U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
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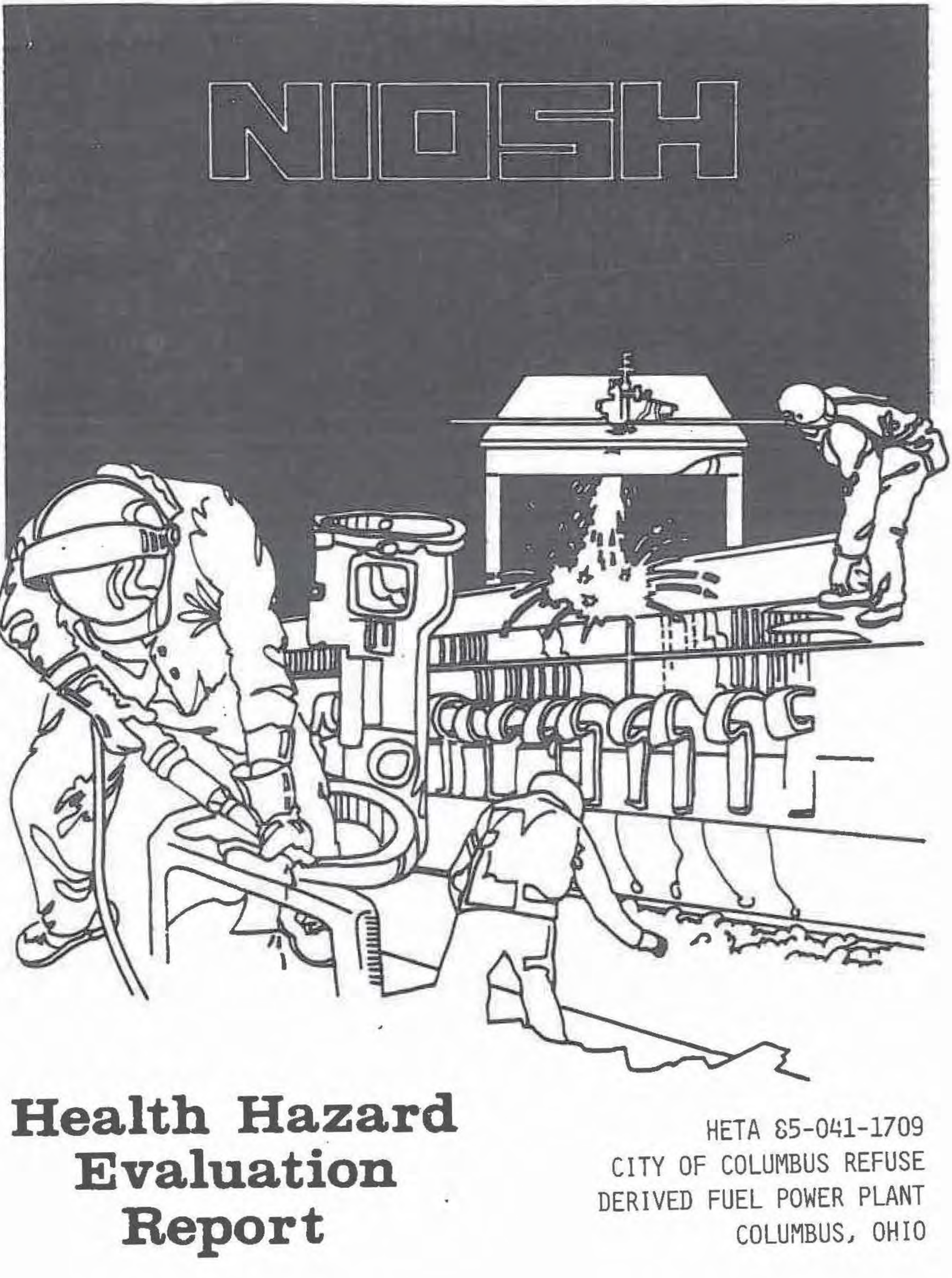

Health Hazard Evaluation Report

HETA 85-041-1709
CITY OF COLUMBUS REFUSE
DERIVED FUEL POWER PLANT
COLUMBUS, OHIO

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.

HETA 85-041-1709
July 1986
CITY OF COLUMBUS REFUSE
DERIVED FUEL POWER PLANT
COLUMBUS, OHIO

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I. SUMMARY

On October 29, 1984, the National Institute for Occupational Safety and Health (NIOSH) received a request from the City of Columbus to conduct a Health Hazard Evaluation (HHE) at the City's Municipal Electric Power Plant. The request initially concerned heat stress but was subsequently modified to include chemical contaminant and airborne microbial exposures of workers at the facility.

The facility uses shredded residential refuse and coal as a fuel for electricity generation. The facility began operation in 1983. The facility operates 24 hours a day and has a total workforce of about 160 workers.

During two surveys, March 4-8, 1985, and August 12-14, 1985, personal exposure monitoring was conducted for cadmium, total chromium, chromium VI (insoluble forms), lead, nickel, respirable dust, respirable coal dust, and respirable crystalline silica. Bulk dust samples were analyzed to identify potential airborne contaminants. Area sampling was conducted for airborne microbial contamination using viable samplers. Heat stress was evaluated both in March and August using a wet bulb globe temperature heat stress monitor.

Worker exposures to compounds of concern identified from the bulk settled dust sample were as follows. Cadmium exposures ranged from non-detectable levels (ND) up to 18 micrograms per cubic meter (ug/m^3); the NIOSH recommended exposure limit (REL) is 40 ug/m^3 and the OSHA permissible exposure level (PEL) 200 ug/m^3. Total chromium exposures ranged from ND up to 18 ug/m^3; the NIOSH REL for noncarcinogenic chromium III compounds is 25 ug/m^3; the OSHA PEL is 500 ug/m^3 for soluble chromium compounds and 1000 ug/m^3 for chromium metal and insoluble salts. Chromium VI (insoluble forms) exposures ranged from ND up to 0.8 ug/m^3. The NIOSH REL for insoluble forms of chromium VI is 1 ug/m^3. Lead exposures ranged from ND up to 509 ug/m^3; the OSHA lead PEL is 50 ug/m^3. Nickel exposures ranged from ND up to 11 ug/m^3; the NIOSH nickel REL is 15 ug/m^3; the OSHA PEL 1000 ug/m^3. Respirable dust exposures, primarily fly ash, ranged from 90 ug/m^3 up to 14000 ug/m^3. The OSHA PEL for nuisance dust is 5000 ug/m^3, although this may not be the most appropriate criterion. Coal dust exposures were 420 ug/m^3; the OSHA coal dust PEL is 2400 ug/m^3. Respirable crystalline silica exposures, consisting of either or both quartz and cristobalite, ranged

from ND up to 240 ug/m^3. The NIOSH silica REL is 50 ug/m^3, the OSHA PEL depends upon crystalline silica content of each sample. No evaluation criteria currently exists for total airborne microbial contamination, although some levels exceeded an advisory 1000 colony forming units (CFU) per m^3 level indicating the need for further evaluation. Total airborne microbial levels ranged from 666 CFU/m^3 to over 4525 CFU/m^{3}for one minute samples. Respirable CFU/m^3 counts ranged from 368 CFU/m^3 to over 2877 CFU/m^3 for a one minute sample. These counts were obtained after 24 hours of aerobic incubation at 37°C. Airborne microbial contamination was generally the highest in the refuse handling areas and lowest in fly ash areas.

Activities in the hot work areas were very limited during the surveys. Heat stress readings for hot areas where work, primarily maintenance, could potentially be performed produced Wet Bulb Globe Temperature (WBGT) heat stress readings of 61°F (16°C) to 84°F (29°C) during the March survey and 90°F (32°C) to 102°F (39°C) in August. The NIOSH REL for heat acclimitized workers performing continuous work ranges from a WBGT value of about 77°F (25°C) for heavywork up to 91°F (33°C) for light work. WBGT levels from both the March and August survey were such that heat illness could potentially occur in numerous areas of the plant.

During this study NIOSH investigators identified worker exposures to lead over the OSHA PEL and crystalline silica exposures exceeding the NIOSH REL. Exposures to lead, chromium compounds, insoluble chromium VI, cadimum, and nickel were associated with the handling of ash. Potentially serious health hazards associated with working in the hot areas of the facility exist, both during cool and warm seasons. Recommendations concerning compliance with the OSHA lead standard, personal hygiene, work practices, housekeeping, engineering controls, respiratory protection, prevention of potential heat stress and heat illnesses, worker education, preplacement and periodic medical surveillance, and the need for further evaluation services of an industrial hygienist are presented in Section IX.

KEYWORDS: SIC 4931 (Electric and other services combined) 4953 (Refuse systems) residential refuse, electric power generation, lead, cadmium, chromium, nickel, chromium VI, crystalline silica, respirable dust, fly ash, coal dust, heat stress, hot environments, airborne microbial contamination, aerobiological sampling, municipality, bulk samples, garbage shredding, refuse derived fuel.

II. INTRODUCTION

On October 29, 1984, the National Institute for Occupational Safety and Health (NIOSH) received a request from the City of Columbus to conduct a Health Hazard Evaluation (HHE) at the City's Municipal Electric Power Plant. The request was submitted subsequent to an investigation conducted in August 1984 by the State of Ohio Industrial Commission. The NIOSH HHE request concerned heat stress. Review of the Industrial Commission's report and information obtained during an initial survey indicated concerns about worker exposures to dusts and airborne microbial contamination throughout the facility. An initial survey was conducted December 5, 1984, and follow-up surveys were undertaken March 4-8, and August 12-14, 1985. Sampling conducted during the follow-up surveys included personal exposure monitoring of workers' airborne exposures to cadmium, chromium, lead, nickel, respirable dust, crystalline silica, and coal dust. Area sampling for total airborne microbial contamination was undertaken at selected locations during the March 1985 survey. Heat stress measurements at various locations throughout the power plant were obtained both in March and August of 1985, representing winter and summer seasons. Follow-up response letters summarizing field activities were distributed February 7, March 20, and September 5, 1985. Interim reports were distributed May 13, July 31, and November 11, 1985.

The July 1985 interim report presented the bulk of information concerning the investigation including the first follow-up survey. The material from that report will be presented here along with the data from the final follow-up survey.

III. BACKGROUND

A. Plant Description:

The Columbus Refuse and Coal Fired Municipal Electric Plant began operation in June of 1983. The facility occupies 52 acres, and has an 11 story power plant with an adjacent refuse shredding station. The plant contains six balanced draft boilers which are intended to burn a mixture of 90% refuse and 10% coal by weight. This facility has the capacity to burn up to 3000 tons of shredded refuse per day. The power plant also has storage capacity for 60,000 tons of shredded refuse. On site shredding facilities can process up to 120 tons of raw refuse per hour for immediate conveyance to the power plant boilers. Residential refuse from the City of Columbus and its suburbs is the primary source of fuel. On-site coal storage serves as a fuel back-up and fuel supplement with the refuse. Three off-site municipal shredding stations as well as private haulers bring refuse into the facility. The plant has a generation capacity of 90 megawatts.

B. Work Force:

The facility currently employs a total of 161 workers. The nature of this operation requires staffing three shifts per day. The day shift (8:00-4:30) is the largest. Twenty-three percent of the workers have the job title of Laborer. Fourteen percent are Pulverizer Operators, and 14 percent are Plant Maintenance Mechanics and Plant Maintenance Helpers. Table I presents in summary form the job titles and job descriptions of workers monitored during the surveys. Five percent of the overall workforce is female. Job titles monitored for exposure to workplace contaminants included Laborer, Boiler Operator, Maintenance Mechanic, Maintenance Helper, Pulverizer Operator, and Maintenance Electrician.

C. Process Description:

The Columbus Refuse and Coal Fired Municipal Electric Plant uses refuse to generate electricity for use by city buildings and equipment as well as in lighting public thoroughfares and properties. Refuse is delivered to the facility in one of two forms: unprocessed and pre-shredded. Pre-shredded refuse is taken directly to the tipping pad area of the power plant and discharged into the enclosed refuse pit (enclosed meaning under roof). Unprocessed refuse is dumped at the shredder station where it is fed by conveyor through a shredder followed by the magnetic separator and then sent by conveyor to the power plant where it is deposited into the refuse pit or into refuse bunkers. Coal is also brought by conveyor from the coal storage area into the plant and deposited into coal bunkers. Coal and refuse are delivered by separate systems to the boilers. Fly ash from electrostatic precipitators and boiler ash from the quench basins underneath the boilers are transported, generally after the addition of water, to an ash pit. From here, the ash is hauled away to a landfill site. Primary raw materials used by the facility are coal and "residential" refuse. The facility also has its complement of boiler water chemicals for water conditioning, scale prevention, and oxygen scavenging (hydrazine); however, the contact time by workers with these substances is very limited.

D. Problem Description:

This facility, the largest of its kind presently operating in the United States, has encountered numerous difficulties with applying existing technologies to new uses - in this case the use of coal fired power plant equipment for reclaiming energy from refuse. Although this is not an unexpected occurrence, the result has been that the plant is maintenance intensive, housekeeping is suboptimal and labor intensive, and operational difficulties and equipment limitations coupled with a rather ill-defined and constantly changing fuel (refuse obtained from innumerable sources) have combined to produce a work environment presenting numerous and varied worker exposures to identified and unidentified workplace contaminants. Examples of potential worker exposures include: solvent vapors, metals, respirable and non-respirable dusts of varying composition, silica, asbestos, fungi, bacteria (including pathogenic forms), combustion products released into the work environment by the boilers, and heat. Since the primary fuel used is refuse, a reasonable assumption is that almost anything that is likely to be discarded in the Columbus metropolitan area may at some time appear at this facility. Couple this knowledge with the realization of the concentration of large quantities of materials in one location and an awareness of the concentration of noncombustible substances in the ash, and one realizes that contaminant exposures can be very dynamic.

E. Previous Evaluations:

The Industrial Commission of Ohio, Division of Safety and Hygiene, conducted an industrial hygiene survey at this facility August 6-9, 1984. The survey identified overexposures to silica-containing dusts, lead, and noise. The report also noted the absence of a confined space entry program. Extensive measurements demonstrated extremely high environmental heat stress levels throughout the plant.

Sampling of the ash produced by the power plant was conducted by a private consultant to determine if the material met the criteria of a hazardous waste, based on lead and cadmium content. The evaluation process consisted of collecting conditioned fly ash (consisting of mechanical collector ash, electrostatic precipitator ash, and water) and total combined ash (quench basin ash and conditioned fly ash) samples from August 16, 1984, to September 14, 1984. Samples were acid extracted and the supernatant analyzed for lead and cadmium. Results showed that lead and cadmium were present in both types of samples, daily fluctuations in metal concentrations in the ash were occurring, and these results indicated that the average lead and cadmium levels were higher in the conditioned fly ash (per liter of supernatant) than the pile ash (containing quench basin ash from the boiler in addition to fly ash). The quench basin ash appears to dilute the lead and cadmium concentrations found in the fly ash samples. Two recommendations by the consultant were that worker exposure to fly ash be limited and that precautions need to be taken due to the presence of lead- and cadmium-containing dusts within the power plant.

