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CITY OF AMES MUNICIPAL POWER PLANT
AMES, IOWA

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I. SUMMARY

On June 23, 1986, the National Institute for Occupational Safety and Health (NIOSH) received a request from the City of Ames Municipal Electric System management and Local 234 of the International Union of Electical Workers to conduct a Health Hazard Evaluation at the city's municipal coal and refuse derived fuel (RDF) power plant. Some specific concerns included health hazards associated with handling and burning RDF, asbestos insulation present on equipment in the facility, exposures to coal dust and fly ash, work in hot environments, and on site chemical storage and use.

Analysis of bulk dust and insulation samples; personal exposure monitoring for asbestos, trace metal, respirable dust (coal dust and crystalline silica), and noise; obtaining heat stress measurements in areas throughout the plant; and a review of personal protective equipment, chemical handling and storage, and other occupational health programs were performed. Two surveys, an initial July 21-23, 1986, and a follow-up with personal exposure sampling January 12-14, 1987 were conducted.

Insulation materials contained from below detectable levels (ND) up to 20% amosite, and 5-20% chrysotile asbestos. A variety of metals were present in the bulk samples of settled dust, coal dust, RDF dust, and fly ash.

Wet Bulb Globe Temperature (WBGT) measurements indicated there were temperatures in excess of the NIOSH Recommended Exposure Limit (REL) for continuous work in hot environments for acclimated healthy workers (WBGT values of 77°F for heavy work up to 86°F for light work). Noise levels were generally below the NIOSH REL of 85 dB(A).

Based upon the results of this hazard evaluation, NIOSH investigators identified hazardous heat levels, noise levels requiring a hearing conservation program, potential asbestos exposures, and elevated coal dust and silica exposures. Exposure to toxic metals were negligible during the time of the survey. Recommendations presented in Section IX address work practice, administrative, personal protective equipment, and hearing conservation programs; additional exposure monitoring; chemical storage and hazard communication; and medical surveillance considerations.

KEYWORDS: SIC 4931 (Electric and other services combined), 4953 (Refuse systems); refuse, refuse derived fuel, coal fired power plant, electric power generation, trace metals, coal dust, fly ash, silica, heat stress, asbestos, noise.

II. INTRODUCTION

On June 23, 1986, the National Institute for Occupational Safety and Health (NIOSH) received a request from the City of Ames, Iowa Municipal Electric System and the International Union of Electrical Workers (IUOE) Local 234 to conduct a Health Hazard Evaluation (HHE) at the city's municipally owned coal and refuse derived fuel (RDF) power plant. The request was a joint effort of a Labor-Management Committee to seek assistance in improving the health and safety program at the city's power plant. A list of potentially hazardous substances or conditions encountered in the course of operating the plant were presented to NIOSH investigators for evaluation. Specific concerns included hazards associated with handling and burning RDF, asbestos insulation present on equipment in the facility, coal dust, fly ash, hot working environments, polychlorinated biphenyl (PCB)-containing grounding transformers, and on-site chemical usage and storage.

NIOSH investigators conducted an initial survey July 21-23, 1986, and a follow-up survey January 12-14, 1987. The initial survey involved a walk-through survey, collection of bulk settled dust and insulation samples, measurement of wet bulb globe temperature (WBGT) levels for heat stress, and discussions with various individuals about operating conditions, potential exposures, and personal protective equipment programs. The follow-up survey involved two primary activities: (1) repeating heat stress measurements obtained during the July 1986 survey in order compare levels to those occurring in a cold season, and (2) conducting worker exposure monitoring for various chemical contaminants potentially present at the facility.

Post-survey letters were sent to both management and labor representatives September 2, 1986, and February 24, 1987 summarizing the survey activities and preliminary findings along with initial recommendations.

III. BACKGROUND

A. History of Ames Municipal Power Plant:

The city of Ames, Iowa, voted in 1896 to construct a municipal power plant. The first plant produced 150 kilowatts for lighting between the hours of 5:00 a.m. and midnight. Over the years additional units were added to replace obsolete equipment and accomodate increased community demands for electricity. The municipal power plant facility currently houses four boilers, but only the newest unit, Unit #8 is used for power generation. Non-operational units #5 (7500 KW, completed in 1951) and #6 (12000 KW, completed in 1958) occupy the north half of the physical plant. Unit #7 (40000 KW, completed in 1967) serves as a back-up unit for Unit #8. Unit #8 (65000 KW) became operational in May 1982. Unit #8 is located on the site of the first power plant.

