chalk. On some items, pre-sintering completes the manufacturing process and the product is shipped to the end user.

3. Sintering. Carbide parts are fully hardened by sintering in automatically controlled furnaces. Hot isostatic pressing

(combining high pressure and temperature) is also performed on larger carbide components to achieve uniform density and a fine finish.

4. Honing. Sintered (hardened) parts receive final grinding (both wet and dry) using both automatic and manually operated machines.

5. Chemical vapor deposition. Used to impart greater wear resistance, carbide parts (usually inserts) are cleaned (sandblasted), then placed in enclosed, pressurized vessels for coating. Coating materials include aluminum trioxide, titanium tetrachloride, and zirconium dioxide.

A major part of a five year process modernization plan at GE Carboloy includes an automatic carbide powder weighing system. Once completed, the processes of powder weighing, milling, screening, and spray drying, currently performed in separate stages under local exhaust ventilation (LEV), will instead be done in enclosed vessels. This remotely operated powder weighing and processing system was not yet operational during the NIOSH survey.

Medical facilities include a two bed infirmary and two examination rooms. The medical staff at the plant includes two registered nurses and one physician. Pre-employment examinations are given and annual check-ups offered to manufacturing employees every third year for office and non-manufacturing workers). These annual physicals include a work history, pulmonary function tests and pulmonary questionnaires, audiograms, routine urinalysis, complete blood count, biochemical screen, and respirator surveillance (offering medical opinion as to fitness and test respirator fit). Chest x-rays are offered annually to employees 45 years and older, less frequently to younger workers. In addition, electrocardiograms are offered to employees 30 years and older (or when indicated).

IV. EVALUATION DESIGN AND METHODS

A. Environmental

The environmental assessment of employees working in buildings 1, 6, 7, 11, and the CCPO areas (buildings 2, 3, 4, and 5) performed on August 25 to 28, 1986, was designed to identify employee overexposures to Co and other metals and to determine the correlation of employee pre- and post-shift urinary Co concentrations (discussed in the next section) with corresponding air concentrations of total and respirable cobalt dust measured by personal sampling during the same shift. These buildings were selected according to current manufacturing activities and by historical industrial hygiene data, provided by GE Carboloy, which optimum collection efficiency for dust particles smaller than 10 microns in diameter. Full-shift total dust sampling, using NIOSH Method 500, used a flow rate of 2.0 lpm.[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% 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.[1]

B. Medical

On August 19 and 22, 1986, twenty-five workers were enrolled in the study. The study was conducted from August 25 to 28, 1986. Twenty-three employees took part in the complete evaluation.

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, indicators of thyroid function, serum concentrations of creatinine and urea nitrogen, and complete blood cell counts. Cobalt, in high concentrations, is known to have adverse effects on the lungs, heart, thyroid, skin, and blood producing system.

Pre- and post-shift urine samples were collected daily during the study period and analyzed for cobalt and creatinine. Urine specimens were collected, after handwashing, in a manner to minimize specimen contamination. Laboratory and field blanks were collected daily and processed identically to the urine samples. Specific gravity was determined and urines were preserved and frozen within 2 to 4 hours after collection. They were then transported to the Centers for Disease Control, Center for Environmental Health, for analysis by a method adapted from one previously published.[2]

Company medical records of the participants and an equal number of other workers, randomly selected, were reviewed. This included an evaluation of pulmonary function tests (PFT's) and chest x-rays. Pulmonary function tests had been offered to employees on an annual basis and the tests were carried out using a standardized protocol. Vital capacity (VC) and forced expiratory volume in one second (FEV_1) were compared to predicted values calculated by GE Carboloy health care providers. The determination of FEV_1 and VC used the greatest value from a set of 3 valid spirograms, regardless of the curve(s) on which they occurred.

All employees exposed to cobalt have an annual chest x-ray. We had the most recent chest x-ray for 54 workers (27 study participants and an equal number of other workers, randomly selected) evaluated by two radiologists, who were certified "B-readers", using the standard international method for classification of pneumoconioses.[3]

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 ACGIH TLV's, and 3) the U.S. Department of Labor (OSHA) PEL's. Often, the NIOSH REL's 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 standards, 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 AND TUNGSTEN CARBIDE

The ACGIH TLV-TWA for cobalt of 50 ug/m^3.[4] The OSHA permissible exposure limit (PEL) for cobalt is 100 ug/m^3.[5] Although NIOSH does not have a recommended exposure limit specifically for cobalt, NIOSH does recommend an action level of 50 ug/m^3 for cemented carbide dust which contains more than two percent cobalt.[6]

The production of tungsten carbide components creates potential exposures to a number of different metal dusts including cobalt, nickel, chromium, tungsten, and titanium. Cemented tungsten carbide is a unique metal commonly used in drills, saw blades and other cutting tools because its strength, rigidity, and resistance to extreme heat.[6] 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).[7]

The production of tungsten carbide requires the techniques of powdered metallurgy.[7] Finely divided (mean diameter 1.5 micron) tungsten and carbon powders are blended and then heated (in an inert atmosphere) to form tungsen carbide. At one time, GE Carboloy manufactured tungsten carbide, but has discontinued production and now purchases the material from an outside supplier. Cobalt is added in varying amounts (3% to 25%) to the tungsten carbide powder as a binding agent.[7]

Depending on the desired properties of the final product, other metal powders such as titanium carbide, tantalum carbide, chromium carbide, and Ni may be added.[7] Exposures to cobalt and other metal constituents may occur during the weighing and blending of the metal powders, cutting and grinding of the pre-sintered and fully hardened parts, and during the cleaning of maintenance of processing equipment. In addition, re-sharpening and repair of old tungsten carbide tools may also generate potential exposures.

Cobalt is a naturally occurring element in the environment. It forms an integral part of the cyanocobalanium molecule (vitamin B 12).[8] This vitamin is essential to the human diet to prevent the development of pernicious anemia (low red blood cell count).[8] The average U.S. daily cobalt intake from food, water and community air have been estimated to be 300 ug, 6 ug and 0.1 ug respectively.[9]

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 concentration of 100 to 200 ug/m^3. A common pattern of illness is described in these reports.[7,10-20] 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 (heart enlargement and failure due to the lung disease), leading ultimately to cardiorespiratory collapse and death.[8] The reported latency period from exposure to disease varies from a few years to 20 years.[8] It is unclear whether this variable latency is related to individual susceptibility or varying levels of exposure between studies.

A series of reports describe lung function test results among 155 Swedish cemented carbide workers and 74 controls matched for sex, age and smoking history.[21-23] Persons exposed to an average of 60 ug/m^3 airborne cobalt showed changes on pulmonary function tests, suggestive of obstructive disease, that did not regress over the weekend. Smokers were more affected than non-smokers.