IV. EVALUATION DESIGN AND METHODS

Sampling and analytical methods used in the evaluation of worker exposures and specific workplace contaminants are presented in summary form in Table II.

All air sampling trains (i.e. personal sampling pumps) were calibrated daily. Proper flow rate and sample integrity during the work shift were checked periodically. Personal exposure samples approximated the full normal work shift of seven and one-half to eight hours. Monitored workers were selected on a daily basis from the following general job titles-these representing workers assigned to plant areas considered to have a greater exposure potential: Laborer, Boiler Operator, Maintenance, and Shredder Operator. Bulk samples of settled dust were collected at eight different locations during the March 1985 follow-up survey for qualitative screening of contaminants as well as for use with the analysis of personal silica exposures. Bulk samples collected during the August 1985 survey were exclusively obtained for use in the analysis of personal silica exposures.

Heat stress measurements were obtained using a Reuter Stokes Canada Ltd. Wibgeté WBGT (Wet Bulb Globe Temperature) Meter, Model RSS-211 Heat Stress Monitor. The unit was mounted on ring stands about four feet above the floor. Following manufacturer's instructions, the unit was allowed to equilibrate in each sampling area for at least five minutes prior to obtaining WBGT readings. This approach permits assessment of the environmental heat load.

Viable air sampling for airborne microorganisms was conducted using two stage Andersen Viable (Microbial) Particle Sizing Samplers. These samplers are designed to separate airborne microbial contaminants into two fractions, respirable and nonrespirable, as well as permitting a total count of airborne microorganisms present. This sampler separates viable particles into two size ranges, with the 50% cut-off diameter of Stage I at 8.0 micrometers for spherical particles of unit density. A general purpose solid bacteriological medium was used (tryptone glucose extract agar). Due to the absence of internal resources for the incubation and evaluation of microbial samples, the NIOSH investigator requested the assistance of the City of Columbus Health Department. The health department agreed to incubate the sample plates and perform the colony counts at 24 and 48 hours of incubation. These samples are considered useful in providing an indication of the levels of airborne bacterial contamination present at different locations of the plant.

No specific characterization or isolation and identification of pathogenic and non-pathogenic bacteria was undertaken due to the previously mentioned limitations. The refuse source and variability easily suggests the potential presence of human pathogens. The plates used in sampling were transported to the health department at the end of each day for incubation. Reference samples were collected outdoors and in the main office area.

V. EVALUATION CRITERIA

A. General Evaluation Criteria Considerations:

1. Evaluation Criteria for Chemical Contaminants:

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 agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the 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), and (3) the U.S. Department of Labor (OSHA) occupational health standards. 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 standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In reviewing the exposure levels, and the recommendations for reducing those levels found in this report, it should be noted that industry is required by the Occupational Safety and Health Act of 1970 to meet those levels specified by OSHA standards.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

Table III presents the evaluation criteria for chemical contaminants evaluated during the health hazard evaluation.

2. Evaluation Criteria for Hot Work Environments:

The hot environments at the power plant involve primarily maintenance activities and periodic tours by plant personnel to assure proper equipment operation. NIOSH originally defined hot environmental conditions as any combination of air temperature, humidity, radiation and wind speed that exceeds a Wet Bulb Globe Temperature (WBGT) of 79°F (26° C).[1] NIOSH, in its revised criteria for occupational exposure to hot environments, provides figures showing WBGT exposures versus duration of exposure and activity level which are not to be exceeded for work in hot areas.[2]

The revised NIOSH criteria and the ACGIH TLV® present a permissible heat exposure for different work-rest regimes and work loads at different WBGT values.[2,11] Table IV presents this criteria. This criteria assumes the workers are acclimatized, fully clothed in summer weight clothing, are physically fit, have good nutrition, and have adequate water and salt intake. Additionally, they should not have any pre-existing medical conditions which may impair the body's thermoregulatory mechanisms. Alcohol use and certain therapeutic and social drugs will also impair the body's heat tolerance.[1,2]

Modifications of the NIOSH and ACGIH evaluation criteria should be made before being applied if the worker or conditions do not meet the previously defined requirements. The following modifications of the evaluation criteria have been suggested:[16]

a. Unacclimatized or physically unconditioned - subtract 4°F (2°C) from the permissible WBGT value for acclimatized workers. Increased air velocity (above 1.5 meters per second or 300 feet per minute) - add 4°F (2°C) to permissible WBGT value. This adjustment cannot be used for air temperatures in excess of 90-95°F (32-35°C). It also does not apply if impervious clothing is worn.

A criticism of this WBGT modification is that an adjustment for increased air velocity is unwarranted since the WBGT index is adequately responsive to wind velocity.[17]

b. Impervious clothing which interferes with evaporation:

i. Body armor, impermeable jackets - subtract 4°F (2°C).
ii. Raincoats, fireman coats, full-length coats - subtract 7°F (4°C).
iii. Completely enclosed suits - subtract 9°F (5°C).

c. Obese or elderly - subtract 2-4°F (1-2°C).

d. Female - subtract 1.8°F (1°C). This adjustment acknowledges generally lower sweat rates for females reported in the literature. Correction "d" is questionable since the difference between the sexes in groups that normally work in hot environments were observed to be complex. Seasonal and work rate considerations enter into determining which sex is better adapted to work in hot environments.[18]

3. <u>Aerobiological Contamination</u>:

Although no evaluation criteria currently exists for airborne microbial contamination, guidelines concerning the significance of different airborne concentrations are beginning to be developed. NIOSH investigators have, through work addressing airborne microbial contamination in office buildings, suggested that a level of viable (capable of living) microorganisms in excess of about 1000 viable particles per m^3 or CFU/m^3 indicates that the indoor environment may be in need of investigation and improvement. Note that this level does not discriminate between different bacterial or fungal organisms, This by itself does not mean that the air is unsafe or hazardous.[19] Essentially this level represents a threshold at which further evaluation is recommended.

The ACGIH Committee on Bioaerosols has proposed a total count of 10,000 CFU/m^3 or more as necessitating remedial action. This appears in their draft protocol for monitoring airborne viable microorganisms in the office environment.[20] These criteria have been proposed for office environments and generally address contamination associated with microbial fouling of the ventilation system or excess humidity levels due to various sources within the office space itself. The applicability of these values to the industrial environment in this HHE has not been established.

B. Toxicology:

1. Chromium:

The dusts of chromium metal and its insoluble salts, chiefly the chromites (Cr II), are usually reported to be relatively non-toxic. This is debatable since exposures associated with toxic effects are usually mixed, involving several hexavalent (Cr VI) chromium compounds. Ferrochrome alloys have been associated with pulmonary disease in humans.

The soluble chromic (Cr VI) and chromous (Cr II) salts have no established toxicity. Since exposures are often mixed, consideration should be given to the possible exposure to hexavalent chromium (Cr VI) which is a more toxic form. Ingestion of trivalent chromium (Cr III) compounds has not been associated with local or systemic effects and these compounds are poorly absorbed. No specific effects are known to result from inhalation. Dermatitis from some chromic (Cr VI) salts has been established. Individuals sensitized to hexavalent (VI) chromium are thought by some investigators to also be sensitive to the trivalent (III) form, although this has not been firmly established.[21]

Chromate (Cr VI) dusts are severe irritants of the nasopharynx, larynx, lungs, and skin. Chromium compounds, especially the hexavalent compounds, are associated with a high incidence of lung cancer in humans. The solubility of chromium VI material appears to influence carcinogenicity, with less soluble compounds considered to have much greater carcinogenic potential than soluble forms.[8] Workers exposed to chromic acid or chromates in concentrations of 0.11 to 0.15 milligrams per cubic meter (mg/m^3), 110 - 150 micrograms per cubic meter (ug/m^3), developed ulcers of the nasal septum and irritation of the conjunctiva, pharynx, and larynx, as well as asthmatic bronchitis. Studies of chromate workers have not demonstrated any unusual incidence of liver diseases or other systemic diseases except for lung cancer.[21]

Chrome ulcer, a penetrating lesion of the skin, occurs chiefly on the hands and forearms where there has been a break in the epidermis. This is believed to be due to a direct necrotizing effect of the chromate ion. The ulcer is relatively painless, heals slowly, and produces a characteristic depressed scar.[21]

Occupational exposure criteria for the different forms of chromium are presented in Table III.

2. Lead:

Inhalation (breathing) of lead dust and fume is the major route of lead exposure in industry. A secondary source of exposure may be from ingestion (swallowing) of lead dust deposited on food, cigarettes, or other objects. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the kidneys, peripheral and central nervous systems, and the blood forming organs (bone marrow). These effects may be felt as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, mental deficiency, or slowed reaction times. Chronic lead exposure is associated with infertility and with fetal demage in pregnant women.

Blood lead levels below 40 ug/deciliter whole blood are considered to be normal levels which may result from daily environmental exposure.[22] However, fetal damage in pregnant women may occur at blood lead levels as low as 30 ug/deciliter. Lead levels between 40-60 ug/deciliter in lead-exposed workers indicate excessive absorption of lead and may result in some adverse health effects. Levels of 60-100 ug/deciliter represent an unacceptable elevation which may cause serious adverse health effects. Levels over 100 ug/deciliter are considered dangerous and often require hospitalization and medical treatment.

The Occupational Safety and Health Administration (OSHA) standard for lead in air is 50 ug/m^3 calculated as an 8-hour TWA for daily exposure.[22] The standard also dictates that workers with blood lead levels greater than 60 ug/deciliter must be immediately removed from further lead exposure and, in some circumstances, workers with lead levels of less than 60 ug/deciliter must also be removed. Removed workers have protection for wages, benefits, and seniority for up to 18 months until their blood levels decline to below 50 ug/deciliter. At this point they can return to lead exposure areas.

Lead has been shown in previous studies[23] to cause chronic kidney disease (nephropathy) in persons with long-time occupational exposure. The process is gradual and dose related. Persons who experience the greatest lifetime risk of manifesting lead-induced kidney disease are those who have experienced the most lead absorption over their working career. The initial signs of lead nephropathy are subtle. Affected workers will usually have no symptoms in the early stages. Their renal function test values may still be within the broad range of normal, although their test results will tend over time to move toward the high end of the normal range.

Because the kidney has an enormous reserve capacity, results of the usual renal function tests - blood urea nitrogen (BUN), serum creatinine, and serum uric acid - will not become frankly abnormal until one-third to one-half of kidney function has been destroyed.[24] For that reason, more sensitive screening tests of renal function have been sought. These include serum measurement of 1,2,5-dihydroxy vitamin D, which may be decreased in persons with kidney damage caused by lead.[25] Other abnormalities which may also be noted in chronic lead nephropathy include aminoaciduria, renal glycosuria, and hypercalcuria. Gout is a particularly noteworthy manifestation of lead nephropathy;[26] the elevated serum uric acid concentrations which may occur in lead nephropathy have been associated with the development of gouty arthritis.

3. Respirable Nuisance Dust:

"Nuisance" dusts, in contrast to fibrogenic dusts which cause scar tissue to be formed in the lungs when inhaled in excessive amounts, have a long history of little adverse effect on the lungs. They do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. The nuisance dusts have also been called (biologically) "inert" dusts, but the latter term is inappropriate to the extent that there is no dust which does not evoke some cellular response in the lung, when inhaled in sufficient amount.[11]

Excessive concentrations of nuisance dust in the workroom air may seriously reduce visibility; may cause unpleasant deposits in the eyes, ears, and nasal passages; or cause injury to the skin or mucous membranes by chemical or mechanical action per se or from the rigorous skin cleaning procedures necessary for their removal.

The TLV® for the respirable nuisance dust fraction, as recommended by the ACGIH, is 5 mg/m^3 and the percent of quartz contributing to the exposure concentration should be below one per cent.[27]

4. Coal Dust:

The inhalation of coal dust causes coal worker's pneumoconiosis (CWP). Simple CWP has no clinically distinguishing symptoms. Simple CWP often occurs simultaneously with chronic bronchitis and emphysema. Although CWP is associated with several respiratory impairments, CWP is not associated with a shortening of life span; the significance of this benign condition is the fact that CWP is a precursor to progressive massive fibrosis (PMF).[15]

Complicated pneumoconiosis or PMF is associated with a reduction in ventilatory capacity, low diffusing capacity, abnormalities of gas exchange, low arterial oxygen tension, pulmonary hypertension, and premature death. CWP may appear several years after exposure has ceased and may progress in the absence of further dust exposure. Obstructive airway disease is common in PMF, probably a consequence of the distortion and narrowing of the bronchi and bronchioles producted by the massive lesson.[15]

The ACGIH TLV® of 2 mg/m^3 is set at a level intended to reduce the risk of developing pneumoconiosis.[27] Coal dust containing appreciable amounts of quartz, greater than five percent (5%), should use the evaluation criteria for quartz containing dusts.[11]

5. Crystalline Silica:

Crystalline silica or quartz dust causes silicosis; a form of disabling, progressive, and sometimes fatal pulmonary fibrosis characterized by the presence of typical nodulation in the lungs. The clinical signs and symptoms of silicosis tend to be progressive with continued exposure to quantities of dust containing free silica, with advancing age, and with continued smoking habits. Symptoms include cough, dyspnea, wheezing, and repeated nonspecific chest illnesses. Impairment of pulmonary function may be progressive. Progression of symptoms usually continues after dust exposure ceases. While there may be a factor of individual susceptibility to a given exposure to silica dust, the risk of onset and the rate of progression of the pulmonary lesion is clearly related to the character of the exposure (dust concentration and duration). The disease tends to occur after an exposure measured in years rather than months. Occasionally, exposures to very high concentrations occur in short periods of time in occupations such as sandblasters and tunnel workers; in these cases of acute or rapidly-developing silicosis there may be severe respiratory symptoms resulting in death. It is generally accepted that silicosis predisposes the individual to active tuberculosis, and that the combined disease tends to be more rapidly progressive than uncomplicated silicosis.[21] The NIOSH recommended 8- to 10-hour TWA for exposure to crystalline silica is 50 ug/m^3.[12]

6. Heat:

Heat stress is defined as the total net heat load on the body with contributions both from exposure to external environmental sources and from metabolic heat production.[28]

Four factors influence the interchange of heat between the human body and the environment. These are: (1) air temperature, (2) air velocity, (3) moisture content of the air, and (4) radiant temperature. Industrial heat problems involve a combination of these factors which produce a working environment that may be uncomfortable or even hazardous because of an imbalance of metabolic heat production and heat loss.