The city of Ames began a solid waste recovery program in the early 70's and this included a Solid Waste Recovery Plant serving Story County Iowa. In late 1975 the waste recovery plant was completed and the electric utility began burning RDF as a supplemental fuel. Unit #7 was retrofitted to utilize RDF at that time in addition to burning coal. Unit #8 is a balanced draft boiler designed to burn both bituminous coal and air classified shredded municipal solid waste or refuse derived fuel (RDF).

B. Refuse Derived Fuel (RDF):

Refuse derived fuel (RDF) is primarily composed of the shredded combustible part of municipal solid waste (refuse). Most of the metal and dense material in the refuse is separated from the light combustibles at the Ames Solid Waste Recovery Plant, which is located just south of the power plant's coal yard. RDF is a supplemental boiler fuel which may provide up to 20% of Unit #8's fuel requirement. Most of the RDF which is blown into either side of Unit #8's boiler is burned on the dump grate at the bottom of the boiler. The Ames Power Plant annually burns about 30,000 tons of RDF; which provide about 10% of the plant's annual fuel requirement. The boiler generally does not exceed a RDF fuel proportion of about 15% since higher percentages of RDF result in control problems with the operation of the unit. Low sulfur western coal is burned as the primary fuel in Unit #8.

C. Process Description:

Figure I provides an overview of the operation of the Unit #8. This figure does not show the handling of shredded refuse and its use as a fuel. In addition to coal from the coal yard, shredded refuse is delivered by pneumatic pipeline from the solid waste recovery plant to the Atlas Bin or RDF Bin, located west of the coal yard and coal stockpile. Shredded refuse from the solid waste recovery plant is delivered at the top of the multistory RDF Bin and accumulated in the conical structure awaiting delivery to the boiler, Figure 2.

Coal is transferred from the coal yard to the bunkers in the power plant by conveyors. Potential exposures to coal dust exist for the shaker house operators and front-end loaders. Noise levels in the shaker house (where railcars are vibrated during the dumping process) necessitated hearing protection. Refuse is transported pneumatically directly from the RDF Bin into the boilers through eight inch pipe. Exposures in the RDF Bin area appear to be primarily to the dust accompanying and originating from the refuse itself. Workers reported development of a rash associated with the RDF dust, especially at locations where their skin would be rubbed by clothing. Disposable nuisance dust respirators were worn by workers in and around the RDF Bin.

Within the power plant itself worker activities involved operation of the equipment (involving equipment monitoring and adjustment), repair activities on any and all of the equipment present, and housekeeping and physical plant maintenance. Potential exposures of workers within the plant included coal dust in the tripper room above the coal bunkers, fugitive dust emissions from the RDF supply lines, water treatment chemicals, insulation materials including asbestos containing materials both in place on the equipment and as used for repairs, hot work environments, fly ash, and noise. Unit #8 is a balanced draft boiler and the induced draft fan maintains a slight negative pressure in the boiler itself.

Fly ash from the boilers and electrostatic precipitators is handled in two different ways. Fly ash from the electrostatic precipitators is pneumatically conveyed to an ash silo for storage prior to sale as an additive to concrete or, if the sulfur content exceeds acceptable ranges, mixed with water and discharged to settling ponds. Ash from the bottom of the boiler is injected with water and hydraulically conveyed out to the ash settling pond. Fouling of the ash handling systems was not reported to be a frequent problem.

The power plant provides steam service, both for steam heat and process steam, to the local hospital. The steam generation equipment for the hospital is separate from the power plant system, and necessitates a network of steam tunnels along the city streets to the hospital. Six steam vaults located at various intervals along the route contain the valves for pipes providing the hospital steam service. The vaults are 10 feet by 15 feet by about 10 feet deep. The resulting heat load inside the vaults is substantial and water seepage into the vaults creates a high humidity environment along with the high heat. Workers normally do not enter the vaults but must periodically inspect them visually and, on occasion, pump out the hot water collecting in the vault. Repair operations requiring work within the vault itself present concerns associated with working in a confined space that is also a hot environment.