Several investigators have suggested evidence of bronchitis among hard metal workers.[11-24] Asthma has been reported (11,12,25,26) as early as within one month after initial exposure.[25] 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.[27,28] Sjogren et.al. has reported three, non-smoking, hard metal workers, having symptoms and signs compatible with allergic alveolitis.[29] 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 (disease of the heart muscle). 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.[30-35] The signs and symptoms of affected individuals included abdominal pain, shortness of breath, lowered blood pressure, heart enlargement, pericardial effusion (fluid around the heart), tachycardia (rapid heart beat), and electrocardiographic (ECG) abnormalities. The amount of cobalt ingested daily by a 6 liter per day drinker was estimated to be about 5-10 milligrams per day (5,000 to 10,000 ug/day). 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.[36-44] Hypothyroidism and goiter has been associated with daily oral doses of 2-10 milligrams per kilogram of cobalt chloride administered over a 2-4 month period in a small percentage of people.[8] 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.[8]

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

"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 (45,46,47) provide suggestive evidence that at least some cobalt containing compounds may prove carcinogenic 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."[11]

CHROMIUM

Some chromium compounds can cause an allergic dermatitis in some workers, and acute exposure to chromium dust and mist may cause irritation of the eyes, nose, and throat.[48] Chromium exists as chromates in one of three valence states: 2+, 3+, and 6+. Chromium metal and its insoluble salts, representing the 2+ state, are considered to be relatively non-toxic.[48] Chromium compounds in the 3+ state are also of a low order of toxicity. In the 6+ state, however, chromium compounds are irritating, corrosive and are known to cause penetrating sores of the skin; ulceration and perforation of the nasal septum; inflamation of the mucous membrane; and may cause kidney or liver damage and tooth erosion and discoloration.[48] This hexavalent form may be carcinogenic or non-carcinoginic, depending on solubility. The less-soluble forms are considered carcinogenic.[49] Workers in the chromate-producing industry have been reported to have an increased risk of lung cancer.

ACGIH has adopted an 8-hour TLV TWA of 500 ug/m^3 for chromium (3+), whereas the OSHA PEL for chromium metal and insoluble salts is 1000 ug/m^3.[4,5] NIOSH's recommended standard for carcinogenic chromium

(6+) compounds is 1.0 ug/m^3.[49] NIOSH also recommends a standard of 25 ug/m^3 for non-carcinogenic hexavalent chromium compounds, along with a 15-minute ceiling level of 50 ug/m^3.

NICKEL

Nickel can exist in both soluble and insoluble forms. Epidemiologic evidence suggests that the hazard presented by insoluble nickel compounds is not as great as that presented by soluble forms.[50] Nickel has been reported to cause "nickel itch," an allergic dermatitis.[48] An increase in nasal, sinus, and lung cancer has been noted in workers employed in nickel refineries, although the specific carcinogenic agent is still not defined.[50] Metallic nickel introduced into the pleural cavity, muscle tissue, and subcutaneous tissue has been shown to be carcinogenic in test animals. NIOSH considers inorganic nickel to be a carcinogen and recommends personal exposures be kept below 15.0 ug/m^3 for a 10-hour TWA.[50]

VI. RESULTS AND DISCUSSION

A. Environmental

Personal sample Co concentrations, measured from total dust samples, ranged from not detectable (ND) to 145 ug/m^3 TWA; Co levels measured from respirable dust samples ranged from ND to 16 ug/m^3 TWA. The limit of detection (LOD) for Co from this sample set was 1.0 ug per filter. Tables I, II, and III present the sample results, expressed as TWA's over the period sampled, for total dust, respirable dust, and Co. Table IV shows the results of area air samples for total and respirable dust and Co collected during this evaluation.

Five personal samples had total Co levels exceeding the ACGIH TLV of 50 ug/m^3 during the study, and 3 of these 5 exceeded the OSHA PEL of 100 ug/m^3 for Co.[4,5] All sample results exceeding 50 ug/m^3 were from employees working in building 6, an area already documented in prior GE Carboloy industrial hygiene studies as having the highest overall personal exposures to Co. The highest personal air concentration, 145 ug/m^3, is approximately 3 times the ACGIH TLV. This employee wore a disposable dust respirator (3M Model 8710) while working. No Co concentrations from the respirable dust samples exceeded 50 ug/m^3.

Respirable dust concentrations from personal samples ranged from 0.01 to 0.96 mg/m^3, levels below the OSHA PEL of 5.0 mg/m^3 for respirable nuisance dust.[5] Total dust levels ranged from 0.07 to 1.99 mg/m^3, well below the OSHA PEL of 15 mg/m^3.[5] It should be noted, however, that nuisance dust exposure limits are not the appropriate criteria to use for these exposures since other contaminants, with lower exposure limits (most notably Co), were identified in these dust samples.

Chromium (no distinction on the valence state or solubility) ranged in concentration from ND to 17 ug/m^3. The Cr concentration of 17 ug/m^3 was from the worker with the highest personal Co concentration (ball mill operator) collected during this evaluation. ACGIH has adopted an 8-hour TLV of 500 ug/m^3 for Cr (+3), whereas the OSHA PEL for Cr metal and insoluble salts is 1000 ug/m^3.[4,5] The NIOSH REL for carcinogenic Cr (+6) compounds is 1.0 ug/m^3.[49] NIOSH also recommends a level of 25 ug/m^3 for non-carcinogenic hexavalent Cr compounds, along with a 15-minute ceiling level of 50 ug/m^3.

Nickel was not detected in any of the personal samples. NIOSH considers inorganic nickel to be a carcinogen and recommends exposures be kept below 15 ug/m^3 for a 10-hour TWA.[50]

B. Medical

1. Questionnaire Data

Eight machinists working in buildings 1-5, 12 workers from building 6, and 4 other workers participated in the medical evaluation. These results characterize the 23 workers that completed the questionnaire. All were male; 3 were black. The mean age was 45 years (range 31 to 62 years). Their mean duration of employment at GE Carboloy was 20.5 years (range 13 to 35 years). All participants denied previous work in shipyards, quarries, or workplaces with known exposures to beryllium, cadmium, cotton, flax, or hemp. Three reported to have worked near asbestos while operating furnaces at GE Carboloy, and 10 were involved in sandblasting operations at the facility for a short time. One worker had been involved in the manufacturing of fibrous glass products for an 8-month period.

Nine of the subjects were current smokers and, as a group, these nine averaged 30.9 pack-years of cigarettes. The 7 ex-smokers had smoked less, averaging 12.3 pack-years.

Since urine concentrations of Co could be influenced by inhalation and ingestion of cobalt dust, workers were asked about the use of respirators and whether they smoked or ate their meals at their work station. Eight workers indicated that they usually or always wore dust masks while working; 5 others wore them occasionally. The workers that usually wore respirators all worked in building 6, where exposure to tungsten carbide dust was highest. Six of the nine current smokers, including 3 from building 6, reported that they smoked at their work station. Two workers that smoked at their work station claimed to wear respirators while working. Five of the 23 workers, including 3 from building 6, reported regularly eating lunch at their work station.

Respiratory symptoms were reported by 13 (57%) of the participants. Five reported a frequent morning cough, and 2 also had a productive cough throughout the day. Nine workers complained of occasional wheezing that was not related to colds. Another 2 workers reportedly had symptoms of wheezing on a daily basis, but only 1 of these workers indicated that he had been diagnosed with work-related asthma. Another worker had been diagnosed with chronic bronchitis by a physician.

2. Blood Tests

The Co concentration for 18 of the blood samples was below the limit of detection (0.20 micrograms per deciliter (ug/dl)). The remaining 5 blood Co concentrations ranged from 0.21 ug/dl to 0.33 ug/dl. Using a similar method, others have reported blood Co levels ranging between 0.57 ug/dl and 0.79 ug/dl in workers exposed to air levels of 100 ug/m^3.[47] Another study found mean blood cobalt levels of 1.05 and 0.07 ug/dl in workers exposed to air cobalt levels of 90 and 10 ug/m^3, respectively.[47] In this NIOSH investigation, the average potential exposure to airborne cobalt for workers with detectable levels of cobalt in their blood was 34 ug/m^3, compared to 84 ug/m^3 for those workers without detectable blood cobalt levels. From these results, there does not appear to be a correlation between air cobalt exposures and blood cobalt levels in this study.