The fundamental thermodynamic processes involved in heat exchange between the body and its environment may be described by the basic equation of heat balance:

$$S = M - E \pm R \pm C$$

where S = change in body heat content (heat gain or loss); M = rate of metabolism (associated with body function and physical work); E = heat loss through evaporation (of perspiration); R = heat loss or gain by radiation (infrared radiation emanated from warmer surfaces to cooler surfaces); and C = heat loss or gain through convection (passage of a fluid (air) over a surface with the resulting gain or loss of heat). Under conditions of thermal equilibrium (essentially no heat stress) heat generated within the body by metabolism is completely dissipated to the environment and deep body or core temperature remains constant at about 98.6°F (37°C).

When heat loss fails to keep pace with heat gain, the core temperature begins to rise. At this point certain physiologic mechanisms begin to function in an attempt to increase heat loss from the body. First, there is dilation of the blood vessels of the skin and subcutaneous tissues with diversion of a large part of the body's blood supply to the body surface and extremities. An increase in circulating blood volume also occurs through the withdrawal of fluids from body tissues. The circulatory adjustments enhance heat transport from the body core to the surface. Simultaneously the sweat glands become active, spreading fluid over the skin which removes heat from the skin surface by evaporation. Evaporative cooling must balance metabolic plus environmental heat load to maintain thermal equilibrum. If this fails, heat storage begins with the resultant strain of increased body temperature.

Prolonged exposure to excessive heat may cause increased irritability, lassitude (weariness), decrease in morale, increased anxiety, and inability to concentrate. The results are mirrored by a general decrease in the efficiency of production and the quality of the finished product.

The acute physical disabilities caused by excessive heat exposure are, in order of increasing severity: heat rash, heat cramps, heat exhaustion, and heat stroke.

a. Heat rash (prickly heat): may be caused by unrelieved exposure to hot and humid air as may occur in warm-moist climatic zones. The openings of the sweat ducts become plugged due to the swelling of the moist keratin layer of the skin which leads to inflammation of the glands. There are tiny red vesicles visible in the affected skin area and, if the affected area is extensive, sweating can be substantially impaired. As a consequence heat rash not only is a nuisance, because of the discomfort it causes, but also can greatly diminish the worker's capacity to tolerate heat.

b. Heat cramps: may occur after prolonged exposure to heat with profuse perspiration and inadequate replacement of salt. The signs and symptoms of heat cramps consist of spasm and pain in the muscles of the abdomen and extremities. Albuminuria (protein in the urine) may be a transient finding.

c. Heat exhaustion: may result from physical exertion in a hot environment when vasomotor control (nerves governing muscular control of the blood vessel walls) and cardiac output are inadequate to meet the increased demand placed upon them by peripheral vasodilation or the reduction in plasma volume due to dehydration. Signs and symptoms of heat exhaustion may include palor, lassitude, dizziness, syncope (fainting), profuse sweating, and cool moist skin. There may or may not be a mild hyperthermia, observable by rectal temperature measurement.

d. Heat stroke: is a serious medical condition. An important predisposing factor is excessive physical exertion. Signs and symptoms may include dizziness, nausea, severe headache, hot dry skin because of cessation of sweating, very high body temperature (usually 106°F or 41°C and rising), confusion, collapse, delirium, and coma. Often circulation is also compromised to the point of shock. If cooling of the victim's body is not started immediately, irreversible damage to vital organs may develop leading to death.[28]

Chronic heat illnesses are those occurring as aftereffects of acute heat illnesses; those brought on by working in excessive hot jobs for a few weeks, months, years, or possibly a working lifetime but without the occurrence of acute heat illness; and those associated with living in climatically hot regions of the world. Chronic aftereffects associated with acute heat illnesses can include reduced heat tolerance, dysfunction of sweat glands, reduced sweating capacity, muscle soreness, stiffness, reduced mobility, chronic heat exhaustion, and cellular damage in different organs-particularly in the central nervous system, heart, kidneys, and liver.[28]

Chronic heat illnesses not associated with an acute incident of heat illness can fall into one of two categories based upon the duration of exposure. After several months of exposure to a hot working environment chronic heat exhaustion may be experienced. Symptoms which may develop include headache, gastric pain, sleep disturbance, irritability, tachycardia, vertigo, and nausea. After many years in a hot job, cumulative effects of long-term exposure which may develop are hypertension, reduced libido, sexual impotency, myocardial damage, nonmalignant diseases of the digestive organs, and hypochromemia (a condition in which the blood has an abnormally low color index).[28] Available data concerning chronic heat effects have not contributed much to protecting workers from heat effects.[2]

7. <u>Aerobiological Contamination</u>:

Currently, no established environmental evaluation criteria exists which can be applied to airborne microbial contamination however some guidelines, as mentioned in Section V Part A have been proposed. Information addressing minimum infective doses of airborne microorganism levels by the inhalation route of exposure is currently lacking. Epidemiologic studies of wastewater treatment workers demonstrate that gastrointestinal illness rates were higher in inexperienced wastewater exposed workers than in experienced workers and controls. Wastewater workers were not found to be subject to any detectable risks due to parasites present in wastewater. There was only slight evidence, if any, to suggest that there were risks due to viruses and bacteria in wastewater.[29]

Data on health effects from the existing epidemiological studies do not show any correlation between the airborne pathogenic microorganism levels at wastewater treatment plants and incidence of disease among treatment plant workers or in nearby populations. However, the worst case of exposure of either the workers or the nearby populations has probably not yet been investigated. No adverse health effects have been reported in workers or in nearby populations at wastewater spray application facilities. From the data on health effects from existing epidemiological studies, the conclusion is that exposure to pathogenic microorganisms in wastewater aerosols is not a unique way of initiating enteric infections.[30]

Dusts generated during sludge heat-treatment operations and land application sites may contain significant quantities of toxins which may represent a potential health risk. The toxins of concern are endotoxins derived from bacteria and mycotoxins produced by fungi. Acute and chronic inflammation observed in workers exposed to dust generated at a sewage treatment plant were attributed to exposure to endotoxins in sewage dust.[30]

This toxicity discussion has been limited to the area of wastewater treatment. Although refuse is significantly different from sewage, there are similarities which may make some of the concerns voiced and the research done for sewage handling environments applicable to refuse and refuse derived fuel (RDF) operations. One would expect these concerns for RDF operations to be primarily applicable up to the point where the material is burned with the combustion process destroying spores and viable microorganisms as well as the endotoxins.

VI. RESULTS

A. March 1985 Follow-up Survey Data:

The results of the industrial hygiene data gathered during the March 1985 field survey will be presented in the following sequence: bulk samples, personal exposures to metals and respirable dust, heat stress measurements, and aerobiological sampling.

1. Bulk Samples:

A total of 16 bulk settled dust samples were collected, two for each of eight locations, in the following areas: the 690 level, the electrostatic precipitators (fly ash), the shredder house, the boiler floor, the refuse feed area, the dustless unloader, the coal feed area, and the catwalk to the overhead cranes at the shredded refuse storage pit.

The set of bulks, one from each location, analyzed for 31 metals indicated that the metals present in higher concentrations; or greater than one percent by weight in at least one sample, were: aluminum, calcium, iron, magnesium, sodium, and zinc. Bulk samples of fly ash from the electrostatic precipitators and dustless unloader had the highest concentrations, respectively, of the following metals: cadmium - 0.02%, 0.01%; sodium - 1.99%, 1.89%, phosphorus - 0.55%, 0.46%; lead - 0.54%, 0.45%; titanuim - 0.24%, 0.24%; and zinc - 1.35%, 1.13%.

The metals aluminum, barium, calcium, iron, magnesium, manganese, sodium, phosphorus, lead, and zinc were present in all bulk samples. Silver, beryllium, cobalt, lanthanum, lithium, platinum, antimony, selenium, tellurium, titanium, vanadium, yttrium, and zirconium were below the analytical limit of detection for all samples.

Crystalline silica identified as quartz was a constituent of all but one of the bulk samples and ranged from a trace amount in the bulk from the crane catwalk up to 4.2% in the bulk settled dust sample obtained from the shredder house.

Table V presents the data for metals and crystalline silica obtained for all bulk dust samples.

2. <u>Personal Exposures to Selected Metals, Respirable Dust, and Crystalline Silica</u>:

   a. Worker Exposures to Metals:

      Table VI presents worker exposures to cadmium, lead, chromium, and nickel. The respective settled dust bulk sample(s) obtained from the workers° general work areas and found in Table V are also listed for each sample.

      A total of 37 personal exposure samples for metals were obtained. Cadmium exposures ranged from below the calculated environmental limit of detection (CELOD) of 1 ug/m^3 up to 18 ug/m^3. Fourteen percent (5) of the samples were above the CELOD but no overexposures were documented.

      Lead exposures ranged from below 6 ug/m^3 up to 509 ug/m^3. Forty-three percent (16) of the samples were above the CELOD of 6 ug/m^3 and 11% (4) exceeded the OSHA permissible limit of 50 ug/m^3 for an eight-hour TWA.

Total chromium exposures ranged from below 3 ug/m^3 up to 18 ug/m^3. Nineteen percent (7) were above the CELOD. In the absence of information identifying the specific chromium compounds present (e.g. carcinogenic or noncarcinogenic compounds of chromium) application of the most stringent evaluation criteria results in 19% (7) of the samples being overexposures to chromium.

Nickel exposures ranged from below 3 ug/m^3 up to 11 ug/m^3 with 11% (4) values greater than the CELOD of 3 ug/m^3. No overexposures were documented.

b. Respirable Dust and Crystalline Silica Exposures:

Table VII presents the results of personal exposure monitoring for respirable dust and crystalline silica. A total of 29 samples were collected for these contaminants. Respirable dust exposures ranged from 0.09 mg/m^3 up to 14 mg/m^3 with an arithmetic mean of 0.81 mg/m^3 and standard deviation (SD) of 2.5 mg/m^3. All 29 samples were analyzed for crystalline silica as quartz and cristobalite. No detectable levels of cristobalite were observed. Two workers had respirable quartz exposures of 40 ug/m^3 and 240 ug/m^3 respectively. Their respective respirable dust exposures were 0.68 mg/m^3 and 14 mg/m^3 (See Table VII). Application of the NIOSH REL of 50 ug/m^3 for respirable free silica results in the identification of one overexposure and one exposure above the NIOSH action level of 25 ug/m^3.

3. Heat:

A total of 30 environmental heat stress measurements were obtained. Twenty-eight were taken at hot locations and a rest area in the plant and two were taken outdoors. Table VIII presents the various locations at which measurements were taken as well as the WBGT values and its constituent temperature measurements.

Outdoor WBGT measurements and the lunchroom have not been included in the following heat stress data summary. Dry bulb (DB) air temperatures at the locations measured ranged from 72°F (22°C) to 103°F (40°C). The arithmetic mean was 93°F (34°C) with a SD of 13°F. Globe temperatures, indicative of the radiant heat burden, ranged from 77°F (22°C) to 111°F (44°C) with a mean value of 99°F (37°C) and a SD of 11°F. Relative humidities for these locations ranged from 14 to 48%. The mean value is 25% with a SD of 8%.

The WBGT readings during the March survey ranged from 61°F (16°C) to 84°F (29°C). The mean WBGT is 77°F (25°C) and the SD is 6°F. NIOSH orginally defined hot environmental conditions as any combination of air temperature, humidity, radiation, and wind speed that exceeds a WBGT of 79°F (26°C).[1] The ACGIH and revised NIOSH heat exposure limit values are presented in Table IV.

4. Aerobiological Sampling:

Table IX presents the results of the aerobiological sampling for all sample durations and the respective sample counts after 24 and 48 hours of incubation. The sampling was limited to obtaining counts of colony forming units (CFU). The sampling train permitted division of the airborne microorganisms into respirable and nonrespirable fractions. These two values were subsequently summed to obtain the total CFU count.

The samples of one minute duration will be summarized here for the 24 hour colony count. The reader is referred to Table IX for the CFU counts obtained over longer sampling periods. The non-respirable CFU counts for the one minute samples ranged from 84 to 7368 CFUs/m^3; the respirable fraction (particles less than 8 um in size) CFU counts ranged from 368 CFU/m^3 to being overgrown (uncountable). The total CFUs/m^3 for samples of one minute duration counted after 24 hours of incubation ranged from 666 CFU/m^3 to 4525 CFU/m^3 with no total count for the sample obtained in the trash feed conveyor area obtained March 6, 1985, due to the respirable CFU plate being overgrown. The significance of these results is discussed in Section VII.

Control samples and blanks were also submitted in a effort to identify contamination of the growth medium during handling or from the samplers. Four unopened plates were submitted for incubation with the samples. One CFU on one plate was noted after incubation for both 24 and 48 hours. Plates placed into the samplers after the days sampling had been done, following the disinfection procedure (alcohol wipe), resulted in the growth of 7 colonies on four plates after 24 hours of incubation and 10 colonies on the four plates after 48 hours incubation.

B. August 1985 Follow-up Survey Data:

The results obtained from the second follow-up industrial hygiene survey conducted in August 1985 involved exposure monitoring for metals, coal dust, silica, and heat stress measurements. The personal exposures to metals and respirable dusts are given first, followed by heat stress measurements.

1. Personal Exposures to Lead, Total Chromium, Chromium VI (insoluble forms), Respirable Dust, Coal Dust, and Crystalline Silica:

   a. Worker Exposures to Lead, Total Chromium, and Chromium VI (insoluble forms):

      Table X presents worker exposures to lead, total chromium, and chromium VI (insoluble form). A total of 22 personal exposure samples for lead and total chromium were collected. Lead exposures ranged from below the CELOD of 4.7 ug/m^3 up to 46 ug/m^3. Thirty-six percent (8) of the samples were above the CELOD and one exposure (46 ug/m^3), when considering the sampling and analytical method's precision, was at the OSHA PEL of 50 ug/m^3 at the 95% confidence level.

      Total airborne chromium exposures were negligible when compared to the NIOSH non-carcinogenic chromium criterion of 25 ug/m^3. Total chromium concentrations were, with one exception, all below the CELOD of 4.6 ug/m^3. A maintenance worker on August 13, 1985 had a total airborne chromium exposure of 5 ug/m^3. This same worker had no detectable (less than 0.4 ug/m^3) exposure to the insoluble form of Chromium VI.

      A total of 20 samples were obtained for worker exposures to insoluble Chromium VI. Eight of 20 (40%) were above the CELOD, with a range from below 0.4 ug/m^3 (the CELOD) up to 0.8 ug/m^3.

      The highest exposure, 0.8 ug/m^3, occurred for the Boiler Rover on August 14. None of the exposures exceeded the NIOSH REL for insoluble (carcinogenic) forms of Chromium VI of 1 ug/m^3.

   b. Worker Exposures to Respirable Dust (including Coal Dust) and Crystalline Silica:

      Table X also presents sampling results for worker exposures to respirable dust, coal dust (in the case of the two workers in Coal Receiving), and respirable crystalline silica (as quartz and cristobalite). A total of seven respirable dust samples were collected. Respirable dust exposures ranged from 90 ug/m^3 to 480 ug/m^3. Coal dust exposures for the worker in Coal Receiving was 420 ug/m^3 both August 13 and 14, 1985. No crystalline silica exposures above the CELOD of 21 ug/m^3 were detected. The ACGIH TLV® for respirable nuisance dust is 5000 ug/m^3 and for respirable coal dust is 2000 ug/m^3. Both criteria have quartz content restrictions of less than 1% for nuisance dust and less than 5% for coal dust.[11]

2. Heat:

Heat stress measurements were repeated at as many of the 30 original locations used in the March survey as possible. A total of 41 heat stress measurements were obtained at 29 locations. Twenty eight included hot locations and one a rest area in the power plant. The remaining location was outdoors. Table XI presents the August results along with a numerical location key pairing locations at which measurements were obtained both in the March and August surveys. Eighteen locations from the March survey were re-evaluated. The remaining locations where similar in nature to those obtained during the previous survey.