D. Work Force Description:

The power plant employs a total of about 44 workers. Thirty people work on the 7:00 a.m.-3:30 p.m. shift. The 3:30 p.m.-11:30 p.m. and the 11:30 p.m.-7:30 a.m. shifts both have a workforce of four. The work force was all male at the time of this investigation. Average tenure at the plant is about 20 years. Some of the job categories of the workers are: power plant operator, auxillary operator, fireman B, fireman C, coal handlers, electrican, electrical technican, mechanic, and maintenance worker. This group comprises the majority of the workforce. Additional job categories are managerial, foreman, and custodial staff. Table I presents a listing of the various job titles for which exposures were evaluated during this investigation along with a brief description of each.

E. Personal Protective Equipment Programs:

All workers are provided with uniforms. Workers have a choice of laundering them at the plant or at home. Disposable coveralls along with hooded denum coveralls are provided for use when working on electrostatic precipitators and showering is required after the work is completed. These denim coveralls are laundered at the plant. Workers are issued ear muffs to use with their hard hats and ear plugs are available. Safety glasses are required and chemical goggles are available. Steel toed shoes are furnished for all maintenance workers, electricians, and any others required to do work involving moving heavy equipment. Rubber suits, boots, and gloves are available when transferring acids or caustics. Work gloves are also available.

No formal respiratory protection program existed, however nuisance dust and disposable organic vapor-acid gas respirators were provided depending upon the area and job. Self contained breathing apparatus units (2) were present in the sulfuric acid and chlorine handling and storage areas of the cooling towers. No program for the use of these devices by qualified personnel was in place.

F. Medical Surveillance:

The city currently conducts pre-employment physicals and offers semi-annual physicals as part of the union contract with the city. The physicals are generally non-specific and as part of this study the city requested guidance in addressing hazards that would also have medical surveillance components that can be included in this program. Participation at the time of the HHE was very low. Workers are permitted to use their own personal physicians, and no plant medical records are maintained on the workers.

G. Previous Industrial Hygiene Activities:

Industrial hygiene activities at the Ames Municipal Power Plant have been very limited. Airborne asbestos sampling has been conducted both by Iowa OSHA and a private consulting firm. A noise survey was conducted by the city's insurance carrier in 1983.

IV. EVALUATION DESIGN AND METHODS

A. Industrial Hygiene Survey Protocols:

1. Initial Survey:

The initial survey consisted of a walk-through of the process and facility to further identify areas or jobs of concern at the power plant. Heat stress measurements were obtained at 24 locations throughout the plant in order to complete this part of the evaluation during a hot season of the year (July). Bulk samples of settled dust and insulation were collected at various locations throughout the plant and analyzed for trace metals content (such as lead, cadmium, total chromium, and nickel) and asbestos. The results of the bulk sample analyses were used in developing the follow-up sampling protocol. A review of the chemicals used at the facility was also conducted.

2. Follow-up Survey:

The follow-up industrial hygiene survey involved a repeat of the previously obtained heat stress measurements during a cold season of the year (January). Personal exposure sampling was conducted for metals (including lead, cadmium, total chromium, and nickel), respirable dust for coal dust and crystalline silica, asbestos, and noise. The three major areas where sampling was conducted were the coal yard, the RDF bin, and the power plant itself. Job titles of workers monitored for contaminant exposures included: auxiliary operator, fireman C, coal handler, maintenance, maintenance mechanic, electrical technican, and custodian. Sampling was conducted over the full work shift whenever possible.

B. Sampling and Analytical Methods:

All air sampling trains (i.e. personal sampling pumps) were calibrated daily. Proper flow rate and sample integrity during the work shift were checked perodically. Field blanks were submitted with all filter samples.

1. Bulk Sample Analyses:

a. Asbestos:

All insulation and selected settled dust samples were examined for homogenity and non-homogeneous samples were ground manually to insure homogeneity. Microscope slides were prepared from each sample using 1.55 refractive index liquid. The slides were then scanned for the presence of asbestos utilizing polarized light microscopy and dispersion staining techniques. A Leitz Dialux 20 microscope equipped with a 16x objective and a 10x eyepiece was used for the analysis.