Thyroid function tests, complete blood counts (CBC), and serum creatinine showed no significant abnormalities in any of 23 workers tested. One worker had an elevated blood urea nitrogen (BUN) of 28 milligrams per deciliter (mg/dl) ("normal" range: 6.0 to 23.0 mg/dl), but the serum creatinine (a more specific indicator of kidney function) was normal.

3. Pulmonary Function Test Data

The pulmonary function tests of 54 employees, 27 initially volunteering for participation and 27 others randomly selected, were evaluated for obstructive and restrictive patterns. A decreased lung volume in the absence of pulmonary obstruction is labeled "restrictive". It may be the consequence of pneumoconiosis, connective tissue disease, an infiltrating tumor, inflammatory exudates, chest wall deformities, or respiratory muscle weakness. Obstruction to air flow in the bronchial tree is seen in emphysema, bronchitis, and, intermittently, in asthma. Cigarette smoking is a common cause of emphysema and bronchitis. For this study, the PFTs were analyzed for airways obstruction and restriction using two epidemiologic methods.

This study did not attempt to correlate PFT results with exposure to cobalt. Half of the participants were self-selected and do not comprise a representative sample of the workers. Rather, the purpose was to appraise the quality of the PFT data to determine if an in depth evaluation could be recommended.

a. Cross-sectional Pulmonary Function Tests

The most recent VC and FEV_1 had been compared to a value predicted from the worker's age, race, and height. For purposes of this study, a FEV_1 or VC less than 80% of the predicted value, or an FEV_1/VC ratio less than 70% of the VC, is considered "abnormal".[51] PFT data for 54 employees of GE Carboloy are given in Table V.

Nine workers had a PFT value below predicted on their most recent test. Three workers had a restrictive lung pattern, 5 had an obstructive pattern, and 1 had a mixed obstructive/restrictive pattern.

One worker with a restrictive pattern had a relatively stable VC until 1983, when there was an 11% decrease from the year before. The same reduced VC was present again in 1985. No symptoms or findings were reported in this worker's medical record. In 1986, the VC for a second worker was 79% of the predicted value. It had been declining since 1981 from 4.45 liters (L) to the 1986 value of 3.95 L, an 11% decline in 5 years (about 3% would be expected on the basis of age alone).[52] No symptoms or findings were reported in this worker's medical record. Of the remaining 2 workers with a restrictive pattern, one was diagnosed as having acute bronchitis at the time of his PFT; earlier PFTs were normal. The other, a heavy smoker with a mixed obstructive/restrictive pattern, has had relatively little change in VC since 1973, when it was 72% of predicted.

Of the 5 workers with an obstructive pattern, 2 were heavy smokers. Another, a light smoker, had been diagnosed with chronic bronchitis in 1952. No documentation of an obstructive pattern, or symptoms related to an obstructive disorder, was noted on the medical records of the remaining 2 workers.

b. Comparison Of Pulmonary Function Tests Over Time

Comparing a person's observed value with previously recorded values has been advocated to improve the sensitivity of spirometry without losing specificity.[51] The reason for this is that the variation in these tests for an individual is less than the variation in a population of like individuals. It also enables the researcher or clinician to use the person as his/her own control. There remain some problems with this method however. Few studies have been conducted, and this makes interpretations of these data difficult since few standards exist for comparison.

The approach we used was to first examine the original PFT tracings to determine the accuracy of the recorded parameters. The review identified three potential sources of error to be considered when evaluating these data:

i. The FEV_1 was measured from the time of onset of expiration, i.e. the back-extrapolation method was not used. The company's method for measuring FEV_1 will yield values close to those that would be obtained using back-extrapolation if the curves take off abruptly. Larger discrepencies will appear if the curves have slow take-offs.

ii. Some of the initial graphs before 1974 were not available, and the chart speeds for those that were seemed quite slow. Slow chart speeds cause measurements of the FEV_1 to be less accurate than faster chart speeds.

iii. The Jones spirometer used for testing assumes a 25°C (77°) room temperature and records volumes that are corrected to body temperature (BTPS). Thus, the ambient temperature was assumed to be constant and close to 25°C during the tests.

At the present time, the most widely used method for assessing rate of change over time in the FEV_1 and VC is the calculation of a regression of these parameters over calender time. The slope (beta) in milliliters per year (ml/yr) is used to quantify the rate of loss of lung function over time.[51]

Appendices I and II provide the Y-intercept, beta coefficient, standard error, and annual percent decline per year. Additionally, a statistical test of the slope of these regression curves compared to that expected due to age alone is included. The expected decline due to age for both FEV_1 and VC was 30 ml/yr.[52] These parameters can be interpreted in the following manner:

i. The regression analysis assumes that the change in both FEV_1 and VC is a linear function of time and fits a line through the observed data points for each individual.

ii. The age of the individual has not been included in the model, nor has smoking status.

iii. The Y-intercept is the point on the fitted line which represents FEV_1 or VC in 1974, the first year for which data was judged to be of sufficient quality to include in these analyses.

iv. The beta coefficient represents the slope of the fitted line and can be interpreted as the average annual change in liters per year for each parameter.

v. The standard error of this coefficient is a measure of the variation between each observed data point from the fitted regression line.

The average annual decline in FEV_1 for the 54 GE Carboloy workers was 25 ml/yr. This represents an average annual decline of 0.65% for each worker and a 7.8% decline in FEV_1 from 1974-1986. Five workers (13, 22, 35, 37, and 42) had an annual decline in excess of 60 ml/yr; this is twice the expected decline of 30 ml/yr due to aging.

Current smokers had the greatest average percent decline in FEV_1. On average, each smoker lost 0.8 +/- 0.86 % per year in FEV_1. Ex-smokers lost on average 0.45 +/- 0.65 % per year, and non-smokers lost 0.69 +/- 0.61 % per year of FEV_1.

The 54 employees experienced an average decline in VC of 19.6 ml per year. On the average, each worker lost 4.2% of VC during the 12 years from 1974-1986. The 3 workers whose most recent VC was below 80% of its predicted value declined an average of 47 ml per year, or 11.8 % in 12 years.

4. Chest X-rays

None of the 54 chest x-rays had any signs of pneumoconioses.

5. Urine Cobalt Measurements

A total of 149 urine specimens were collected from 24 participants. At most, seven specimens were collected from each person: pre-shift on Monday through Thursday, and post-shift Monday through Wednesday. Seven lab blanks and 7 field blanks were also analyzed. The limit of detection for Co was 3.4 micrograms per liter (ug/l). One lab blank contained 4.9 ug/l; the remaining lab blanks and the field blanks had no detectable Co.

Table VI presents the shift change in urine cobalt concentrations by work area. The work areas have been categorized into grinding or machining operations in buildings 1 through 5, employees in building 6 who were not wearing respirators, employees in building 6 wearing respirators, and 4 other workers in low exposure areas. Airborne exposure to cobalt was reflected in the measured urinary excretion of cobalt.

Personal air cobalt results were compared with pre- and post-shift urine cobalt measurements during the same period. Air and urine samples were collected for three consecutive days, August 25 to 27, 1986 (referred to as Day 1, Day 2, and Day 3 in the remainder of this section). An additional pre-shift urine sample was collected on August 28, 1986 (Day 4). Total cobalt, expressed in ug/m^3, 8-hour TWA, was used in this analysis. Urine samples were analyzed for cobalt, specific gravity, and creatinine.