Outdoor WBGT measurements and the lunchroom have not been included in the following heat stress data. Dry bulb air temperatures ranged from 103°F (39°C) to 120°F (49°C). The arithmetic mean was 111°F (44°C) with a SD of 4°F. Globe temperatures, indicative of the radiant heat burden, ranged from 97°F (36°C) up to 130°F (54°C) with a mean value of 116°F (47°C) and a SD of 6°F. Relative humidities for these locations ranged from 30 to 53% with a SD of 4%.

The WBGT readings during the August survey ranged from 90°F (32°C) to 102°F (39°C). The arithmetic mean WBGT is 96°F (36°C) with a SD of 3°F. The lowest WBGT value observed exceeds the original NIOSH 79°F (26°C) WBGT threshold defining hot environments. This data also exceeds all ACGIH and revised NIOSH evaluation criteria involving different work-rest regimens.

VII. DISCUSSION

A. Bulk Samples:

Bulk samples collected where ash was present contained higher concentrations of some metals than did the bulk samples of the unburned refuse. The removal of organic compounds during combustion appears to concentrate nonvolatile materials, including metals, in the residue or ash. Thus a given mass of airborne refuse has a much lower concentration of nonvolatile contaminants (for example metals such as lead or cadmium) per unit volume of air than an airborne suspension of an equal weight of ash in the same volume of air.

Work done by a Columbus engineering and architecture firm indicated that conditioned fly ash, obtained from the electrostatic precipitator ash collection equipment, should be classified as a hazardous waste based on its cadmium content. One sample was also considered to represent a hazardous waste based on a high lead content. Their data primarily addressed water quality associated with land fill disposal of the fly ash and therefore were not comparable to bulk sample data collected during this evaluation. The consultant recommended that personnel exposures to fly ash be limited and that appropriate action be taken to address the presence of cadmium and lead containing dusts in the workplace.

A note of caution concerning the extrapolation of metal content in the ash to a worker exposure is that it should not be done without also conducting actual exposure monitoring because of variables such as varying metal content in the refuse being burned, amount of refuse burned, and time period over which the bulk sample is collected (e.g. does it represent what was burned over two hours versus two weeks, is the ash from one or more boilers, etc.). In addition, where and how the sample is collected and the possibility of some nonuniform distribution in the ash (e.g. fly ash versus ash from the boiler grates) reinforces the need for not only (1) identifying if the contaminants are present, thus providing a potential for exposure, but also (2) characterizing actual exposures in the workplace during plant operation.

B. Metal Exposures:

The personal exposure monitoring data presented in Table VI demonstrates that worker overexposures to lead are occurring (up to a full-shift TWA of 509 ug/m^3, OSHA PEL = 50 ug/m^3). All lead overexposures were documented among workers having assignments for at least a portion of the workshift in areas where fly ash was collected or mechanically handled. Repeat sampling conducted during the second follow-up survey indicated the continued presence of lead. The lower lead exposures during the second follow-up survey are attributed to a lower number of activities involving fly ash exposures. The nature of the workers' activity in the various areas also influences the magnitude of their exposure: for example, rovers would pass through the area during the workshift tour of the entire power plant and have only a brief exposure in the area, dustless unloader operators would be operating equipment in the area all day, maintenance mechanics in the area may have a greater or lesser exposure depending upon their assigned task, and the exposure of personnel (e.g. electrician) required to enter a confined space such as an electrostatic precipitator may be very high.

Tampering with the samples collected was not considered a likely factor contributing to the observed high lead exposures because of the following considerations: (1) visual inspection of the filters during the workshift and upon sample termination did not result in any notably excessive amounts of loose material in the filter cassette; (2) the analytical laboratory report did not indicate any irregularities such as loose material, presence of coarse material, or damage to the filter (all cassettes had been assembled with shrink bands preventing their disassembly); and (3) a high lead content material or lead exposure process accessible to workers would need to be available. None had been noted during the walk-through and chemical inventory of the facility. One set of samples obtained during the August survey contained an excessively large amount of loose material. This set was not analyzed.

The use of steel grating on several of the floors in the electrostatic precipitator area allows the dispersion of ash released from the precipitators to drop down several floors. The ash handling areas are also open to other areas such as the boiler floor. During the March survey the power plant was burning about 500 to 600 tons of refuse per day while the average per day refuse consumption at the end of July 1985 was 1200 to 1400 tons per day. Not all boilers were operating during either survey and about 50% of the boilers in operation were burning coal.

Chromium exposures may also present a health risk due to the uncertain identity of the chromium compounds present. NIOSH, in the criteria document on chromium VI, considers water insoluble forms of chromium VI to be carcinogenic. The document also states that unless information provided by the employer can refute the assumption than any chromium VI compounds present are the carcinogenic forms, all airborne chromium VI compounds shall be considered to comprise carcinogenic materials.[8]

A variety of chromium compounds are likely to be present in the exposures occurring at the power plant. Chromium at different oxidation states (II, III, VI) is considered possible because of the combustion processes occurring in the boilers. Note that chromium content of the bulk samples was minimal or below analytical detection limits (Table V). Chromium sampling conducted during the second follow-up survey to further define exposures to this metal is presented in Table X. Total chromium and insoluble chromium VI exposures did not appear to present a problem during this latter survey. Again the potential for exposures to different chromium compounds is considered to be variable.

Cadmium and nickel exposures during the surveys were below applicable exposure criteria, however their presence in several exposure samples confirms these contaminants as being airborne in the workplace.

C. Respirable Dust Exposures:

Respirable dust exposures were surprisingly low, suggesting that the airborne dust may be fairly coarse. Note that this does not reduce the level of concern for more toxic contaminants such as lead. Additionally, the exclusive application of nuisance dust criteria to a substance of varying composition such as fly ash from refuse is not appropriate. One of the higher respirable dust exposures was noted for an electrician entering the electrostatic precipitators. This is a confined area with potentially very high dust levels. Referring to Table VII the reader will note that this worker was overexposed to crystalline silica (as quartz) and also had the highest lead, cadmium, chromium, and nickel exposures (See Table VI). The worker reportedly worked in the electrostatic precipitators for about three hours. One additional worker had a crystalline silica exposure (as quartz) which exceeded the NIOSH action level of (25 ug/m^3) but was below the maximum recommended exposure limit of 50 ug/m^3. He was involved with maintenance work in the trash bunkers from which shredded refuse is fed to the boilers.

Dust exposures during the August survey were negligible. Due to the lower general and maintenance activity levels, opportunities to monitor workers performing dust generating tasks were limited. No crystalline silica exposures were documented for these workers during this last survey. Activity in the coal receiving area was limited to several truck loads a day and mechanical problems in the Shredder House put activity there at a stand still. Inside the power plant, work requiring entry into electrostatic precipitators or on dust and fly ash handling equipment was very limited when compared to the earlier follow-up (March) survey.

Poor housekeeping practices, mechanical malfunctions, and deficient personal hygiene facilities and practices all contribute to the workers' exposure to the previously discussed identified airborne contaminants. A central vacuum cleaning system was noted to be present in the facility but reportedly was not used due to system performance limitations and mechanical malfunctions. Air lances were reportedly used to blow down shredded refuse dust by the eighth floor refuse conveyor, increasing any potential inhalation and explosion hazards. At some locations dust several inches deep was observed. Malfunctions in both refuse feed systems and ash handling equipment result in massive releases of both shredded refuse and ash into the work environment. Plugging of refuse feed conveyors resulted in the burial of stairways to the trash bunkers during conveyor cleanouts; unplugging of electrostatic precipitator hoppers resulted in fly ash cascading down through several floors; boiler ash handling system malfunctions resulted in mounds of debris on expanded steel catwalks and the use of bobcats to move sludge accumulations on the basement floor all represent examples of mechanical and work practice problems causing contaminant release into the work room.

The practice of permitting boiler operators to eat out on the boiler floor is unacceptable in the presence of contaminants such as lead and cadmium, as is the carrying and use of cosmetics or smoking materials in any of the plant areas where these contaminants are present. At the time of the August survey, boiler operators were no longer permitted to eat out by the boilers. Shower and locker facilities are deficient in that workers are provided with a single locker and locker room, preventing the separation of dirty and clean clothes and areas. Uniforms and laundry service for all employees is provided.

The use of nuisance dust respirators, especially in the fly ash handling areas, does not provide adequate protection against more toxic contaminants such as lead. The wearing of respirators by bearded employees is unacceptable because the protection offered by the respirator is greatly reduced due to the inability to obtain a good seal of the respirator on the worker's face.[31] A respiratory protection program was being implemented at the time of the second follow-up survey.

D. Heat Stress:

Heat stress measurements indicated the existence of hot work environments throughout the power plant. The work performed in these hot areas is limited primarily to maintenance activity and inspections by boiler or engineering rovers. The fifth through the ninth floors appear to contain the majority of hot areas (See Table VIII and XI). No maintenance activity was performed in these areas during the NIOSH surveys but discussion with the maintenance supervisors indicated that the duration spent in hot areas by maintenance personnel could range from 30 minutes to four hours, and possibly longer, depending on the job. The types of jobs performed can vary from light work (e.g. walking through an area and checking gauges) to heavy work (entering boiler hoppers and physically dislodging klinkers or breaking into rotary seal valves and breaking loose ash accumulations). Workers reportedly are permitted to self-pace their work. No provisions for resting in cooled areas existed in any of the hot work areas. The closest designated break area is the lunch room on the basement level.

Provisions for fluid replacement during work in hot areas was reported to be variable. No drinking fountains were present. Additionally there is no determination of worker fitness for work in a hot environment. Many of the maintenance activities may also require the use of respiratory protection.

Heat stress measurements obtained for various areas presented in Tables VIII and XI (excluding outdoors) are considered to represent a continuing heat exposure. The evaluation criteria presented in Table IV considers the rest area to be of the same thermal conditions as the work area. Many of the measurements for hot areas of the plant were taken in the aisles between equipment. When the monitor was moved closer to valves or equipment, the WBGT readings often increased. The measurements obtained here serve as indicators of problem areas. Measurements obtained in August represent levels during the hot season whereas the March survey is indicative of conditions during colder weather.

Eighteen of the measurements in March (Table VIII) and all of the August measurements, including outdoors, (Table XI) exceed the WBGT level for continuous heavy work as recommended by the ACGIH TLVé and the NIOSH revised hot environment exposure limits. Higher WBGT readings require longer resting periods per hour. For example, heavy work resulting in the production of 350 to 500 kilocalories of metabolic heat per hour that the activity is performed, would necessitate a work-rest regimen of 30 minutes of work combined with 30 minutes of rest per hour for WBGT values between 78.6 and 82.2°F (26 and 28°C) WBGT. Work of this intensity at WBGT values greater that 82.2°F and up to WBGT values of 86.0°F (30°C) would permit 15 minutes of work per hour and require 45 minutes of rest. Heat levels seen in August essentially preclude working on equipment or in the area without special heat-protective clothing and equipment.

E. <u>Aerobiological Sampling</u>:

Aerobiological sampling demonstrated that areas handling the refuse had higher airborne microbial levels than the ash handling area, office area, or outside of the facility. The significance of these levels is unclear since the types of organisms present and the innoculating doses required via inhalation exposures to pathogenic organisms are unknown. Additionally, evaluation guidelines that have been developed do not address this type of work environment. Variation was observed in the proportions of respirable and non-respirable fractions for airborne microbial contamination. Samples obtained outdoors and in the office environment had the majority of microbes in the respirable size range (8 microns and less). The lower non-respirable fraction may be due to the absence of gross airborne particle generation. The lowest total microbial count (for a 2 minute sample) was obtained in the dustless unloader area. The reason for this may be that the airborne contaminants released in this area have been burned and, based on the results of bulk ash sample analyses, probably do not provide a medium favorable to bacterial or fungal growth and survival. The fact that microbial counts fell for samples of longer duration (which were begun at the same time and location as the shortest sampling period sets) is considered to be due to the destruction of bacteria and/or fungi (the vegetative cells) by trauma (the mechanical shock of impact with the collection medium) and dessication (drying out of the cells due to longer periods of air passage across the collection medium). Relative humidity levels were low in all of the areas sampled for airborne microbial contamination.

VIII. CONCLUSION/SUMMARY

Based on the results of this investigation, health hazards from lead and silica exposures were concluded to exist. The overexposures to these chemical contaminants were limited to jobs and plant areas associated with the handling of ash. Low levels of exposure to lead as well as chromium, chromium VI, cadmium, and nickel were also seen in the facility. Excessive heat stress during maintenance activities in hot areas of the plant (floors 5 to 9) presents a potentially serious health hazard during both cool and hot seasons, but especially during warmer weather. Work in hot areas of the facility during hot weather, except for emergency activities, is not advisable. If such activities must be undertaken, extreme caution accompanying heat stress management activities and equipment is recommended. The higher airborne microbial contamination levels in the refuse handling areas at the facility indicate that exposure by the inhalation and ingestion routes exists. The extent to which this presents a health hazard is unknown. Considering the variability, source, and composition of the refuse, there is a potential for human pathogens to be present. Comparison to office and outdoor levels of airborne microbes demonstrates that indoor levels are elevated. This last area is one that will need further evaluation as techniques for assessing airborne microbial contamination and its significance evolve.

IX. RECOMMENDATIONS

A. Lead:

Worker exposures to lead should be reduced through the use of engineering controls. The plant management had indicated that all of the ash handling equipment currently present was scheduled to be replaced. A system designed in such a way to minimize the release of ash into the plant and also to allow for routine maintenance and dislodging of ash accumulation without breaking into the system and producing a subsequent release of ash into the work area is recommended. Work practices will also influence the effectiveness of this approach.

Employers with workers in lead contaminated areas where their time-weighted airborne exposure exceeds 50 ug/m^3 are required by the OSHA lead standard, 1910.1025[13] to provide clean change rooms and assure that change rooms are equipped with separate storage facilities for protective work clothing and equipment and for street clothes which will prevent cross-contamination.

The reader is referred to the OSHA lead standard, 1910.1025, for further discussion of the steps to be implemented in order to reduce worker exposures to lead. The areas to be addressed include engineering controls and work practices (administrative), personal protective equipment, maintenance of personal protective equipment, housekeeping, personal hygiene facilities and practices, medical surveillance, and medical removal protection, employee information and training, and signs.