The percentage of fibrous asbestos is estimated by a microscopic examination of the sample. If present, asbestos identities are confirmed with the appropiate refractive index liquids applying dispersion staining techniques. All samples are analyzed by two separate analysts. Results are averaged and reported in percent by volume. Specific limits of detection were not applicable to this particular analysis.

b. Metals:

i. Initial Survey:

Bulk settled dust samples were prepared and analyzed using NIOSH Method No. 7300.[1] Samples were diluted 25 milliliters (mL) after digestion. A Perkin-Elmer ICP/6500 sequential scanning inductively coupled plasma (ICP) atomic emission spectrometer (AES) controlled by a Perkin-Elmer Model 7300 laboratory computer was used for all measurements. The limits of detection for these samples are presented in Table II by the specific metal.

ii. Follow-up Survey:

Bulk samples were analyzed by ICP-AES for metals. Three replicate aliquots of each bulk sample were weighed and then digested with nitric and perchloric acids. The residues were dissolved in a dilute solution of the same acids and analyzed for trace metals by ICP-AES. Since these samples were to be used as a reference for those previously analyzed from the initial survey, no attempt was made to remove silicon from the samples, thereby keeping analytical conditions the same. The limits of quantitation (LOQ) for this sample set were 0.01 percent by weight.

c. Free Silica:

Bulk dust samples collected at the time exposure sampling was conducted for crystalline silica were analyzed for quartz and cristobalite using x-ray diffraction. NIOSH Method No. 7500[1] was used to analyze the samples with the following modifications: (1) Filters were dissolved in tetrahydrofuran rather than being ashed in a furnace; (2) standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure. Two milligram (mg) portions of the bulks were weighed onto FWS B filters prior to analysis.

The LOD and LOQ for this analysis are: quartz (in a 2 mg portion of the bulk) LOD 0.75%, LOQ 1.5%; cristobalite (in a 2 mg portion) LOD 0.75%, LOQ 1.5%. Data falling between the LOD and the LOQ are semiquantitative and are reported as trace quantities because the contaminant is present in a detectable amount analytically but not enough to reliably quantify.

2. Total Fiber Counts (as Asbestos):

Personal exposure samples for asbestos were evaluated using 25 millimeter (mm) mixed cellulose ester filters (MCEF) equipped with conductive cowls sampling at a flow rate of 3 liters per minute (Lpm). The samples were analyzed according to NIOSH Method No. 7400 Set B utilizing phase contrast microscopy (PCM).[1] The sample results were reported in total fibers per filter. Subjective comments about the fibers observed were also indicated with the analytical results.

The limit of detection (LOD) has been determined to be 0.03 fibers/field or 1500 fibers/filter for 25mm diameter filters and 3500 fibers/filter for 37mm filters. A detection limit is calculated by dividing the minimum observable fibers by the maximum number of fields specified by the method. The reported LOD for this analysis is lower than that cited within the referenced NIOSH method.

3. Asbestos Analysis by Transmission Electron Microscopy (TEM):

Selected filter samples analyzed by PCM for total fibers as asbestos were submitted for fiber count and identification by TEM. The samples were prepared for TEM analysis via the Zumwalde-Dement procedure outlined in NIOSH Publication No. 77-204.[2] One hundred fields were examined on each preparation on the Philips 420 Scanning Transmission Electron Microscope (STEM) at 10,500X magnification (a field area is equal to $7.06 \times 10^{-3} mm^2$). Elemental spectra and diffraction patterns were obtained during the TEM analysis.

One should remember when comparing PCM and TEM fiber counts, that approximately one-fourth of the 25mm filter (effective collection area $=385mm^2$) is prepared for PCM analysis. Of this 1/4 wedge, at least three (3) radii are traversed during a 100-field count. On the other hand, only approximately $1.5mm^2$ of filter area is examined during a 100-field TEM count.

4. Airborne Metals Analysis:

Personal exposures to airborne metals were evaluated by sampling with MCEF filters at a flow rate of 2 Lpm. The filter samples were digested with nitric and perchloric acids and analyzed in the same manner as presented in paragraph IV A (1) (b) (ii) previously for bulk dust samples. The LOQ for these samples was one microgram per filter.

5. Respirable Coal Dust:

Respirable dust samples were collected using 10 mm nylon cyclones and preweighed filters sampling at a flow rate of 1.7 Lpm. The total weight of each sample was determined by weighing the sample plus the filter on an electrobalance and subtracting the previously determined tare weight of the filter. The tare and gross weighings were done in duplicate. The instrumental precision of weighings done at one sitting is 0.01 mg. Due to variable factors such as overloading, hygroscopicity of sample, humidity, and the physical integrity of the filter itself, the actual precision can be considerably poorer and occasional slight net negative particulate weights are to be expected.