The results of this evaluation are reported below. A number of questions were taken into consideration:

i. Was there a detectable difference in urine cobalt concentration from the beginning of the shift to the end of the shift, and if so, in what direction?

ii. Did urine cobalt concentrations change from the end of one shift to the beginning of the next? If so, did these pre-shift urine cobalt concentrations return to the pre-shift concentrations of the previous day?

iii. Did the average shift change urine Co concentrations differ between the three days? Similarly, did average airborne Co exposures differ from one day to the next?

iv. Was creatinine adjustment useful in adjusting the urine cobalt data for differences in urine concentration?

v. What was the correlation between the personal air samples and urine cobalt concentrations? Was the correlation affected by the use of a particulate dust mask?

The means, standard deviations, and ranges for total airborne cobalt exposure, pre- and post-shift urine cobalt concentrations, and adjusted pre- and post-shift urine cobalt concentrations are given in Table VII. On each day, the post-shift urine cobalt means were higher than the pre-shift means. The post-shift urine cobalt means were also higher than the subsequent pre-shift means of the next day, indicating that urine cobalt concentrations tended to return towards a baseline within sixteen hours.

The results of the adjusted and unadjusted values differ slightly. Due to the small volume of urine collected from a few of the participants, creatinine determinations were not possible for seven of the samples. This resulted in an overall loss of sample size for the adjusted data. Because of this loss, the unadjusted urine Co data were used in the analysis.

The changes in urine Co concentrations were tested with a students' t-test.[53] The repeated measurements on each day were accounted for by testing the absolute difference between urine cobalt concentration for each participant. The means of the differences in urine cobalt concentration over the shift (post-shift Day 1 - pre-shift Day 1) and from one morning to the next (pre-shift Day 2 - pre-shift Day 1) were compared with the null hypothesis of no change. The results appear in Table VIII.

The means of the differences in urine Co concentrations from one pre-shift measurement to the pre-shift measurement of the day before were very small. On the average, the pre-shift measurements for Day 2 were slightly higher than for Day 1 (1.73 ug/l). The average of the differences between preshift urine concentrations on Day 3 and Day 2 was similar (1.12 ug/l). Preshift urine concentrations on Day 4 were, on average, lower than on Day 3 (-2.10 ug/l). None of these differences was statistically significant. It would appear that urine Co concentrations at the beginning of each work day were not affected by workplace exposures encountered the previous day.

Increase in urine Co concentrations over each workshift averaged 7.87 ug/l on Day 1, 8.37 ug/l on Day 2, and 5.46 ug/l on Day 3. With the exception of Day 2, when the shift change values varied widely, the increase in urine concentration over each shift was statistically significant. This implies that urine Co concentrations are affected by workplace exposures, and that these changes were detectable by the end of the work day.

In the next step, the differences between the average daily shift change in urine Co concentration, and differences in the average daily airborne Co exposures, were tested using a one-way analysis of variance (ANOVA). Since airborne Co exposure data were not normally distributed, airborne Co values were transformed to natural log values and are reported in this form. The average change in urine Co concentration did not differ statistically from one day to the next ($F_{2,57}$ df= 0.15; p= 0.86). Similarly, there were no statistically significant differences seen between the average daily log airborne cobalt exposures ($F_{2,64}$ df= 0.20; p=0.82). As a group, the GE workers' exposures to Co did not differ significantly during the three days of this evaluation, nor did their average shift change in urine Co concentration.

Table IX lists the Pearson correlation coefficients (PCC) for airborne cobalt exposures and changes in urine Co concentration for each day. Without regard to the use of a particle dust mask, the PCC for Day 1 to Day 3 are quite similar (0.611, 0.451, and 0.574 respectively), and all are statistically significant. The relationship is similar when the workers that wore a dust mask are removed from the analysis (Table IX, part B). However, on Day 2 the PCC decreased from 0.451 to 0.275 and is no longer statistically significant. For the 5 workers who wore a dust mask, the PCC increased on Day 2 and Day 3 to 0.976 and 0.937 respectively.

The data were then fit into a regression model to predict airborne Co exposure based on the shift change in urine Co concentration and the use of a particle dust mask. Day of the week was not considered in the analysis since there were no obvious day-to-day differences in the study group's airborne exposures, shift changes in urine Co concentration, or pre-shift urine Co values. Justification for this is strengthened by the relatively consistent PCCs seen in Table IX. The resulting regression analysis considered the 59 paired observations of airborne Co and change in urine Co as independent of each other.

The regression analysis included 59 observations, 19 from Day 1, 21 from Day 2 and 19 from Day 3. Five workers in building 6, more heavily exposed than other workers, wore a dust mask each day. As a result, 44 of the observations did not involve the use of a dust mask, while 15 observations did. The following equation describes the model:

$$\log_e \text{TCO8TW ug/m}^3 = A + B_1(\text{Urine shift change, ug/l}) + B_2(\text{MASK})$$

Where:

TCO8TW =Total airborne Co exposure measured as ug/m^3 per 8 hour time-weighted average.

And:

MASK = 0 when no dust mask was worn, or

1 when a particle dust mask was worn.

$A = 0.9664$
$B_1 = 0.0216$
$B_2 = 2.3384$

The overall model was highly significant ($p<0.0001$) and had an R^2 of 0.598. In other words, the shift change in urine Co concentration, together with the use of a dust mask, explains 60% of the variance in the observed airborne cobalt exposures, and this relationship is not likely to have been the result of chance. The coefficients of the two predictors were both statistically significant:

Variable	Parameter estimate	Standard error	T	p
A	0.966421	0.152843	6.323	0.0001
B_1	0.021572	0.007429	2.904	0.0053
B_2	2.333836	0.305327	7.644	0.0001

Thus, a person who has not been wearing a dust mask, and has had a shift change in urine Co concentration of 168 ug/l, would be predicted to have had an 8-hour TWA exposure to total airborne cobalt of 100 ug/m^3 (the OSHA PEL). If the same individual had been wearing a dust mask, this increase in urine Co would indicate an exposure of 1036 ug/m^3. The equation predicts that a urine Co shift change of 60.2 ug/l in a worker who has been wearing a mask would indicate an exposure of 100 ug/m^3. These estimates must be interpreted with caution since the air values have been extrapolated from the data and the confidence intervals surrounding these estimates are extremely broad.

VII. CONCLUSIONS

Based on these results, a hazard from airborne exposure to cobalt exists among some employees in building 6. The process modernization plan underway at this GE plant, however, should significantly reduce exposures to cobalt (and other metals) in building 6. This remotely operated system, which was not yet fully operational during our evaluation, will perform operations such as powder weighing, milling, screening, and spray drying, in enclosed vessels. These material handling operations are currently performed manually, in separate stages, under local exhaust ventilation. As evidenced by the results of the sampling conducted in this evaluation, overexposures to cobalt among workers in these areas can still occur.

The results of this study suggest that measurements of urine Co concentration may be useful as an indicator of daily airborne cobalt exposures, at least within the range of exposures encountered. At these exposure levels, urine Co concentrations returned to a baseline within the 16 hours between shifts. Under these conditions, urine Co is therefore more appropriately a reflection of acute, rather than chronic, exposure to Co. Finally, the use of a respirator must be considered when using urine Co concentrations as an estimate of airborne Co exposure.