B. Other Metals and Contaminants:

Eating, drinking, carrying or using tobacco products, and the carrying or use of cosmetics in the power plant and refuse handling areas should be prohibited. Due to the variety of toxic substances potentially present, exposures by all routes including ingestion and inhalation should be prevented. This has also eliminated the practice of boiler operators eating their lunches out on the boiler floor.

Dry sweeping and the use of compressed air for removing dust accummulations from surfaces should be discontinued and vacuuming or wet clean-up used instead. Concern was expressed by the NIOSH investigators during the March 1985 survey over the practice of blowing shredded refuse dust off of walkways and the explosion potential this suspended material would present.

Enclosure or collection of airborne dust at material transfer points is recommended. The plant management indicated that dust collection systems were scheduled for installation on refuse handling equipment.

Single-use disposable dust respirators are not recommended for general use in this facility. This type may be acceptable in the refuse preparation and handling areas, but in areas where toxic substances such as lead, silica, and chromium are present the higher protection factors provided by half- or full-face respirators, for example, is advised. In regard to using powered air purifying respirators, or negative pressure air purifying respirators with high efficiency particulate air (HEPA) filters, pre-filters should be used to extend the life of the HEPA filter and prevent rapid plugging from larger particles. Establishment of a respiratory protection program complying with the OSHA respiratory protection standard 1910.134[13] is also required.

Workers who are required to wear respirators must also be clean shaven. Facial hair interferes with the facepiece to face seal of the respirator reducing the amount of protection provided by leakage around the respirator.

C. Heat:

The control of heat can be approached by addressing the various components which contribute to heat stress.[32]

The four environmental heat exchange components contributing to heat stress and possible corrective actions which can be taken are:

(1) Metabolism: reduce this component by; mechanization of some or all tasks, sharing of workload with others (particularly during peak heat periods), increasing the rest time.

(2) Radiation: reduction of this component occurs by; minimizing the line-of-sight to source (shielding), insulating furnace walls, using reflective screens, wearing reflective aprons (particularly valuable when workers face the source), and covering exposed body parts.

(3) Convection: corrective action for this component is influenced by air temperature. If air temperature is above 98°F (35°C), reduce convection heat gain by; lowering air temperature, lowering air velocity, and wearing clothing. If air temperature is below 95°F (35°C) convective heat gain is reduced by; lowering air temperature, increasing air velocity, and removing clothing.

(4) Maximum evaporative capacity of the environment can be increased by increasing air velocity (taking into consideration item 3 above) and decreasing humidity.

Work schedule modifications to reduce heat stress are:

(1) Duration: shorten the time of exposure, use more frequent rest periods.

(2) Recovery: use nearby air conditioned space for a rest area, adjust air velocity in rest area for effective cooling.

(3) Other items: allow the worker to self-limit exposure on the basis of signs and symptoms of heat strain.

Clothing can be used to control heat stress. For extreme conditions, use of cooled clothing (by vortex tube or other means) may be effective. Workers should wear a type of clothing permitting a maximum evaporation rate in excess of the required evaporation rate, resulting in a minimum amount of sweat accumulation.

Worker education concerning the signs and symptoms of heat stress as well as corrective actions to be taken by the individual should be a part of the workers' training. Workers should also be free to discontinue their work in hot environments if extreme discomfort is experienced.

A buddy system should be implemented in which workers in designated hot areas are responsible for observing fellow workers for early signs and symptoms of heat intolerance such as weakness, unsteady gait, irritability, disorientation, changes in skin color, or general malaise.[2]

Adequate amounts of cool, i.e., 50° to 59°F (10° to 15°C) potable water near the work area should be provided. All workers are encouraged to drink a cup of water, about 5 to 7 ounces (150-200 milliliters) every 15 to 20 minutes even in the absence of thirst. Individual drinking cups are to be provided.[2]

A written Heat-Alert Program should be developed and implemented whenever the National Weather Service or other competent weather forecast service forecasts that a heat wave is likely to occur the following day or day. A heat wave is indicated when daily maximum temperature exceeds 95°F (35°C) or when the daily maximum temperature exceeds 90°F (32°C) and is 9°F (5°C) or more above the maximum reached on the preceeding days.[2]

Dangerous heat-stress areas, areas where protective clothing or equipment are required, should be posted in a readily visible manner upon approach to the area. The sign should contain information on the required protective clothing or equipment, hazardous effects of heat stress on human health, and information on emergency measures for heat injury or illness.[2]

Preplacement and periodic medical examinations should be provided for workers in any hot job where the work load is heavy or heat exposures are extreme.

Modifications in air circulation through the hotter areas of the plant is unlikely by itself to resolve the heat stress problem. The radiant heat load (GT) and high DB temperatures (above body temperature) would contribute to a net heat gain for unprotected workers spending any amount of time in the hot areas of the plant.

D. Aerobiological Contamination:

Good personal hygiene practices should be stressed for workers in the refuse processing and handling areas. The use of dust masks in the absence of toxic chemical contaminants or high dust levels is optional. A half-face respirator equipped with dust cartridges is preferable if a respirator is used.

Further study of this situation to characterize the types and identities of microorganisms present would assist in defining the exposures workers are receiving. A resource available to conduct such work may be the local university biology or environmental health departments.

E. General:

A pre-employment, pre-placement physical should be offered to new employees with consideration given to the job or work areas to which the worker will be assigned. Conditions which the worker can encounter at this facility are high dust levels, toxic metals, use of respiratory protection, hot work environments, silica, microbial contaminants (pathogenic and non-pathogenic types), and heavy manual labor.

Workers should be informed of the hazards in the workplace and instructed in the proper work practices, use of engineering controls, use of personal protective equipment, and personal hygiene to reduce their exposures to hazardous contaminants or conditions.

The services of a qualified industrial hygienist should be obtained to conduct further industrial hygiene evaluations characterizing worker exposures throughout the facility. This would serve to establish a data base of worker exposures useful in identifying problem areas. Additionally his/her services would be valuable in developing and implementing corrective measures addressing problem exposures and in evaluating the effectiveness of these actions. This individual would need to work with the safety program manager and the plant manager.

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XII. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Publications Dissemination Section, 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. City of Columbus, Division of Electricity
2. American Federation of State, County, and Municipal Employees, Local 1632
3. Ohio Industrial Commission
4. NIOSH Region V
5. OSHA Region V

For the purpose of informing the approximately 150 affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Job Titles and Descriptions of Workers Participating in Exposure Monitoring

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 1985

Job Title	Description and Examples
Boiler Operator	Responsible for firing one or more boilers, assure that combustion of fuel occurs properly, monitor burning of refuse in boilers; performs related tasks as required. May be designated rover-requiring tours of the boiler house to check boiler equipment located outside of the boiler floor area.
Steam Operating Engineer	Responsible for the operation of turbines, high pressure steam boilers and related auxiliary equipment, and the refuse/coal-fired municipal electric plant; performs related tasks as required. Duties include inspection of operating equipment to insure proper function, perform major maintenance and repair, and make adjustments to operating equipment giving direction and assignments to high pressure boiler operators in the operation and maintenance of plant equipment. May be assigned as a rover.
Bridge Crane Operator	Responsible for operating a high speed overhead bridge crane at the Refuse/Coal-Fired Municipal Electric Plant; performs related duties as required.
Plant Maintenance Electrician	Responsible for performing journeyman level skilled electrician work in connection with the installation, servicing, and maintenance of electrical equipment and wiring systems; performs related tasks as required. Examples include cleaning and inspecting electrical equipment and motors and replacing brushes and defective parts; works with high voltage equipment within a building or on grounds adjacent to buildings.
Laborer	Responsible for performing routine manual labor work. Duties at the electric power facility may include working in refuse delivery, fuel preparation, and boiler feed areas, operating ash handling equipment, and unloading coal from coal cars.
Plant Maintenance Helper	Serves as a helper to Plant Maintenance Mechanics or greases, oils and wipes moving parts of turbines, engines and pumps; performs related duties as required. Activities may include assisting Plant Maintenance Mechanics in dismantling, repair and reassembly of motors, pumps, and related equipment; assisting maintenance crews in the repair and maintenance of boilers; filling boiler hoppers with coal; and removing ashes from boiler ash pits.

continued

Table I (continued)

Job Titles and Descriptions of Workers Participating in Exposure Monitoring

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 1985

Job Title	Description and Examples
Plant Maintenance Mechanic	Responsible for installing, maintaining, and repairing a wide variety of mechanical equipment used in utility plants; performs related tasks as required. Duties include installing and repairing pumps, motors, compressors, and generating equipment, welding; repairing high and low pressure boilers, stokers, and steam turbines; may operate air hammers, air pipe cleaners, rotary masonary drills, threading machine, high lift trucks, metal drills, power saws, soot blowers, grinders, and welding equipment.
Plant Pulverizer Operator	Responsible for operating and monitoring a refuse pulverizer and for operating heavy duty motorized equipment used in the processing of refuse and coal, performs related tasks as required. Duties include operating remote controls for a refuse pulverizer, monitoring equipment function, operating a four-wheel drive front-end loader, guide refuse trucks to conveyor belt to dump load, and cleans floor area next to conveyor belt using front-end loader and broom.

TABLE II

Air Sampling and Analytical Methods

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 1985

Contaminant*	Sample Type+	Collection Medium@	Flow Rate**	Analysis and Modification++	LOD (LOQ)@@	Reference
Heat	Area	Wibget® Direct Reading Heat Stress Monitor	NA	Direct reading instrumentation-WBGT	NA	1,2
Microbial Contamination	Area	Tryptone glucose extract agar, Andersen two stage viable sampler®	1 cfm	Aerobic incubation at 35-37°C, colony counts at 24 and 48 hours	NA	3
Metals-Screens for 31 elements	Bulk rafter	Scintillation vial	NA	Aliquots weighed and digested with nitric and perchloric acids. Residues redissolved in dilute solution of same acids, resulting solution analyzed by inductively coupled plasma - atomic emission spectroscopy.	0.01% by weight	-
Cadmium, Lead Chromium, Nickel	Breathing Zone	37 millimeter mixed cellulose ester filter	1-2Lpm	Filters wet-ashed with nitric and perchloric acid Ashed sample diluted to 25 mL and analyzed by atomic absorption spectrophotometry.	Cd - 1ug Pb - 5ug, 3ug Cr - 3ug Ni - 3ug	NIOSH Method P&CAM 173, ref. 4; 7300, ref. 5
Chromium VI, insoluble hexavalent form	Breathing zone	37 millimeter unweighted PVC filter	1-2Lpm	Visible sprectroscopy	0.2 ug	NIOSH Method-7600, ref. 5
Respirable Dust, Respirable Coal Dust	Breathing zone	37 millimeter pre-weighted PVC filter preceeded by a 10 millimeter nylon cyclone	1.7 Lpm	Tared filters re-weighed in duplicate after sampling on an electrobalance Instrumental precision of weighing done at one sitting is 0.01 milligrams.	Instrumental precision 0.01mg	Sampling Data Sheet #29.02 ref. 6; NIOSH Method 0600, ref. 5

continued

TABLE II (continued)

Air Sampling and Analytical Methods

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 1985

Contaminant*	Sample Type+	Collection Medium@	Flow Rate**	Analysis and Modification++	LOD (LOQ)@@	Reference
Crystalline Silica (Quartz and Cristobalite)	Bulk rafter	Scintillation vial	NA	Bulk samples analyzed for quartz and cristobalite using X-ray diffraction. Modifications: 1) Filters were dissolved in tetrahydrofuran rather than being ashed in a furnance. 2) Standards and samples were run concurrently and an external calibration curve was prepared from the integrated intesities rather than using the suggested normalization procedure.	March results: Quartz-0.75% by wt. (1.5% LOQ) Cristobalite-0.75% by wt. (1.5% LOQ) August results: 1-5%	NIOSH method 7500, ref. 5
Crystalline Silica (Quartz and Cristobalite)	Breathing zone	37 millimeter preweighed PVC filter preceeded by a 10 millimeter cyclone (same sample previously weighed for respirable dust).	1.7 Lpm	Same analytical procedure as was used for the bulk samples.	Quartz - 15 ug/ filter (30 ug/ filter LOQ) Cristobalite - 15 ug/ filter (30 ug/filter LOQ)	NIOSH Method 7500, ref. 5

* Analytes or agent of interest.

\+ Sample types were general area (designated Area); Bulk rafter (i.e. settled dust collected from horizontal structural surfaces); and Breating zone - a sample obtained by having the worker wear a personal exposure sampling pump clipped onto the collar.

@ Collection medium indicates what the sample was collected or taken with, on, or in. Pre-calibrated Andersen Samplers® were equipped with a critical orifice, air was drawn through the sampler with a Gast® vacuum pump. Personal exposure samples were collected using pre-calibrated SKC universal sampling pumps. Calibration of these personal sampling pumps was checked during the workshift. PVC = polyvinyl chloride.

** Air sampling rate is indicated by not applicable (NA), cubic feet per minute (cfm), or liters per minute (Lpm).

++ This column indicates analytical method used and any modifications indicated in the laboratory report of analytical results. WBGT = wet bulb globe temperature; C=degrees celsius; mL-milliliters.

@@ LOD = limit of detection with LOQ (limit of quantitation) given in parentheses if applicable. NA = not applicable; ug = microgram; mg = milligram; Cd = cadmium, Pb = lead, Cr = chromium, Ni = nickel. Percentages given (%) are contaminant in sample by weight. For breathing zone metal analyses, the LOD of Pb for the August survey was 3ug/sample.

TABLE II (continued)

Air Sampling and Analytical Methods

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 1985

Contaminant*	Sample Type+	Collection Medium@	Flow Rate**	Analysis and Modification++	LOD (LOQ)@@	Reference
Crystalline Silica (Quartz and Cristobalite)	Bulk rafter	Scintillation vial	NA	Bulk samples analyzed for quartz and cristobalite using X-ray diffraction. Modifications: 1) Filters were dissolved in tetrahydrofuran rather than being ashed in a furnance. 2) Standards and samples were run concurrently and an external calibration curve was prepared from the integrated intesities rather than using the suggested normalization procedure.	March results: Quartz-0.75% by wt. (1.5% LOQ) Cristobalite-0.75% by wt. (1.5% LOQ) August results: 1-5%	NIOSH method 7500, ref. 5
Crystalline Silica (Quartz and Cristobalite)	Breathing zone	37 millimeter preweighed PVC filter preceeded by a 10 millimeter cyclone (same sample previously weighed for respirable dust).	1.7 Lpm	Same analytical procedure as was used for the bulk samples.	Quartz - 15 ug/filter (30 ug/filter LOQ) Cristobalite - 15 ug/filter (30 ug/filter LOQ)	NIOSH Method 7500, ref. 5

* Analytes or agent of interest.

\+ Sample types were general area (designated Area); Bulk rafter (i.e. settled dust collected from horizontal structural surfaces); and Breating zone - a sample obtained by having the worker wear a personal exposure sampling pump clipped onto the collar.