6. Respirable Crystalline Silica:

Exposures to crystalline silica were determined from the same samples used for obtaining respirable dust exposures. The samples were analyzed for quartz and cristobalite using x-ray diffraction. NIOSH

Method 7500[1] was used with the same modifications as presented in paragraph (1) (c) previously presented for determination of crystalline silica in the bulk samples. The LODs and LOQs for the air samples were: quartz on a filter-LOD 0.015%, LOQ 0.03%; cristobalite on a filter-LOD 0.015%, LOQ 0.03%. Results falling between the LOD and the LOQ are semi-quantitative and are presented as trace quantities.

7. Heat Stress Measurements:

Heat stress measurements were obtained using Reuter-Stokes Heat Stess Monitors, Model RSS-211D at numerous locations throughout the facility where workers may have occasion to work. These instruments provided wet bulb globe temperature (WBGT) values for comparison to various WBGT evaluation criteria applicable to working in hot environments. In addition to the WBGT readings, air temperature, natural wet-bulb temperature, and globe temperature were obtained. These latter values provide additional information in assessing the individual parameters that can contribute to heat stress such as the convective heat load, ability of the body to eliminate heat through perspiration, and the radiant heat burden. The monitors were mounted on tripod stands at a height of about four feet from the floor and allowed to equilibrate for a period of time at each measurment site prior to obtaining instrument readings.

8. Worker Noise Exposures:

Individual worker noise exposures were evaluated using Metrosonics db-301 Metrologger noise dosimeters. The dosimeters were calibrated daily using a Metrosonics CL-302 calibrator. The dosimeters were placed on standby during periods of absence from the workers' work area whenever possible. Dosimeter readouts were obtained at the end of each sampling day providing a time-weighted noise exposure as well as information on the maximum noise levels the indvidual encountered during the work shift.

V. EVALUATION CRITERIA AND TOXICOLOGY DISCUSSION

A. Evaluation Criteria:

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 and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects 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 Recommended Exposure Limits (REL's), 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH REL's and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH REL's and ACGIH TLVs 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 REL's, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. 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 HHE.

2. Evaluation Criteria for Physical Agents:

a. Hot Work Environments:

NIOSH originally defined hot environmental conditions as any combination of air temperature, humidity, infrared radiation, and wind speed that exceeds a WBGT value of 79 Farenheit (F) (26 Celsius (C)).[8] NIOSH, in its revised criteria for occupational exposure to hot environments, presents maximum recommended heat stress levels on a sliding scale of WBGT values versus metabolic heat levels (work effort). The recommended heat stress limits are a series of five curves on the graph, four different work-rest regimens, and a ceiling limit which is not to be exceeded at any time for the respective work levels.[9] In order to use the criteria one must have a WBGT value for the work area and an estimate of the work effort (metabolic heat) required of the tasks performed by the worker in the hot environment. Figures 3 (Recommended Heat-Stress Alert Limits (RAL) for Heat-Unacclimatized Workers) and 4 (Recommended Heat-Stress Exposure Limits for Heat-Acclimatized Workers) present this information.

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.[5,9] This criteria, which is presented in tablular form in Table IV, assumes the worker is acclimatized, fully clothed in summer weight clothing, is physically fit, has good nutrition, and has adequate water and salt intake. Additionally the workers are not to 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.[9]

Modifications for 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:[10]

i. Unacclimatized or physically unconditioned workers:

Subtract 4°F (2°C) from the permissible WBGT value for acclimatized workers. Note that Figure 3 from the Revised NIOSH Hot Environments Criteria Document presents values for unacclimatized workers.

ii. Increased air velocity (above 1.5 meters per second or 300 feet per minute):

Add 4°F (2°C) to the 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.(11)

iii.Impervious clothing which interferes with evaporation:

a. Body armor, impermeable jackets-subtract 4°F (2°C).
b. Raincoats,fireman coats, full-length coats-subtract 7°F (4°C).
c. Completely enclosed suits-subtract 9°F (f°C).

iv. Obese or elderly workers:

Subtract 2-4°F (1-2°C).

v. Female workers:

Subtract 1.8°F (1°C). This adjustment acknowledges generally lower sweat rates for females reported in the literature. Correction "v." is questionable since the difference between the sexes in groups that normally work in hot environments was observed to be complex. Seasonal and work rate considerations enter into determining which sex is better adapted to work in hot environments.(12)

b. Noise:

Exposure to high levels of noise may cause temporary or permanent hearing loss. The extent of damage depends primarily upon the intensity of the noise and the duration of exposure. There is abundant epidemiological and laboratory evidence that protracted noise exposure above 90 decibels A-weighted (dB(A)) causes hearing loss in a portion of the exposed population.