Before changes in urine Co concentrations can be used with a great deal of accuracy more data need to be collected. This is especially true for workers who do not wear masks and are exposed to moderately high levels of cobalt. In this study, the greatest exposure to those who did not wear a particle mask was 24.6 ug/m^3. For those who wore masks, 3 results were below 24.6 ug/m^3. The average Co exposure for all workers in this study who wore respirators was 55.5 +/-49.9 ug/m^3. As a result, there are no data points in this study that correspond with high exposures and a lack of respiratory protection.

Although 3 potential sources of error were identified, the PFT's conducted by GE Carboloy since 1974 were thought to be reliable. Workers with restrictive or obstructive findings were generally referred for follow-up treatment. However, two of the 54 workers had a decrease in FVC which had not been noted in their medical record. Both workers were asymptomatic. Workers with a decrease in FVC or FEV_1 should be evaluated for pulmonary disease.

The extensive PFT data assembled by GE Carboloy represents a valuable resource for further research. Such a study should include a reconstruction of cobalt exposures by job description and task. This exposure matrix could then be utilized to compare past exposures with longitudinal changes in pulmonary function parameters.

VIII. RECOMMENDATIONS

1. Single-use (disposable) respirators, such as the 3M Model 8710 half-mask respirators used by building 6 employees, should be replaced by half-mask or full-face non-disposable respirators until such time as engineering controls are implemented to reduce employee exposures below the ACGIH TLV for Co of 50 ug/m^3, 8-hour TWA. NIOSH does not recommend single-use respirators for protection against cobalt.[6]

2. The GE Carboloy respiratory protection program should comply with the guidelines found in DHEW (NIOSH) Publication No. 76-189, "A Guide to Industrial Respiratory Protection," and the General Industry Occupational Safety and Health Standards, OSHA (29 CFR Part 1910.134). NIOSH investigators observed several building 6 employees with facial hair wearing disposable half-face, negative pressure dust respirators in areas where concentrations exceeded the ACGIH TLV for cobalt. A proper respirator face-piece to face seal may not be established if there is facial hair (beard and/or sideburns) in the sealing area.

3. Since materials may be ingested, employees should not be permitted to smoke or to consume food and beverages at their workstations if there are toxic materials present. Employees were observed smoking, eating, and drinking at their workstations in buildings 1 and 6. Eating, drinking, and smoking should be restricted to break or lunch rooms which are separate from production areas and have easy access to wash facilities. Workers should be encouraged to wash prior to eating, drinking, or smoking.

4. The empty eye wash bottle, part of an eye wash station located north of column 38L in building 6, should be removed. Furthermore, all similar eye-wash bottles throughout the plant should be removed since they are unlikely to provide sufficient water flow and can become contaminated after long periods of disuse.

5. Pneumoconiosis in workers exposed to Co is a severe and debilitating disease. Early recognition and removal of the worker from further exposure is warranted. It is recommended that any worker with a PFT indicating a decrease in vital capacity should be notified and evaluated for the early onset of this condition.

6. The pulmonary function test data collected by GE Carboloy should be analyzed to characterize trends in FEV_1 and FVC over time. This data provides an unique opportunity to correlate lifetime exposure data (to airborne cobalt) with 14 year changes in PFT's. The results of this work may prove useful for early identification of workers with heavy-metal disease. Pulmonary function testing equipment and procedures should conform to the American Thoracic Society's recommendations.[54]

7. As evidenced by the results of the air sampling conducted in this evaluation, overexposures to cobalt among workers in operations such as powder weighing, milling, screening, and spray drying still occur. The modernization underway at this GE plant, once completed, has the potential to significantly reduce employee exposure to cobalt and other toxic materials in building 6. It is recommended that this remotely operated system, when operational, be thoroughly evaluated to determine the extent of employee exposures to cobalt, chromium, and other toxic materials.

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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. General Electric Carboloy Systems, Warren, MI.
2. United Auto Workers Local 771, Detroit, MI.
3. The National Institute for Occupational Safety and Health (NIOSH) Cincinnati Region.
4. The Occupational Safety and Health Administration (OSHA) Region V.

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

General Electric Carbology Systems
Detroit, Michigan
HETA 85-295

August 25, 1986

				CONCENTRATION[a]			
ID[b]	BLDG	JOB	SAMPLE TIME (MIN)	TOTAL DUST[c] mg/m^3	COBALT[d] ug/m^3	RESP. DUST[c] mg/m^3	COBALT[e] ug/m^3
22	1	GE SPINDLES	506	0.32	2	0.14	ND
21	1	AGATHON	487	0.41	3	0.13	ND
17	1	AGATHON	498	0.39	3	0.23	ND
19	1	WIT O MATIC	505	0.33	2	0.13	ND
18	1	AGATHON	490	0.29	2	0.13	ND
5	1	CLEAN UP	384	0.29	ND	0.08	ND
23	1	TIP WASHER	493	0.10	ND	0.11	ND
20	1	WIT O MATIC	483	0.12	ND	0.06	ND
2	3	MILLING	522	0.34	9	0.08	ND
3	3	SOFT GRINDER	NS	NS	NS	NS	NS
1	3	MILLING	452	0.18	2	0.08	ND
13	6	METAL PROCESSER	469	0.61	64*	0.08	5
9	6	POWDER	466	0.75	48	0.06	ND
14	6	METAL PROCESS B	502	0.27	14	0.07	ND
8	6	PRESS ROOM 2	481	0.46	19	0.07	ND
16	6	POWDER WEIGHER	NS	NS	NS	NS	NS
7	6	PRESS ROOM 1	523	0.16	7	0.06	ND
11	6	BALL MILL OPER	NS	NS	NS	NS	NS
15	6	METAL PROCESS B	469	0.54	22	0.06	ND
4	6	EXTRUSION	461	0.62	27	0.13	2
10	6	SPRAY DRIER	504	0.19	8	0.05	ND
12	6	PG ROOM	495	0.36	19	0.10	ND
25	6	METAL PROCESS B	471	0.45	6	0.18	ND
Evaluation Criteria:							
ACGIH				10	50	5	50
NIOSH				NONE	f	NONE	f
OSHA				15	100	5	100

For explanation of footnotes see page after Table III.

Table II

Personal Air Sampling Results for Total Dust, Respirable Dust, and Cobalt

General Electric Carboloy Systems
Detroit, Michigan
HETA 85-295

August 26, 1986

				CONCENTRATION[a]			
ID[b]	BLDG	JOB	SAMPLE TIME (MIN)	TOTAL DUST[c] mg/m^3	COBALT[d] ug/m^3	RESP. DUST[c] ug/m^3	COBALT[e] ug/m^3
22	1	GE SPINDLES	501	0.21	2	0.06	ND
21	1	AGATHON	484	0.22	2	0.15	ND
17	1	AGATHON	499	0.20	2	0.08	ND
19	1	WIT O MATIC	495	0.21	1	0.15	ND
18	1	AGATHON	459	0.13	ND	0.45	5
5	1	CLEAN UP	390	0.21	ND	0.03	ND
23	1	TIP WASHER	492	0.22	3	0.10	ND
20	1	WIT O MATIC	450	0.17	1	0.09	ND
2	3	MILLING	525	0.44	2	0.13	ND
3	3	SOFT GRINDER	519	0.20	2	0.14	ND
1	3	MILLING	486	0.24	5	0.08	ND
13	6	METAL PROCESSER	458	0.40	39	0.05	ND
9	6	POWDER	481	0.53	37	0.07	ND
14	6	METAL PROCESS B	487	0.36	16	0.08	ND
8	6	PRESS ROOM 2	483	0.28	8	0.06	ND
16	6	POWDER WEIGHER	472	0.64	28	0.19	1
7	6	PRESS ROOM 1	516	0.17	5	0.08	ND
11	6	BALL MILL OPER	402	1.99	116*	0.53	16
15	6	METAL PROCESS B	452	0.51	33	0.12	ND
4	6	EXTRUSION	485	0.67	4	0.13	ND
10	6	SPRAY DRIER	487	0.65	25	0.12	ND
12	6	PG ROOM	483	2.72	145*	0.11	2
25	6	METAL PROCESS B	483	0.61	4	0.19	ND
6	7	PRODUCTION	536	0.25	ND	0.10	ND

Evaluation Criteria:

ACGIH	10	50	5	50
NIOSH	NONE	f	NONE	f
OSHA	15	100	5	100

For explanation of footnotes see page after Table III.