@ Collection medium indicates what the sample was collected or taken with, on, or in. Pre-calibrated Andersen Samplers® were equipped with a critical orifice, air was drawn through the sampler with a Gast® vacuum pump. Personal exposure samples were collected using pre-calibrated SKC universal sampling pumps. Calibration of these personal sampling pumps was checked during the workshift. PVC = polyvinyl chloride.

** Air sampling rate is indicated by not applicable (NA), cubic feet per minute (cfm), or liters per minute (Lpm).

++ This column indicates analytical method used and any modifications indicated in the laboratory report of analytical results. WBGT = wet bulb globe temperature; C=degrees celsius; mL-milliliters.

@@ LOD = limit of detection with LOQ (limit of quantitation) given in parentheses if applicable. NA = not applicable; ug = microgram; mg = milligram; Cd = cadmium, Pb = lead, Cr = chromium, Ni = nickel. Percentages given (%) are contaminant in sample by weight. For breathing zone metal analyses, the LOD of Pb for the August survey was 3ug/sample.

Table III

Chemical Contaminant Exposure Evaluation Criteria and Health Effects Summary

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 1985

Contaminant+	Recommended Exposure Limit++ (ug/m³)	Source*	OSHA** (ug/m³)	Symptoms***	Target Organs***
Cadmium (Cd)	40	NIOSH	200	Pulmonary edema, dyspnea, cough, tightness in chest, substernal pain; headache, chills, muscle ache; nausea, diarehea; anosmia, emphysema; proteinuria; anemia; lung cancer	Respiratory system, lungs, kidney, prostate, blood
Coal Dust (Respirable)	2000 (5% quartz)	ACGIH	2400	coal workers pneumoconiosis, progressive massive fibrosis	Lungs
Chromium (Cr)	1 (Note 1) 25 (Note 2)	NIOSH	500 (Note 3) 1000 (Note 4) 100-C (Note 5)	Respiratory irritation; nasal septum irritation; leukocytosis, leukopenia, monocytosis, eouinophilia; eye injury, conjunctivitis; skin ulcers, sensitization dermatitis; lung cancer, histologic fibrosis lungs.	Blood lungs, respiratory system, liver, kidneys, eyes, skin
Lead (Pb)	<100	NIOSH	50	Lassitude, insomnia, pallor, eye grounds; anorexia, weight loss, malnutrition, constipation, abdominal pain, colic; hypotense, anemia; gingival lead line, tremors, wrist paralysis.	Gestrointestinal system, central nervous system, kidneys, blood, ginguval tissue.
Nickel (Ni)	15	NIOSH	1000	Sensitization dermatitis; cancer lungs, nasal cavities; pneumonitis; allergic asthma.	Nasal cavities lungs, skin.
Respirable Dust (Nuisance)	5000 (<1% quartz)	ACGIH	5000	Long history of little adverse effect on lungs and do not produce significant organic disease or toxic effect. No contaminants having greater individual toxicity are present. Long-time reaction caused by inhalation of nuisance dusts has the following characteristics: 1) the architecture of the air spaces remains intact. 2) Collagen (scar tissue) is not formed to a significant extent. 3) The tissue reaction is potentially reversible.	Lungs

continued

Table III (continued)

Chemical Contaminant Exposure Evaluation Criteria and Health Effects Summary

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 1985

Contaminant+	Recommended Exposure Limit++ (ug/m3)	Source*	OSHA** (ug/m3)	Symptoms***	Target Organs***
Silica (SiO_2) (crystalline)	50	NIOSH	Note 6	Cough, dyspnea, wheezing; impaired pulmonary function; progressive symptoms.	Respiratory system, lungs

+ Contaminants listed by the name of the metal with the symbol in parenthesis.
++ Recommended exposure limits are given in micrograms per meter cubed (ug/m3).
* NIOSH recommended exposure limits obtained from the respective criteria documents except for lead which is obtained from NIOSH testimony to the U.S. Department of Labor. See references 7(Cd), 8(Cr), 9(Pb), 10(Ni), 11(dusts), and 12(SiO_2).
** OSHA Permissible Exposure Limits (PEL) given in micrograms per meter cubed (ug/m3), reference 13.
*** Symptoms and Target Organs listings obtained from the NIOSH/OSHA Pocket Guide to Chemical Hazards, reference 14. Description of nuisance dust criteria from the ACGIH TLV's® for 1985-86, reference 11. Symptoms of coal dust overexposure taken from reference 15.

Note 1: The 1 ug/m3 recommended chromium exposure limit is for carcinogenic chromium (VI) compounds. See Toxicity Discussion in Section V.
Note 2: The 25 ug/m3 recommended chromium exposure limit is for noncarcinogenic chromium (VI) compounds. See Toxicity Discussion Section V.
Note 3: The 500 ug/m3 OSHA-PEL is for soluble chromic and chromous salts as chromium.
Note 4: The 1000 ug/m3 OSHA PEL is for chromium metal and insoluble salts.
Note 5: The OSHA ceiling value (C) for chromic acid and chromates is 100 ug/m3. All other values presented in this table are for full-shift eight-hour time weighted averages (8-10 hours for NIOSH criteria).
Note 6: The OSHA respirable crystalline silica PEL in ug/m3 is calculated for each sample by the following formula: $\frac{10000\ ug/m^3}{(\%\ SiO_2\ in\ sample)+2} = PEL\ ug/m^3$

Table IV

ACGIH and NIOSH Recommended Heat Exposure Limit Values

City of Columbus R.D.F. Electric Power Plant
Columbus, Ohio
HETA 85-041

Work-Rest Regimen*	Work Load** Light (up to 200 Kcal/hr)	Moderate (200-350 k cal/hr)	Heavy (350-500 kcal/hr)
	Values are given in °C(°F) WBGT		
Continuous work	30.0 (86.0)	26.7 (80.1)	25.0 (77.0)
75% work - 25% rest, each hour	30.6 (87.1)	28.0 (82.4)	25.9 (78.6)
50% work - 50% rest, each hour	31.4 (88.5)	29.4 (84.9)	27.9 (82.2)
25% work - 75% rest, each hour	32.2 (90.0)	31.1 (88.0)	30.0 (86.0)

* The work-rest regimen defines what portion of each hour is spent working in the hot environment with the assumption that thermal conditions (WBGT) in the rest area are the same or very close to those of the work place. Where WBGT of the work area is different from that of the rest area a time-weighted average value should be used for both environmental and metabolic heat. Use of this latter approach (rest area with a different WBGT) requires the use of figure 1 presented in reference 11.

** Work load category is established by ranking each job or task performed into light, medium, and heavy categories based on the type of physical activity (and resulting metabolic heat generated) required by the job. Examples of work in the different categories is given as: light work - sitting or standing to control machines, performing light hand or arm work; moderate work - walking about with moderate lifting and pushing; heavy work - pick and shovel work.

Kcal/hr = kilocalories per hour or essentially the metabolic energy requirement for the activity (which results in internal heat generation by the worker's body). Values in the table are given in degrees celcius (°C) with values in degrees farenheit (°F) in parentheses for the Wet Bulb Globe Thermometer (WBGT).

Note: The reader is referred to the ACGIH Heat Stress Threshold Limit Value found in reference 11 and the NIOSH Occupational Exposure to Hot Environments Revised Criteria, reference 2.

Table V

Selected Bulk Sample Constituents Given In Percent By Weight

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 1985

Sample Location*:	690 Level	Fly Ash ESP	Shredder House	Boiler Floor	Refuse Feed	Dustless Unloader	Coal Feed	Crane Catwalk
SAMPLE:	402	403	404	407	408	412	414	415
AG+	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
AL	3.23	4.84	0.92	3.85	0.28	4.25	0.34	0.23
AS	0.02	0.03	<0.01	0.03	<0.01	0.03	<0.01	<0.01
BA	0.07	0.08	0.04	0.06	0.01	0.06	0.01	0.01
BE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CA	6.17	5.91	5.98	4.74	1.91	4.81	1.17	1.78
CD	<0.01	0.02	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
CO	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CR	0.01	0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01
CU	0.05	0.04	0.03	0.04	<0.01	0.04	<0.01	<0.01
FE	2.19	1.82	1.32	2.04	0.41	1.85	0.85	0.36
LA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LI	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MG	0.93	1.09	0.71	0.85	0.21	0.81	0.15	0.21
MN	0.09	0.12	0.08	0.09	0.03	0.10	0.02	0.03
MO	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NA	1.14	1.99	0.39	1.47	0.30	1.89	0.17	0.26
NI	0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01

continued

Table V (continued)

Selected Bulk Sample Constituents Given In Percent By Weight

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 1985

Sample Location*:	690 Level	Fly Ash ESP	Shredder House	Boiler Floor	Refuse Feed	Dustless Unloader	Coal Feed	Crane Catwalk
SAMPLE:	402	403	404	407	408	412	414	415
P	0.40	0.55	0.40	0.43	0.15	0.46	0.06	0.12
PB	0.24	0.54	0.04	0.36	0.03	0.45	0.02	0.04
PT	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SB	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SR	0.03	0.03	0.02	0.03	<0.01	0.03	<0.01	<0.01
TE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TI	0.20	0.24	0.03	0.22	<0.01	0.24	<0.01	<0.01
TL	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
V	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Y	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ZN	0.66	1.35	0.10	1.00	0.05	1.13	0.06	0.06
ZR	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sample:	405	411	401	406	400	413	409	410
Quartz+	2.9	2.5	4.2	2.7	<0.75	1.8	3.6	Trace
Cristobalite+	<0.75	<0.75	<0.75	<0.75	<0.75	<0.75	<0.75	<0.75

* Sample Location: indicates area where bulk was obtained.
Refuse feed area located on 4th floor, Coal feed area located on 8th floor, ESP = electrostatic precipitators.

\+ Less than (<) values indicated that the contaminant, if present, was below the analytical limit of quantitation for the metals analyses and below the analytical limit of detection for silica (quartz, cristobalite) analyses. The trace quartz value indicates quartz was identified as being present in the bulk but below the limit of quantitation of 1.5%.

Metals analyzed are: silver (AG), aluminum (AL), arsenic (AS), barium (BA), beryllium (BE), calcium (CA), cadmium (CD), cobalt (CO), chromium (CR), copper (CU), iron (FE), lanthanum (LA), lithium (LI), magnesium (MG), manganese (MN), molybdenum (MO), sodium (NA), nickel (NI), phosphorus (P), lead (PB), platinum (PT), antimony (SB), selenium (SE), strontium (SR), tellurium (TE), titanium (TI), thalluim (TL), vanadium (V), yittrium (Y), zinc (ZN), zirconium (ZR).

TABLE VI

Workers Exposures to Cadmium, Lead, Chromium, and Nickel

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 5-7, 1985

Sample Description*			Sample Duration (minutes)	Contaminant Concentrations in ug/m3**				Settled Dust Bulk Sample***
Date	Job Title	Work Location		Cd	Pb	Cr	Ni	
3/6	Plant Pulverizer Operator	Shredder House	405	ND	ND	ND	ND	404
3/6	Front-end Loader	Shredder House	415	ND	7.2	ND	ND	404
3/7	Plant Pulverizer Operator	Shredder House	445	ND	ND	ND	ND	404
3/7	Front-end Loader	Shredder House	445	ND	ND	5.6	ND	404
3/5	Laborer	Tipping Pad	475	ND	ND	ND	ND	404, 408, 415
3/6	Laborer	Tipping Pad	479	ND	ND	ND	ND	404, 408, 415
3/5	Laborer	Refuse Feed-4th floor	483	ND	ND	ND	ND	408
3/5	Laborer	Refuse Feed-4th floor	481	ND	9.4	ND	ND	408
3/6	Laborer	Refuse Feed-4th floor	492	ND	6.1	ND	ND	408
3/7	Laborer	Refuse Feed-4th floor	492	ND	ND	ND	ND	408
3/5	Laborer	Coal Delivery-8th floor	465	ND	ND	ND	4.4	414
3/5	Operating Engineer Rover	Power Plant (entire)	461	ND	ND	ND	ND	403, 407, 412
3/5	Boiler Operator	Boiler Floor	475+	ND	6.3	ND	ND	407
3/5	Boiler Operator	Boiler Floor	461	ND	ND	ND	ND	407
3/5	Boiler Rover	Power Plant (entire)	477	ND	ND	ND	ND	403, 407, 412
3/6	Operating Engineer Rover	Power Plant (entire)	447	ND	ND	ND	ND	403, 407, 412
3/6	Boiler Rover	Power Plant (entire)	463	ND++	10.4++	ND++	ND++	403,407,412
3/7	Boiler Operator	Boiler Floor	476	ND	ND	ND	ND	407
3/7	Boiler Operator	Boiler Floor	475	ND	ND	ND	ND	407
3/7	Boiler Rover	Boiler Floor/Quench Basin	470	ND	ND	ND	ND	402, 407
3/7	Operating Engineer Rover	Power Plant (entire)	417	ND	ND	ND	ND	402, 407
3/5	Electrician	Electrostatic Precipitators	491+++	18	509	17	11	403
3/6	Maintenance Mechanic	Electrostatic Precipitators@	356	ND	11	ND	ND	403
3/6	Maintenance Mechanic	Electrostatic Precipitators@	400	ND	21	ND	ND	403
3/5	Laborer-Operator	Dustless Unloader	480	6.3	156	9.4	4.2	412
3/5	Maintenance Helper	Dustless Unloader	474	ND	8.4	ND	ND	412
3/5	Maintenance Mechanic	Dustless Unloader	439	ND	23	18	ND	412
3/5	Maintenance Mechanic	Dustless Unloader	437	ND	19	ND	ND	412
3/7	Laborer	Dustless Unloader/Quench Basin	486	5.1	175	6.2	3.1	402, 412
3/7	Maintenance Mechanic	Dustless Unloader @@	460	ND	17	11	ND	412
3/7	Maintenance Mechanic	Dustless Unloader@@	457	1.1	18	9.8	ND	412