OSHA's existing standard for occpational exposure to noise (29 CFR 1910.95)(6) specifies a maximum permissible noise exposure level of 90 dB(A) for a duration of eight hours, with higher levels allowed for shorter durations. NIOSH, in its criteria for a recommended standard(13), proposed a limit of 85 dB(A), 5 db less than the OSHA standard. Time-weighted average noise limits as a function of exposure duration are shown below:

Duration of Exposure (hrs/day)	Maximum Sound Level, dB(A) NIOSH	OSHA
16	80	85
8	85	90
4	90	95
2	95	100
1	100	105
1/2	105	110
1/4	110	115*
1/8	115*	-
	-	140 dB**

* No exposure to continuous noise above 115 dB(A)
** No exposure to impact or impulse noise above 140 dB peak sound pressure level (SPL)

When workers are exposed to sound levels exceeding the OSHA standard, feasible engineering or administrative controls must be implemented to reduce levels to permissible limits. The OSHA noise standard has been expanded with the addition of a hearing conservation amendment.[14] For workers exposed at or above a time weighted average (TWA) of 85 dB(A), this amendment requires noise exposure monitoring, audiometric testing, the use of hearing protective devices where necessary, record keeping provisions, and employee education.

B. Toxicology Discussion:

The following toxicology discussion is limited to asbestos, coal dust, crystalline silica, and heat stress, the primary existing health hazards identified during the course of the HHE.

1. Asbestos:

Asbestos causes asbestosis, cancer of the lungs and digestive tract, and mesothelioma. Asbestosis is a lung disorder characterized by a diffuse interstitial fibrosis, at times including pleural changes of fibrosis and calcification. Accompanying clinical changes may include fine rales, finger clubbing, dyspnea, dry cough, and cyanosis. The onset of asbestosis probably depends upon the asbestos dust concentration, the fiber morphology, and the length of exposure. Asbestosis is a progressive disease which may develop fully in seven to nine years after the first exposure. Usually the pneumoconiosis becomes evident 20 to 40 years after the first exposure to asbestos. Once established, the asbestosis progresses even after the exposures have ceased. In its severe forms, death results from the inability of the body to obtain requisite oxygen or from failure of the heart to pump blood through the scarred lungs.[15]

Bronchogenic carcinoma and mesothelioma of the pleura and peritoneum are causally associated with asbestos exposures; excesses of cancer of the stomach, colon, and rectum have been observed. Neoplasm, such as mesothelioma, may occur without radiologic evidenceof asbestosis at exposure levels lower than those required for prevention of radiologically evident asbestosis. Mesothelioma can occur after a short intensive exposure. Mesothelioma tumors have yet to be successfully cured by any types of treatment, including chemotherapy, radiation, or surgery; death usually results within a year of diagnosis.[15]

Calculations suggest that cigarette smoking asbestos workers have approximately eight times the risk of developing lung cancer compared with other smokers.[15]

2. 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 appears to be a precursor to progressive massive fibrosis (PMF).[7]

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 lesion.[7]

The ACGIH TLV* of 2 mg/m^3 is set at a level intended to reduce the risk of developing pneumoconiosis.[16] The OSHA PEL is 2.4 mg/M^3.[6] For situations involving coal dust containing appreciable amounts of quartz (greater than five percent (5%)), one should use the evaluation criteria for quartz containing dusts.[5]

3. 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.[17] The NIOSH recommended 8- to 10-hour TWA for exposure to crystalline silica is 50 ug/m^3.[18]

4. 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.[19]

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 emanating 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.[19]

Chronic heat illnesses are those occurring as after effects 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.[19]

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).[19] Available data concerning chronic heat effects have not contributed much to protecting workers from heat effects.[9]

VI. Results

A. July 1986 Initial Survey Sampling Results:

1. Asbestos Content of Bulk Samples:

Table V presents the identity of bulk samples collected during the initial survey along with their respective per cent asbestos content. Three of the nine samples contained significant amounts of asbestos (1% or greater) identifying them as asbestos containing materials (ACM). Amosite, chrysotile asbestos or both were identified as present in these three samples. Three other samples contained less than 1% amosite asbestos. No crocidolite, actinolite/tremolite, or anthophyllite asbestos was determined to be present in any of these bulk samples.