Table III

Personal Air Sampling Results for Total Dust, Respirable Dust, and Cobalt

General Electric Carboloy Systems
Detroit, Michigan
HETA 85-295

August 27, 1986

ID[b]	BLDG	JOB	SAMPLE TIME (MIN)	CONCENTRATION[a] TOTAL DUST[c] mg/m³	COBALT[d] ug/m³	RESP. DUST[c] mg/m³	COBALT[e] ug/m³
22	1	GE SPINDLES	495	0.25	3	0.11	ND
21	1	AGATHON	486	0.29	4	0.11	2
17	1	AGATHON	501	0.19	3	0.07	2
19	1	WIT O MATIC	476	0.26	2	0.12	2
18	1	AGATHON	456	0.38	7	0.22	2
5	1	CLEAN UP	514	0.12	1	0.08	ND
23	1	TIP WASHER	492	0.36	5	0.05	ND
20	1	WIT O MATIC	452	0.18	3	0.07	ND
2	3	MILLING	532	0.24	5	0.13	ND
3	3	SOFT GRINDER	529	0.13	5	0.04	ND
1	3	MILLING	489	0.07	1	0.02	ND
13	6	METAL PROCESSER	NS	NS	NS	NS	NS
9	6	POWDER	479	1.09	61*	0.05	ND
14	6	METAL PROCESS B	437	0.16	11	0.01	ND
8	6	PRESS ROOM 2	508	0.51	25	0.08	ND
16	6	POWDER WEIGHER	NS	NS	NS	NS	NS
7	6	PRESS ROOM 1	510	0.13	5	0.02	ND
11	6	BALL MILL OPER	462	1.56	184*	0.27	15
15	6	METAL PROCESS B	446	0.46	27	0.04	ND
4	6	EXTRUSION	464	0.09	ND	0.96	4
10	6	SPRAY DRIER	451	0.33	18	0.01	ND
12	6	PG ROOM	377	0.62	41	0.06	ND
25	6	METAL PROCESS B	472	0.68	8	0.26	ND
6	7	PRODUCTION	534	0.15	ND	0.20	ND

Evaluation Criteria:

	TOTAL DUST mg/m³	COBALT ug/m³	RESP. DUST mg/m³	COBALT ug/m³
ACGIH	10	50	5	50
NIOSH	NONE	f	NONE	f
OSHA	15	100	5	100

For explanantion of footnotes see page after Table III.

Table IV

Area Air Sampling Results for Total Dust, Respirable Dust and Cobalt

General Electric Carbology Systems
Detroit, Michigan
HETA 85-295

Date	Sample No.	Location (Building)	Time (Min)	Flowrate (LPM)[b]	Concentration[a]	
					Total Dust[c]/Cobalt[d]	Respirable Dust[c]/Cobalt[e]
8/25/86	7982	1	390	2.0	0.29/2.0	
	7968	4	376	2.0	0.09/ND[f]	
	7974	6	361	2.0	0.24/13.0	
	7986	1	390	1.7		0.15/ND
	7987	4	376	1.7		0.03/ND
	7967	6	361	1.7		0.05/ND
8/26/86	8139	1	469	2.0	0.11/ND	
	8127	CCPO[g]	463	2.0	0.09/ND	
	8123	6	418	2.0	0.05/ND	
	8124	1	469	1.7		0.08/ND
	8125	6	418	1.7		0.04/ND
8/27/86	8011	CCPO	374	2.0	0.04/ND	
	8010	6	431	2.0	0.07/5.0	
	8227	11	430	2.0	0.09/4.0	
	8226	1	385	1.7		0.06/ND
	8229	CCPO	374	1.7		0.03/ND
	8136	6	431	1.7		0.03/ND

Evaluation Criteria:		
ACGIH	10/50 (proposed)	5/50 (proposed)
NIOSH	None[h]	None[h]
OSHA	15/100	5/100

Comments

a All values have been field blank corrected and are expressed as the time weighted average over the period sampled. It should be noted, however, that nuisance dust exposure limits (whether total or respirable) are not the most appropriate criteria to use since other contaminants, with lower exposure limits (most notably Co), were identified in the dust samples.

b Liters per minute.

c Concentrations of total and respirable dust are expressed in milligrams per cubic meter (mg/m^3).

d Cobalt concentration from total dust samples, expressed in micrograms per cubic meter (ug/m^3).

e Cobalt concentration from respirable dust samples, expressed in micrograms per cubic meter (ug/m^3).

f Below the limit of detection.

g Custom Carbide Products Operations.

h The NIOSH recommended action level for cemented tungsten carbide dust, containing more than two percent cobalt, is 50 ug/m^3, ten-hour TWA.
Concentrations of other trace metals.
Chromium: Chromium was not detected in any of the area samples.

Footnotes to Tables I, II, and III

General Electric Carboloy Systems
Detroit, Michigan
HETA 85-295

a	All values have been field blank corrected and are expressed as the time-weighted average over the period sampled. It should be noted, however, that nuisance dust exposure limits (whether total or respirable) are not the most appropriate criteria to use since other contaminants, with lower exposure limits (most notably Co), were identified in the dust samples.
b	NIOSH identification number assigned to each study participant.
c	Total dust and respirable dust concentrations expressed in milligrams per cubic meter.
d	Cobalt concentration from total dust samples, expressed in micrograms per cubic meter.
e	Cobalt concentration from respirable dust samples, expressed in micrograms per cubic meter.
f	The NIOSH recommended action level for cemented tungsten carbide dust, containing more than two-percent cobalt, is 50 ug/m^3, ten-hour TWA.
ND	Below the limit of detection.
NS	No sample.
*	Indicates concentrations at or above the ACGIH TLV for cobalt of 50 ug/m^3.

Concentrations of other trace metals with corresponding evaluation criteria.

Nickel: Nickel was not detected in any of the personal samples. NIOSH considers inorganic nickel to be a carcinogen and recommends exposures be kept below 15.0 ug/m^3, ten-hour TWA.