continued

TABLE VI

Workers Exposures to Cadmium, Lead, Chromium, and Nickel

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 5-7, 1985

Sample Description*			Sample Duration (minutes)	Contaminant Concentrations in ug/m3**				Settled Dust Bulk Sample***
Date	Job Title	Work Location		Cd	Pb	Cr	Ni	
3/6	Plant Pulverizer Operator	Shredder House	405	ND	ND	ND	ND	404
3/6	Front-end Loader	Shredder House	415	ND	7.2	ND	ND	404
3/7	Plant Pulverizer Operator	Shredder House	445	ND	ND	ND	ND	404
3/7	Front-end Loader	Shredder House	445	ND	ND	5.6	ND	404
3/5	Laborer	Tipping Pad	475	ND	ND	ND	ND	404, 408, 415
3/6	Laborer	Tipping Pad	479	ND	ND	ND	ND	404, 408, 415
3/5	Laborer	Refuse Feed-4th floor	483	ND	ND	ND	ND	408
3/5	Laborer	Refuse Feed-4th floor	481	ND	9.4	ND	ND	408
3/6	Laborer	Refuse Feed-4th floor	492	ND	6.1	ND	ND	408
3/7	Laborer	Refuse Feed-4th floor	492	ND	ND	ND	ND	408
3/5	Laborer	Coal Delivery-8th floor	465	ND	ND	ND	4.4	414
3/5	Operating Engineer Rover	Power Plant (entire)	461	ND	ND	ND	ND	403, 407, 412
3/5	Boiler Operator	Boiler Floor	475+	ND	6.3	ND	ND	407
3/5	Boiler Operator	Boiler Floor	461	ND	ND	ND	ND	407
3/5	Boiler Rover	Power Plant (entire)	477	ND	ND	ND	ND	403, 407, 412
3/6	Operating Engineer Rover	Power Plant (entire)	447	ND	ND	ND	ND	403, 407, 412
3/6	Boiler Rover	Power Plant (entire)	463	ND++	10.4++	ND++	ND++	403,407,412
3/7	Boiler Operator	Boiler Floor	476	ND	ND	ND	ND	407
3/7	Boiler Operator	Boiler Floor	475	ND	ND	ND	ND	407
3/7	Boiler Rover	Boiler Floor/Quench Basin	470	ND	ND	ND	ND	402, 407
3/7	Operating Engineer Rover	Power Plant (entire)	417	ND	ND	ND	ND	402, 407
3/5	Electrician	Electrostatic Precipitators	491+++	18	509	17	11	403
3/6	Maintenance Mechanic	Electrostatic Precipitators@	356	ND	11	ND	ND	403
3/6	Maintenance Mechanic	Electrostatic Precipitators@	400	ND	21	ND	ND	403
3/5	Laborer-Operator	Dustless Unloader	480	6.3	156	9.4	4.2	412
3/5	Maintenance Helper	Dustless Unloader	474	ND	8.4	ND	ND	412
3/5	Maintenance Mechanic	Dustless Unloader	439	ND	23	18	ND	412
3/5	Maintenance Mechanic	Dustless Unloader	437	ND	19	ND	ND	412
3/7	Laborer	Dustless Unloader/Quench Basin	486	5.1	175	6.2	3.1	402, 412
3/7	Maintenance Mechanic	Dustless Unloader @@	460	ND	17	11	ND	412
3/7	Maintenance Mechanic	Dustless Unloader@@	457	1.1	18	9.8	ND	412

continued

TABLE VI (continued)

Workers Exposures to Cadmium, Lead, Chromium, and Nickel

City of Columbus R.D.F. Power Plant
Columbus, Ohio
HETA 85-041

March 5-7, 1985

Sample Description*									
Date	Job Title	Work Location	Sample Duration (minutes)	Contaminant Concentrations in ug/m3** Cd	Pb	Cr	Ni	Settled Dust Bulk Sample***
3/5	Laborer	690 Level	462	ND	ND	ND	ND	402
3/5	Laborer	690 Level/Dustless Unloader	458#	2.2	51	ND	ND	402,412
3/5	Laborer	690 Level/Quench Basin	479	ND	ND	ND	ND	402
3/6	Laborer	690 Level	182	ND	ND	ND	ND	402
3/6	Laborer	690 Level/Quench Basin	475	ND	ND	ND	ND	402
3/7	Laborer	690 Level	490	ND	ND	ND	ND	402
Analytical Limit of Detection in ug per sample:				1	5	3	3	
Calculated Environmental Limit of Detection in ug/m3				1	6	3	3	
Evaluation Criteria in ug/m3:##		NIOSH		40	<100	Note 1	15	
		ACGIH		50	150	Note 2	Note 3	
		OSHA		200	50	Note 4	1000	

* Sample Description: Presents worker's job title and the primary work area to which assigned.

** Contaminant concentration is given in micrograms per meter cubed (ug/m^3). ND indicates that the exposure was below detectable levels. See Limits of Detection at the bottom of this table. Cd=cadmium; Pb=lead; Cr=chromium; Ni=nickel.

*** This column refers the reader to settled dust samples collected for areas where personal exposure monitoring was conducted. The bulk samples are indicative of airborne contaminants present over time. Multiple samples indicate workers had exposures from a combination of areas or materials. The reader is referred to Table V for information on the composition of the different bulk samples.

\+ Sampling pump malfunction. Pump had to be replaced. Sampling time given is an estimated maximum.

++ Sampling medium irregularity. Exposure value should be considered subject to more error than other values in this table.

+++ Worker reported spending three hours in the electrostatic precipitators.

@ Worker performed welding on electrostatic precipitators.

@@ Worker performed welding and burning on dustless unloader equipment.

\# Worker spent four hours on the dustless unloaders and four hours on the 690 level.

\## NIOSH Criteria are obtained from reference 14.
ACGIH Criteria obtained from the Threshold Limit Value for 1985-86, reference 11.
OSHA General Industry Standards, reference 13.

Evaluation Criteria Notes:

1: NIOSH recommends occupational exposure to carcinogenic chrome VI be 1 ug/m^3, non-carcinogenic forms, 25 ug/m^3. See Section V Evaluation Criteria.

2: ACGIH recommends occupational exposures to carcinogenic forms of chrome VI not exceed 50 ug/m^3; noncarcinogenic chrome VI-50 ug/m^3; chromium III-500 ug/m^3; chromium II-500 ug/m^3. Sampling and analytical methods for chromium during this survey do not separate the different forms of chrome.

3: ACGIH recommends full-shift occupational exposures to nickel not exceed 1000 ug/m^3 for nickel; 100 ug/m^3 for soluble nickel compounds evaluated by nickel content.

4: The OSHA standard for soluble chromium salts, evaluated as chrome is 500 ug/m^3; metal and insoluble chromium salts as chrome-1000 ug/m^3.

Table VII

Respirable Dust Exposures*

City of Columbus RDF Power Plant
Columbus, Ohio
HETA 85-041

March 5-7, 1985

Sample Description					
Date	Job Title	Work Location	Sample Duration (minutes)	Dust Exposure** (mg/m^3)	Bulk Samples+
3/6	Pulverizer Operator	Shredder house	405	0.14	401
3/6	Front-end Loader	Shredder house	415	0.21	401
3/7	Pulverizer Operator	Shredder house	445	0.24	401
3/7	Front-end Loader	Shredder house	445	0.34	401
3/5	Laborer	Refuse feed - 4th floor	483	0.28	400
3/5	Laborer	Refuse feed - 4th floor	481	0.16	400
3/6	Laborer	Rufuse feed - 4th floor	500	0.21	400
3/7	Laborer	Refuse feed - 4th floor	486	0.22	400
3/7	Laborer	Refuse feed - 4th floor	252	0.19	400
3/7	Maintenance Mechanic	Trash bunkers - 4th floor	457	0.71	400
3/7	Maintenance Mechanic	Trash bunkers - 4th floor	451	0.68 (Note 1)	400
3/5	Laborer	Coal Delivery - 8th floor	465	0.66	409
3/5	Laborer	Tipping pad	475	0.14	400, 410
3/6	Laborer	Tipping pad	492	0.18	400, 410
3/6	Boiler Operator	Boiler floor	470	0.33	406
3/6	Boiler Operator	Boiler floor	463	0.37	406
3/5	Operating Engineer Rover	Power plant	461	0.10	406, 411, 413
3/5	Boiler Rover	Power plant	477	0.26	406, 411, 413
3/6	Operating Engineer Rover	Power plant	447	0.09	406, 411, 413
3/6	Boiler Rover	Power plant	483	0.41	406, 411, 413

continued

Table VII (continued)

Respirable Dust Exposures*

City of Columbus RDF Power Plant
Columbus, Ohio
HETA 85-041

March 5-7, 1985

Sample Description					
Date	Job Title	Work Location	Sample Duration (minutes)	Dust Exposure** (mg/m^3)	Bulk Samples+
3/5	Electrician	Electrostatic precipitators	491	14 (Note 2)	411
3/6	Maintenance Mechanic	Electrostatic precipitators	400	0.57	411, 413
3/5	Laborer-Operator	Dustless unloader	480	0.63	413
3/5	Maintenance Helper	Dustless unloader	474	0.19	413
3/5	Maintenance Mechanic	Dustless unloader	439	0.56	413
3/6	Laborer-Operator	Dustless unloader	469	0.82	413
3/5	Laborer	690 level	462	0.34	405
3/5	Laborer	690 level/Quench basin	479	0.23	405
3/6	Laborer	Crane operation	484	0.30	410

Evaluation Criteria in mg/m^3: ACGIH (Nuisance dust - see applicability statement below)++ 5.0
OSHA (Nuisance dust - see applicability statement below)++ 5.0

* Quartz exposures and cristobalite exposures for all samples presented in this table (with the exception indicated in Note 1 and 2) were below the arithmetic average environmental limits of detection of 19 micrograms per meter cubed (ug/m^3).

** Dust exposures are presented in milligrams per meter cubed (mg/m^3). All values are blank corrected.

Note 1 Worker had a respirable quartz exposure of 40 ug/m^3. The NIOSH recommended 8-10 hour time-weighted average exposure limit for respirable free silica (including quartz) is 50 ug/m^3.

Note 2 Worker had a respirable quartz exposure of 240 ug/m^3. See Note 1 for evaluation criterion.

\+ The column indicating Bulk Samples refers the reader to Table V which presents data on settled dust samples collected in the general area where these personal exposure samples were obtained. They (the bulk samples) serve only as an indicator of past and present contaminants present in the areas of interest. Multiple bulk sample entries indicate the worker did not stay exclusively at one work station or area.

++ Nuisance dust evaluation criteria is presented only as a rough guide to evaluating respirable dust exposures. This criteria does not apply to the exposure values associated with Notes 1 and 2 since both exceed 1% quartz content. As Table V indicates, the varying composition of these dusts and the presence of specific contaminants with differing toxicities pre-empts the exclusive application of nuisance dust criteria. Additionally this dust would not meet the strict definition of a nuisance dust as presented by the American Conference of Governmental Industrial Hygienists (ACGIH).

Table VIII

Heat Stress Measurements

City of Columbus RDF Power Plant
Columbus, Ohio

HETA 85-041
March, 1985

Measurement Location*	Date	Wibget® Temperature Readings**				RH%+
		GT	NWB	DB	WBGT	
1) Lunch room, vending area	3/7	78	58	78	64	28
2) 690' level, catwalk, front of quench basin for boiler #2	3/7	72	60	72	64	48
3) 713' level - (boiler floor), front of boiler #1, burning trash	3/7	78	57	74	64	33
4) 713' level - (boiler floor), boiler operators' break table	3/7	74	56	72	61	35
5) 735' 10" level (4th floor), by center rotary seal feeder, boiler #1	3/7	90	64	81	71	36
6) 735' 10" level, by center rotary seal feeder, boiler #3	3/7	90	64	82	72	38
7) 757' 10" level (5th floor), by center rotary seal feeder, boiler #1	3/7	108	70	98	82	24
8) 757' 10" level, by boiler feed water pipes, N-side boiler #1	3/7	97	70	91	78	32
9) 757' 10" level, by center rotary seal feeder, boiler #4	3/7	109	69	99	81	19
11) 757' 10" level, by boiler feed water pipes, N side boiler #4	3/7	98	68	94	77	26
13) 766' 10" level (6th floor), between boilers 1&2	3/7	108	73	102	83	23
14) 766' 10" level, by steam drain pipes & valves, boiler #1	3/7	101	69	95	78	23
15) 766' 10" level, between boiler 4&5	3/7	111	73	103	84	22

continued

[illegible] (continued)

Heat Stress Measurements
City of Columbus RDF Power Plant
Columbus, Ohio

HETA 85-041
March, 1985

Measurement Location*	Date	Wibget® Temperature Readings**				RH%+
		GT	NWB	DB	WBGT	
(17) 766' 10" level, steam drain pipes & valves, boiler #4	3/7	101	70	96	79	25
(15) 775'10" level (7th floor), 4 feet from center S. wall of boiler #2	3/7	108	71	101	82	20
(21) 775'10" level, center valves, N side of boiler #4	3/7	108	70	102	82	20
(22) 775'10" level, center valves, N side of boiler #5	3/7	107	71	102	82	19
(23) 775 10" level, 4 feet from center S wall of boiler #5	3/7	108	70	102	81	19
(25) 785 10" level, (8th floor) aisle, E end, between boilers 1&2	3/5	102	68	96	78	20
(26) 785'10" level, Aisle, W-end, between boilers 1 & 2	3/5	96	65	93	75	20
(27) 785'10" level, E end, top of boiler #1 by aisle between boilers #1 & #2. (steamleaks noted)	3/5	102	67	96	78	20
(28) 785'10" level, center-side of boiler #1, by boiler turbine cycle pipes	3/5	109	69	98	81	21
(29) 785'10" level, aisle between boilers 4 & 5, east end	3/5	95	68	93	76	25
(31) 785'10" level, aisle between boilers 4 & 5, west end	3/5	95	67	92	75	26
(33) 785'10" level, alongside top of boiler #4, E end, between 4 & 5	3/5	106	67	103	78	14

continued

Table VIII (continued)

Heat Stress Measurements
City of Columbus RDF Power Plant
Columbus, Ohio

HETA 85-041
March, 1985

Measurement Location*	Date	Wibget® Temperature Readings**				RH%+
		GT	NWB	DB	WBGT	
(35) 705'10" level, center-side of boiler #4, by boiler turbine cycle pipe	3/5	109	72	97	83	27
(37) Ninth floor, walkway above E end of boiler #1	3/5	104	68	103	79	15
(38) Ninth floor, walkway above E end of boiler #4	3/5	98	66	98	76	14
(40) Outdoors-S side of plant	3/5	36	33	34	34	92
(41) Outdoors-E side of plant, near base of stacks	3/7	44	38	43	39	62

* Measurement Locations include a numerical designation in parentheses of 1 to 42 for comparison with measurements obtained in August of 1985, Table XI.

** Wibget® Heat Stress Monitor, Reuter-Stokes Ltd., Canada. WBGT values read directly from the instrument. Four columns present globe thermometer (GT), natural wet bulb (NWB), dry bulb (DB) and the wet bulb globe temperature (WBGT) in degrees Farenheit. The formula for obtaining WBGT is 0.7 NWB + 0.3 GT indoors or outdoors with no solar load; 0.7 NWB + 0.2 GT + 0.1 DB if solar load present.

\+ RH% = percent relative humidity. NWB and DB were used here to obtain RH%.