2. Metals Content of Bulk Settled Dust Samples:

Table VI presents the various dust samples and their respective metal content. No silver, or cobalt was found in any of the eight samples analyzed. Arsenic, lanthanum, antimony, selenium, tin, tellurium and thallium content could not be accurately determined due to interferences which elevated the limits of detection from five to 10 times those for the other metals. Metals of greater toxicologic interest such as beryllium, cadmium, chromium, nickel, and lead were present in at least 50% or more of the samples.

3. Heat Stress Measurements:

Table VII presents the heat stress measurements obtained from both the July 1986 and the January 1987 surveys. Wet Bulb Globe Temperatures (WBGT) ranged from 80 to 93°F in the power plant. The geometric mean (GM) was 88°F with a geometric standard deviation (GSD) of 1.04. The median WBGT value (the value below and above which fell 50 percent of the measurements) was 88°F. Higher values were found on the Main Level around Boiler #8, the burner levels, the seventh floor, and the ninth floor at the top of Boiler #8. Outdoor WBGT values obtained at two locations were 78 and 84°F. A WBGT value obtained inside the Seventh Street steam vault, after passive ventilation and removal of standing water, was 118°F.

B. January 1987 Follow-up Survey Sampling Results:

1. Follow-up Survey Heat Stress Measurements:

Table VII also presents the WBGT values, globe temperatures, dry and wet bulb temperatures, and the relative humidity for previously measured locations thoroughout the power plant obtained during a colder season (winter). WBGT values ranged from 65 to 82°F within the power plant. The GM was 74°F with a GSD of 1.08. The median WBGT value among the measurements in the power plant was 74°F. The highest WBGT values during this survey within the plant were found on the seventh and ninth floors around Boiler #8. Outdoor WBGT values were 39, 42, and 54°F. Air temperatures were 39 to 56°F. Two WBGT values obtained inside the Sixth and Seventh Street steam vaults were 128 and 99°F respectively.

2. Personal Exposure Sampling for Asbestos Exposures:

Although no insulation work or maintenance operations were performed around equipment insulation known to contain asbestos, exposure monitoring was conducted for several workers having assignments that would take them throughout the power plant or out in the RDF Bin area. Table VIII presents the results of individual breathing zone samples for asbestos exposures. All exposures, as evaluated by phase contrast microscopy for fibers, were at or below one tenth of the OSHA asbestos PEL of 0.2 fibers/cc. TEM analysis of the highest exposure encountered by the Fireman C revealed the presence of very short, narrow asbestos fibers.

3. Breathing Zone Exposures to Trace Metals:

Worker exposures to all metals were negligible during the survey. Table IX presents this data. Exposures to lead ranged from below the analytical limit of quantitation of 1 ug per sample up to 6 ug/m^3, well below the OSHA lead standard of 50 ug/m^3. Exposures to metals including arsenic, beryllium, cadmium, cobalt, chromium, and nickel were below reportable levels (less than 1 ug per sample). Table II presents all the metals evaluated on the personal exposure samples. Table IX reports all metals for which at least one individual's exposure was above the analytical limit of quantitation. Exposures to calcium, iron, and sodium as well as barium and phosphorus were excluded from the worker exposure table. Table VI presents the various metals content of the bulk samples collected throughout the power plant and supporting areas, representing the potential sources of contaminants to which the workers may be exposed.

4. Worker Exposures to Coal Dust and Crystalline Silica:

Table X presents the results of exposure monitoring for individual exposures to coal dust, encountered primarily by coal handlers, and crystalline silica as quartz and cristobalite. Exposures generally were negligible, and many were nondetectable. One coal handler had a quartz exposure of 0.04 mg/m^3, above the NIOSH action level of 0.025 mg/m^3.[18] Respirable dust exposures were again low, with the exception of the previously mentioned individual whose respirable dust exposure was 3.4 mg/m^3, in excess of the OSHA and ACGIH respirable coal dust evaluation criteria of 2.4 and 2 mg/m^3 respectively. Worker exposure to fly ash was very limited during the NIOSH survey, few workers monitored reported or were observed to be, working in areas were fly ash exposures may occur. Two workers in Table IX and one worker in Table X are indicated as having worked at least a portion of their workday in an area where fly ash exposures may occur.