Table V

Pulmonary Function Tests from Medical Records

General Electric Carboloy
Detroit, Michigan
HETA 85-295

ID NO.	MOST RECENT PFTs % PREDICTED VALUE					SMOKING
	VC	FEV$_1$	(FEV$_1$/VC)*100	CONDITION	TYPE	PACK-YEARS
1	81	82	82	N	X	15
2	102	109	76	N	C	40
3	82	88	78	N	X	4
4	108	128	88	N	C	49.5
5	92	90	74	N	X	4
6	95	95	78	N	C	56
7	98	106	81	N	N	0
8	89	85	74	N	C	7.5
9	99	91	71	N	N	0
10	83	89	80	N	X	36
11	93	101	84	N	C	24
12	86	94	81	N	N	0
13	90	86	75	N	X	0.5
14	106	123	89	N	N	0
15	108	108	74	N	N	0
16	101	113	81	N	X	14
17	100	116	85	N	X	27
18	104	107	78	N	C	38.8
19	85	92	77	N	N	0
20	107	105	74	N	C	7.8
21	89	98	78	N	O	0
22	106	110	79	N	X	2
23	98	108	83	N	X	9
24	77	74	68	R-O	C	51
25	94	100	74	N	C	107.5
26	87	84	73	N	C	48
27	81	90	79	N	X	52
28	88	90	72	N	X	43.5
29	84	92	81	N	X	0
30	99	82	63	O	C	50
31	99	100	74	N	X	28
32	93	85	69	O	X	14
33	96	107	84	N	C	56

continued

Table V (continued)

Pulmonary Function Tests from Medical Records

General Electric Carboloy
Detroit, Michigan
HETA 85-295

ID NO.	MOST RECENT PFTs % PREDICTED VALUE				SMOKING	
	VC	FEV$_1$	(FEV$_1$/VC)*100	CONDITION	TYPE	PACK-YEARS
34	83	92	84	N	C	36
35	92	94	78	N	X	11
36	90	98	78	N	C	38
37	90	64	51	O	C	132
38	99	105	80	N	C	42
39	89	81	66	O	C	20
40	97	106	82	N	X	12
41	78	82	73	R	X	66
42	109	110	77	N	N	0
43	87	91	78	N	X	28.5
44	94	101	79	N	O	0
45	71	75	82	R	N	0
46	92	98	80	N	C	36
47	91	92	79	N	C	39
48	120	127	81	N	N	0
49	88	89	77	N	N	0
50	93	98	84	N	N	0
51	101	110	87	N	N	0
52	86	78	70	N	X	22
53	119	108	68	O	N	0
54	79	83	78	R	N	0

* The condition indicates the interpretation of the pulmonary function tests.
where - R = Restrictive
N = Normal
O = Obstructive
R-O = Restrictive and Obstructive

Type - X = Ex-smoker
C = Current smoker
N = Nonsmoker
O = Used other tobacco products but not cigarettes

Table VI
Mean Work-shift Change in Urinary Cobalt Concentrations by Work Area.

General Electric Carboloy
Detroit, Michigan
HETA 85-295

Work Area	No. of Workers	samples	Co in urine (ug/l) mean +/- s.d. (range)
other low exposed workers	4	10	0.8 +/- 2.5 (-2.5 to 5.6)
Bldg.1-5 grinding	8	20	3.7 +/- 3.8 (-3.9 to 11.4)
Bldg. 6 no dust masks	6	12	8.8 +/- 12.7 (-4.4 to 41.0)
Bldg. 6 used dust masks	6	16	14.5 +/- 31.6 (-8.2 to 126.0)

Table VII
Statistical Analysis of Airborne and Urine Cobalt Concentrations

General Electric Carboloy
Detroit, Michigan
HETA 85-295

The following are the means (m), standard deviations and ranges of personal airborne cobalt samples, pre- and post-shift urine cobalt concentrations, and pre- and post-shift adjusted urine cobalt concentrations.

	AIR COBALT (ug/m³)[b]	URINE COBALT (ug/l)[c] pre-shift	URINE COBALT (ug/l)[c] post-shift	ADJUSTED[a] URINE COBALT (ug/l) pre-shift	ADJUSTED[a] URINE COBALT (ug/l) post-shift
Day 1					
Mean	12.3	9.5	16.7	10.8	19.0
S.D.	16.8	6.7	15.0	7.0	14.8
Range	ND-70.0	ND-35.0	ND-51.2	ND-25.5	ND-64.3
n	21	21	20	19	20
Day 2					
Mean	20.0	12.1	19.4	18.3	25.1
S.D.	36.5	9.7	31.5	20.3	21.4
Range	ND-145.0	ND-33.3	ND-156.2	ND-88.1	ND-79.1
n	24	21	23	21	23
Day 3					
Mean	19.3	12.6	16.4	15.0	27.0
S.D.	39.7	20.9	21.3	15.4	21.9
Range	ND-145.0	ND-97.2	ND-105.4	ND-63.4	ND-117.1
n	24	20	23	20	23
Day 4					
mean	NS	9.6	NS	22.1	NS
sd	NS	11.3	NS	26.2	NS
range	NS	ND-54.6	NS	ND-126	NS
n	NS	21	NS	21	NS

ND Not detectable.
NS No sample collected.
a Urine cobalt levels adjusted for creatinine.
b Micrograms of cobalt per cubic meter of air.
c Micrograms of cobalt per liter of urine.

Table VIII
Shift Changes and 24-Hour Changes In Urine Cobalt Concentrations For G.E. Carboloy Workers
August 25 to 28, 1986

General Electric Carboloy
Detroit, Michigan
HETA 85-295

	Mean[a]	S.D.[b]	n	t[c]	p-value
Day 1					
Post shift - pre shift	7.87	12.08	19	2.83	>0.02
Pre shift (Day 2) - Pre shift (Day 1)	1.73	6.34	19	1.19	>0.25
Day 2					
Post shift - Pre shift	8.37	27.98	21	1.37	>0.19
Pre shift (Day 3) - Pre shift (Day 2)	1.12	16.85	18	0.28	>0.78
Day 3					
Post shift - Pre shift	5.46	5.21	20	4.68	>0.01
Pre shift (Day 4) - Pre shift (Day 3)	-2.10	10.67	18	-0.84	>0.41

[a] Units for urine cobalt concentrations are micrograms per liter (ug/l).
[b] Standard deviation.
[c] Students' t-test of $H_0=0$.

Table IX

The Pearson Correlation Coefficients (PCC) For The Correlation Between The Shift Change In Urine Cobalt Concentration And Airborne Cobalt Exposure At Work, By Day And Use Of An Air-Purifying Respirator

General Electric Carboloy
Detroit, Michigan
HETA 85-295

A. ALL PARTICIPANTS

	Day 1	Day 2	Day 3
PCC	0.611	0.451	0.574
p	>0.01	0.04	0.01
n	19	21	19

B. PARTICIPANTS WHO DID NOT WEAR A RESPIRATOR

	Day 1	Day 2	Day 3
PCC	0.594	0.275	0.583
p	0.02	0.31	0.03
n	14	16	14

C. PARTICIPANTS WHO DID WEAR A RESPIRATOR

	Day 1	Day 2	Day 3
PCC	0.613	0.976	0.937
p	0.27	>0.01	0.02
n	5	5	5

Comments:

Airborne cobalt exposures were measured as the $\log_e$ ug/m^3, as an 8-hour time-weighted average.

Urine cobalt concentrations were the (post shift - pre shift) urine cobalt concentrations in micrograms per liter (ug/l).

n=Number of subjects tested.