Table IX

Viable Anderson Sampling for Airborne Microbial Contamination

City of Columbus RDF Power Plant
Columbus, Ohio
HETA 85-041

March 5-6, 1985

Sample Description*					Colony Forming Units (CFU) per meter cubed**						Comments***
Location	D (min)	T (°F)	RH %	Vol. (m^3)	24 hour incubation NR (%)	R (%)	Total	48 hour incubation NR (%)	R(%)	Total	
Trash feed conveyors to Boiler #1, 4th floor, 3/5	1	55	20	0.028	2736(60)	1789 (40)	4525	2771 (57)	2105 (43)	4876	
	4			0.116	945(55)	773 (45)	1718	1030	overgrown	-	
	8			0.226	157(29)	123 (71)	545	overgrown	overgrown	-	Numerous fungi & bacillus spreaders 24 hrs. (8 min)
Dustless unloader for Boiler #2, 3/5	2	61	30	0.057	298(45)	368 (55)	666	385 (46)	456 (54)	841	Roof vents open, perceptible air movement. Heavy fungal growth at 24 hrs. (4 min.) Maintenance work on unloader.
	4			0.113	257(53)	230 (47)	487	407 (44)	514 (56)	921	
	8			0.233	107(27)	287 (73)	394	137	overgrown	-	
Main office area, receptionist, 3/5	5	72	20	0.142	84(11)	659 (89)	743	133	overgrown	-	
	10			0.282	85(24)	265 (76)	350	overgrown	overgrown	-	Fungi spreading across plates (10, 15 min.)
	15			0.436	116(31)	256 (69)	372	121	overgrown	-	
Shredder house - North shredder, out on refuse	2	31	30	0.056	1879(75)	638 (25)	2517	overgrown	851	-	Spreading bacillus at 24 hrs. (4 min.)
	4			0.114	219(41)	315 (59)	534	412 (52)	385 (48)	797	
	8			0.233	554(67)	274 (33)	828	687	overgrown	-	
Tipping pad (concrete buttress by #2 pole), 3/6	2	34	20	0.056	2482(72)	957 (28)	3439	overgrown	overgrown	-	Large spreading colonies on all plates at 24 hrs. (2,4,8 min.) No trucks dumped during sampling, crane picking up refuse.
	4			0.116	1202(57)	893 (43)	2095	1202	overgrown	-	
	8			0.228	877(62)	526 (38)	1403	877 (62)	525 (38)	1412	
Trash fed conveyors to boilers #1 and #2, 4th floor, 3/6	1	63	20	0.029	7368	overgrown	-	overgrown	overgrown	-	Sweeping being done in area, piles of refuse accumulated under conveyor for boiler #3.
	3			0.087	2313(53)	2084 (47)	4397	overgrown	overgrown	-	
	5			0.141	1099(86)	177 (14)	1276	overgrown	333	-	
Lunch table, boiler floor main aisle, front of # 2 boiler), 3/6	2	72	20	0.057	1456(34)	2877 (66)	4333	1403	overgrown	-	Large spreading bacillus colonies at 24 hr. (5,10 min.) Boilers 2&4 refuse, 1&5 coal.
	5			0.146	570(34)	1106 (66)	1676	overgrown	overgrown	-	
	10			0.282	496(41)	709 (59)	1205	567	overgrown	-	

continued

Table IX (continued)

Viable Anderson Sampling for Airborne Microbial Contamination

City of Columbus RDF Power Plant
Columbus, Ohio
HETA 85-041

March 5-6, 1985

Sample Description*					Colony Forming Units (CFU) per meter cubed**						Comments***
Location	D (min)	T (°F)	RH %	Vol. (m^3)	24 hour incubation NR (%)	R (%)	Total	48 hour incubation NR (%)	R(%)	Total	
Outdoors, 25ft. west of south entrance to Tipping pad, 3/6	5	37	a	0.146	206(22)	728 (78)	934	219	overgrown	-	Sunny, windy, clear, cold
	10			0.285	178(26)	494 (74)	672	171	overgrown	-	
	15			0.423	172(37)	293 (63)	465	overgrown	overgrown	-	
Control Samples and Blanks											
Unopened agar plates, 3/5	-	-	-	-	-	-	0 CFU	-	-	0 CFU	Handled with all other plates
	-			-	-	-	0 CFU	-	-	0 CFU	
Placed in sampler, no air	-	-	-	-	2 CFU	1 CFU	3 CFU	3 CFU	1 CFU	4 CFU	Done after samples collected
Unopened agar plates, 3/6	-	-	-	-	-	-	1 CFU	-	-	1 CFU	Handled with all other plates
	-			-	-	-	0 CFU	-	-	0 CFU	
Placed in sampler, no air flow, 3/6	-	-	-	-	0 CFU	4 CFU	4 CFU	0 CFU	6 CFU	6 CFU	Done after samples collected.

* Sample Description: D = duration of sample in minutes
T = ambient temperature in degrees farenheit (°F)
RH = relative humidity given in percent (%)
Vol = sample volume given in meters cubed (m^3)

** NR = nonrespirable fraction (CFU), stage 0
R = respirable fraction (CFU), stage 1

Total = total CFU, sum of both plates

Percentages of total CFU's for sample in each fraction (respirable or nonrespirable) are given in parentheses.

Overgrown = designates plates that could not be counted because of overgrowth by colonies with each other.

*** Comments: include observations both during sampling and from colony counting. Count observations include incubation time, with the sample set referred to (e.g. 4 minute sample as 4 min.) in parentheses.

Table X

Worker Exposures to Lead, Total Chromium VI, Respirable Dust, and Crystalline Silica
City of Columbus RDF Power Plant
Columbus, Ohio
HETA 85-041

August 13-14, 1985

Date	Sample Description* Job Title	Work Location	Sample Duration (minute)	Contaminant Concentrations in ug/m3** Pb	Cr	CrVI	R. Dust	Silca
8/13	Pulverizer Operator	Coal Receiving	480	-	-	-	420	ND
8/14	Pulverizer Operator	Coal Receiving	605	-	-	-	420	ND
8/13	Front-end Loader	Shredder House	483	ND	ND	ND	-	-
8/14	Front-end Loader[a]	Shredder House	473	ND	ND	ND	-	-
8/13	Rover	Shredder House	488	ND	ND	-	370	ND
8/13	Rover[a]	Shredder House	416	ND	ND	ND	-	-
8/13	Boiler Rover	Power Plant (entire)	488	46	ND	ND	-	-
8/14	Boiler Rover	Power Plant (entire)	508	17	ND	0.8	-	-
8/13	Boiler Operator	Boiler Floor	477	ND	ND	ND	-	-
8/14	Boiler Operator	Boiler Floor	493	ND	ND	ND	-	-
8/13	Maintenance	Unspecified[b]	502	20	5	ND	-	-
8/13	Maintenance	Dustless Unloader	481	9	ND	0.5	-	-
8/14	Maintenance	Unspecified	c	d	d	ND	160	ND
8/14	Maintenance	#4 Boiler-2nd Floor	471	ND	ND	0.4	-	-
8/13	Electrician	Electrostatic Precipitator	451	ND	ND	0.4	230	ND
8/14	Electrician	Unspecified	438	ND	ND	-	90	ND
8/14	Electrician	Unspecified	440	ND	ND	ND	-	-
8/13	Laborer	Dustless Unloader	465	17	ND	ND	-	-
8/14	Laborer	Dustless Unloader	479	30	ND	0.4	480	ND
8/13	Laborer	690 Level/Quench	497	8	ND	0.6	-	-
8/14	Laborer	690 Level/Quench Basin	475	7	ND	ND	-	-

continued

Table X (continued)

Worker Exposures to Lead, Total Chromium VI, Respirable Dust, and Crystalline Silica
City of Columbus RDF Power Plant
Columbus, Ohio
HETA 85-041

August 13-14, 1985

Date	Sample Description* Job Title	Work Location	Sample Duration (minute)	Contaminant Concentrations in ug/m3** Pb	Cr	CrVI	R. Dust	Silca
8/13	Laborer	Ash Pit/Ash Loading	465	ND	ND	0.7	-	-
8/13	Laborer	Ash Truck Driver	480	ND	ND	ND	-	-
8/14	Laborer	Ash Truck Driver	320[e]	ND	ND	-	-	-
8/14	Laborer	Ash Truck Driver	470	ND	ND	0.3	-	-
Analytical Limit of Detection in ug per sample:				3	3	0.2	10[f]	15[f]
Calculated Environmental Limit of Detection in ug/m^3: (arithmetic mean calculated from NDs)				4.7	4.6	0.4	-	21
Evaluation Criteria in ug/m^3:g	NIOSH			<100	Note 1	1	-	50
	ACGIH			150	Note 1	50	5000	Note 2
	OSHA			50	Note 1	1000	5000	Note 2

* Sample Description: Presents worker's job title and the primary work area to which he/she is assigned. All sampling was conducted on the day shift (8:00-4:30)

** Contaminant concentration is given in micrograms per meter cubed (ug/m^3). ND indicates that the exposure was below detectable levels. See Limits of Detection at the bottom of this table. Pb= lead, Cr= chromium; Cr VI= chromium having a charge of +6, present in the insoluble (carcinogenic) form; R. Dust = respirable dust, Silica = respirable crystalline silica, - = Worker wasn't monitored for specified contaminant.

a. Shredders down 8/14/85. No garbage being shredded.
b. Unspecified work location - workers were not assigned for major portion of day to one task. For these workers, area definition is limited to "dusty areas of the plant."
c. Sample volume for metals - 365 minutes; dust and silica = 325 minutes
d. Sampling error, sample lost in field.
e. Partial shift sample. Worker didn't haul ash in the afternoon.
f. For the gravimetric analyses (respirable dust) insturmental precision of weighings done at one sitting is 10 ug. The analytical limit of detection for both quyartz and cristobalite (allotropes) of crystalline silica.
g. NIOSH criteria are obtained from reference 14
   ACGIH criteria obtained from the threshold Limit Values and Biological Exposures Indices for 1985-86, reference 11
   OSHA General Industry Standards, reference 13

Evaluation Criteria Notes:

Note 1: NIOSH REL (recommended exposure limit) to carcinogienic Cr VI = 1 ug/m^3; non-carcinogenic forms, 25 ug/m^3. ACGIH TLV's; carcinogenic forms of CR VI should not exceed 50 ug/m^3; noncarcinogenic CrVI-50 ug/m^3; Cr III - 500 ug/m^3; Cr II 500 ug/m^3. The OSHA PEL (permissible exposure limit) for soluble Cr salts, evaluated as Cr is 500 ug/m^3; metal and insoluble chromium salts-1000 ug/m^3. See the section entitled Evaluation Criteria.

Note 2: For both the ACGIH-TLV and OSHA-PEL, the exposure limit crystalline silica, the percentage of the various allotropes in the sample is required. The limit for respirable quartz is 10000 ug/m^3 divided by the poercent of respirabl quartz present plus two. The Cristobolite TLV and PEL equal 1/2 the quartz value.

TABLE XI

Heat Stress Measurements

City of Columbus RDF Power Plant
Columbus, Ohio
HETA 85-041

August, 1985

Measurement Location*	Date	Wibget* Temperature Readings** GT	NWB	DB	WBGT	RH*
(1) Lunch room, vending area	8/13	83	76	83	79	75
(2) 690 level, catwalk, front of quench basin for boiler #2	8/13	97	87	103	90	53
(3) 713 level-(boiler floor), front of boiler #1, burning coal	8/13	113	85	109	94	39
(4) 713 level-(boiler floor), boiler operators' break table	8/13	104	85	103	91	48
(5) 735'10" level (4th floor), by center rotary real feeder, boiler #1	8/13	112	86	110	95	40
(6) 735'10" level, by center rotary seal feeder, boiler #1	8/13	113	86	108	94	42
(7) 757'10" level (5th floor), rotary seal feeder, boiler #1	8/13	130	91	118	102	37
	8/14	124	90	114	100	40
(8) 757'10" level, by boiler feed water pipes, N-side boiler #1	8/13	115	89	112	97	41
	8/14	111	86	108	94	42
(10) 757'10" level, by center rotary seal feeder, boiler #5	8/13	122	88	114	98	35
	8/14	122	88	114	98	38
(12) 757'10" level, by boiler feed water pipes, N-side boiler #5	8/13	107	85	106	92	43
	8/14	105	85	104	92	46
(13) 766'10" level (6th floor), between boilers 1&2	8/13	113	86	110	94	40
(14) 766'10" level, by steam drain pipes & valves, boiler #1	8/13	113	87	110	94	40
(16) 766'10" level, between boilers 5&6	8/13	112	86	108	93	39
(18) 766'10" level, steam drain pipes & valves, boiler #5	8/13	112	85	109	93	39
(19) 775'10" level (7th floor), 4 feet from center S wall of boiler #2	8/13	118	87	114	96	35
(20) 775'10" level, center valves, N side of boiler #1	8/13	118	89	114	98	39
	8/14	119	88	115	98	35

continued

TABLE XI (continued)

Heat Stress Measurements

City of Columbus RDF Power Plant
Columbus, Ohio
HETA 85-041

August, 1985

(22) 775'10" level, center valves, N side of boiler #5	8/13 8/14	118 117	88 88	114 112	98 97	37 40
(24) 775'10" level, 4 feet from center S wall of boiler #6	8/13	114	86	109	95	40
(25) 785'10" level, (8th floor), aisle, E end, between boilers 1 & 2	8/13	117	87	111	96	40
(26) 785'10" level, aisle, W end, between boilers 1 & 2	8/13	113	88	109	96	44
(27) 785 10" level, E end, top of boiler #1 by aisle between boilers 1 & 2 (steam leaks noted)	8/13 8/14	118 120	89 88	114 116	99 98	39 34
(28) 785'10" level, center-side of boiler #1, by boiler turbine cycle pipes	8/13 8/14	122 125	90 90	113 114	99 101	42 40
(30) 785'10" level, aisle between boilers 5 & 6, E end	8/13	112	88	110	96	42
(32) 785'10" level, aisle between boilers 5 & 6, W end	8/13	110	87	108	94	42
(34) 785'10" level, alongside top of boiler #5, E end, between 5 & 6	8/13 8/14	114 126	88 90	111 115	96 101	41 39
(36) 785'10" level, W end, boiler turbine cycle pipes, N-side #5	8/13 8/14	120 116	89 88	110 114	98 96	43 38
(37) 799'5.5" level, (ninth floor) walkway above E end of boiler #1	8/13 8/14	116 121	89 88	115 120	98 98	38 30
(39) 799'5.5" level, aisle walkway above E end of boilers 5 & 6	8/13	113	88	113	96	38
(40) Outdoors-S side of plant	8/13 8/14	107 106	81 81	94 95	87 89	59 55

* Measurement Locations include a numerical designation in parentheses of 1 to 42 for comparison with measurements obtained in March of 1985, Table VIII.

** Wibget® Heat Stress Monitor, Reuter-Stokes Ltd., Canada. WBGT values were read directly from the instrument. Four columns present globe thermometer (GT), natural wet bulb (NWB), dry bulb (DB), and the wet bulb globe temperature (WBGT) in degrees Farenheit. The formula for calculating WBGT is 0.7 NWB + 0.3 GT indoors or outdoors with no solar load; 0.7 NWB + 0.2 GT + 0.1 DB if solar load is present.

\+ RH% = percent relative humidity. NWB and DB were used with a psychrometric chart to obtain RH%.

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