APPENDIX I

REGRESSION ANALYSIS
AVERAGE ANNUAL DECLINE IN FEV$_1$

General Electric Carboloy
Detroit, Michigan
HETA 85-295

ID	FEV$_1$ Y-INT	PACK-YEARS	BETA	S.E.	DELTA/YR (%)	T:Ho = -0.03
1	3.49	15	-0.027	0.012	-0.77	0.25
2	3.99	40	-0.024	0.018	-0.60	0.33
3	2.97	4	-0.015	0.015	-0.51	1.00
4	4.07	50	-0.009	0.058	-0.22	0.36
5	3.37	4	0.019	0.012	0.56	4.08
6	3.19	56	-0.023	0.025	-0.72	0.28
7	3.39	0	-0.005	0.014	-0.15	1.79
8	3.74	8	0.004	0.016	0.11	2.13
9	4.3	0	-0.036	0.011	-0.84	-0.55
10	3.38	36	0.004	0.001	0.12	3.40
11	3.31	24	-0.017	0.012	-0.51	1.08
12	4.7	0	-0.012	0.019	-0.26	0.95
13	4.24	0	-0.064	0.015	-1.51	-2.27 *
14	4.29	0	0.039	0.021	0.91	3.29
15	4.11	0	-0.032	0.019	-0.78	-0.11
16	4.27	14	-0.023	0.033	-0.54	0.21
17	3.79	37	0.002	0.023	0.05	1.39
18	4.18	39	-0.039	0.015	-0.93	-0.60
19	3.53	0	-0.041	0.015	-1.16	-0.73
20	2.99	8	0.021	0.01	0.70	5.10
21	3.29	0	-0.037	0.015	-1.12	-0.47
22	4.73	2	-0.065	0.035	-1.37	-1.00
23	3.84	9	-0.042	0.015	-1.09	-0.80
24	3.33	51	-0.023	0.02	-0.69	0.35
25	3.47	99	-0.04	0.011	-1.15	-0.91
26	3.41	48	-0.04	0.01	-1.17	-1.00
27	3.25	52	-0.027	0.015	-0.83	0.20
28	2.89	44	0.015	0.015	0.52	3.00
29	3.55	0	-0.027	0.021	-0.76	0.14
30	4.24	50	-0.051	0.032	-1.20	-0.66
31	3.49	28	0.002	0.009	0.06	3.56
32	3.29	14	-0.007	0.023	-0.21	1.00
33	4.42	56	-0.039	0.018	-0.88	-0.50
34	3.44	36	0.026	0.025	0.76	2.24
35	5.14	11	-0.083	0.03	-1.61	-1.77 *
36	3.7	38	-0.033	0.016	-0.89	-0.19
37	2.82	132	-0.092	0.015	-3.26	-4.13 *
38	4.22	42	-0.056	0.018	-1.33	-1.44
39	2.75	20	-0.034	0.013	-1.24	-0.31

continued

APPENDIX I, continued

REGRESSION ANALYSIS
AVERAGE ANNUAL DECLINE IN FEV_1

General Electric Carboloy
Detroit, Michigan
HETA 85-295

ID	FEV_1 Y-INT	PACK-YEARS	BETA	S.E.	DELTA/YR (%)	T:Ho = -0.03
40	3.24	12	0.008	0.013	0.25	2.92
41	2.93	66	-0.034	0.014	-1.16	-0.29
42	5.19	0	-0.061	0.017	-1.18	-1.82 *
43	4.27	28	-0.026	0.01	-0.61	0.40
44	3.8	0	-0.026	0.012	-0.68	0.33
45	3.69	0	-0.043	0.024	-1.17	-0.54
46	4.41	36	-0.028	0.013	-0.63	0.15
47	4.26	39	-0.053	0.025	-1.24	-0.92
48	4.46	0	0.004	0.017	0.09	2.00
49	3.84	0	-0.034	0.01	-0.89	-0.40
50	3.33	0	-0.022	0.009	-0.66	0.89
51	3.56	0	-0.006	0.024	-0.17	1.00
52	2.45	22	-0.014	0.017	-0.57	0.94
53	5.38	0	-0.051	0.022	-0.95	-0.95
54	3.59	0	-0.044	0.007	-1.23	-2.00 *

* $p < 0.05$ for a one-sided test of Ho $\geq$ 0.03 L/yr

APPENDIX II

AVERAGE ANNUAL DECLINE IN VITAL CAPACITY (VC) REGRESSION ANALYSIS

General Electric Carboloy
Detroit, Michigan
HETA 85-295

ID	Y-INT	BETA	S.E.	DELTA/YR	T:Ho = -0.03
1	4.14	-0.02	0.015	-0.48	0.67
2	4.97	-0.015	0.026	-0.30	0.58
3	3.65	-0.001	0.024	-0.03	1.21
4	5.29	-0.069	0.032	-1.30	-1.22
5	4.32	0.043	0.015	1.00	4.87
6	4.09	-0.021	0.018	-0.51	0.50
7	4.05	0.017	0.015	0.42	3.13
8	5.01	0.006	0.015	0.12	2.40
9	5.64	-0.019	0.009	-0.34	1.22
10	4.25	-0.001	0.014	-0.02	2.07
11	3.85	-0.016	0.017	-0.42	0.82
12	5.46	-0.003	0.016	-0.05	1.69
13	5.16	-0.036	0.015	-0.70	-0.40
14	4.73	0.051	0.02	1.08	4.05
15	5.45	-0.017	0.021	-0.31	0.62
16	4.96	-0.004	0.039	-0.08	0.67
17	4.36	0.017	0.023	0.39	2.04
18	5.26	-0.035	0.021	-0.67	-0.24
19	4.04	-0.002	0.015	-0.05	1.87
20	4.17	0.013	0.011	0.31	3.91
21	4.04	-0.029	0.014	-0.72	0.07
22	5.96	-0.088	0.046	-1.48	-1.26
23	4.52	-0.041	0.019	-0.91	-0.58
24	4.54	-0.001	0.024	-0.02	1.21
25	4.24	-0.016	0.019	-0.38	0.74
26	4.34	-0.025	0.009	-0.58	0.56
27	3.97	-0.022	0.017	-0.55	0.47
28	4.32	-0.011	0.015	-0.25	1.27
29	4.39	-0.043	0.027	-0.98	-0.48
30	5.76	0.006	0.022	0.10	1.64
31	4.64	0.021	0.016	0.45	3.19
32	4.7	-0.022	0.021	-0.47	0.38
33	5.25	-0.061	0.019	-1.16	-1.63 *
34	4.28	-0.005	0.016	-0.12	1.56
35	6.37	-0.083	0.028	-1.30	-1.89 *
36	4.64	-0.021	0.025	-0.45	0.36
37	5.05	-0.108	0.026	-2.14	-3.00 *
38	5.14	-0.057	0.016	-1.11	-1.69 *
39	3.65	-0.018	0.011	-0.49	1.09

continued

APPENDIX II, continued

AVERAGE ANNUAL DECLINE IN VITAL CAPACITY (VC) REGRESSION ANALYSIS

General Electric Carboloy
Detroit, Michigan
HETA 85-295

ID	Y-INT	BETA	S.E.	DELTA/YR	T:Ho = -0.03
40	3.84	0.015	0.019	0.39	2.37
41	4.13	-0.058	0.018	-1.40	-1.56
42	6.44	-0.065	0.019	-1.01	-1.84 *
43	5.21	-0.005	0.015	-0.10	1.67
44	4.71	-0.028	0.012	-0.59	0.17
45	4.33	-0.041	0.028	1.00	0.39
46	5.04	0.007	0.008	0.14	4.63
47	5.23	-0.047	0.023	-0.90	-0.74
48	5.75	-0.037	0.011	-0.64	-0.64
49	4.57	-0.014	0.007	-0.31	2.29
50	3.93	-0.006	0.012	-0.15	2.00
51	4.12	0	0.026	0.00	1.15
52	3.21	-0.004	0.018	-0.12	1.44
53	7.24	0.001	0.025	0.01	1.24
54	4.48	-0.043	0.016	-0.96	-0.81

* $p < 0.05$ for a one-sided test of $Ho \geq -0.03$ L/yr