5. Bulk Dust Sample Analyses for Crystalline Silica:

The crystalline silica content of bulk samples of coal dust, fly ash, and refuse dust, (although limited in number (4)) was fairly constant. Cristobalite was not detected as being present in any of these bulk samples. Quartz content was about three percent, with a range of 2.8 to 3.0 percent by weight. The coal and refuse dust samples both contained three percent quartz. The fly ash obtained from the ash silo contained 2.8 to 2.9 percent quartz.

6. Full-Shift Noise Exposures:

Although none of the workers monitored for full-shift noise exposure exceeded the OSHA PEL of 90 dB(A), 43 percent of the exposures measured approached or exceeded 85 dB(A), requiring the implementation of a hearing conservation program. Noise exposures ranged from 74 to 87 dB(A) projected over a full work shift based upon the noise levels encountered in the workers' work areas during the actual sampling period. Maximum noise levels experienced by the workers measured over any one minute sampling period ranged from 92 to 101 dB(A). These levels were below the maximum noise level permitted by OSHA of 115 dB(A). Table XI presents the individual noise exposures of the workers monitored January 12-13, 1987.

VII. DISCUSSION

Asbestos exposures during the survey did not identify an immediate health hazard, however the presence of asbestos containing materials throughout the plant, especially on older boilers and supporting equipment still in use provides a potential health hazard as the insultation deteriorates. Some degree of background asbestos contamination was observed in association with loose ACM in older parts of the plant and the presence of asbestos fibers in a power plant worker's breathing zone sample. The absence of an asbestos operations and maintenance program, improper handling of asbestos insulated equipment and gasket material observed during the initial survey, and the co-mingling of equipment and pipes with and without ACM containing insulation provide an increasingly greater probability for both localized and wide spread asbestos contamination and worker exposure or overexposure. Plans by the city to decommission in place Boilers #5 & #6 will still require the identification, labelling, proper handling, maintenance, repair and possibly removal of asbestos containing materials within the plant. An additional potential source of ACM is the refuse burned at the plant, however, except for work performed in the RDF Bin and over at the refuse processing facility that shreds the refuse, exposures from the RDF probably represent less of a risk to the power plant workers than the ACM insulation present in the plant. The significance and magnitude of asbestos exposures from the refuse is unknown.

A number of workers had been certified by an asbestos training contractor for working on ACM, but a point of discussion during the survey was the unacceptability of fit testing bearded workers and permitting them to use respiratory protection contrary to the OSHA respirator standard. The plant had initiated an Asbestos Operations and Maintenance Program by the time of the follow-up survey. The use of asbestos-containing gasket materials for gasket replacement had also reportedly been discontinued at that time.

Exposures to various metals, especially some of the more toxic elements such as cadmium, chromium, arsenic, nickel, and lead, were very low. This is in contrast to a similar HHE conducted at another RDF power plant where exposures to cadmium, chromium, nickel, and lead were found to be much higher. Lead exposures in excess of the OSHA PEL of 50 ug/m^3 were also documented in this earlier study.[20] Several factors probably influence the differences in trace metal exposures observed between this study and the previous RDF study. In the case of lead, although the metal was present in bulk samples collected for both studies, the lead content in bulk samples collected at the Ames facility was on the order of from below 0.01% up to 0.09%. The lead content of bulk samples from this other municipal RDF power plant study was higher and ranged from 0.02 to 0.54% by weight.[20]

Other factors contributing to the low exposure levels observed at Ames are its small size (only one boiler is operating) and scale, the fuel mixture of RDF and coal generally does not exceed 15% refuse (versus operation of up to 100% refuse), all processed refuse delivery systems operate inside the power plant in a closed system, and the dependence upon an ash handling system that uses pressurized water to mix and transport ash. When water isn't used for ash transport, as in moving the ash from the electrostatic precipitators, it is transported pneumatically. Maintaining the refuse content of the fuel at 15% or less may contribute significantly to the lower trace metal content of the ash by diluting higher levels present in refuse ash with fly ash from coal.

The exposures to metals observed during this HHE should be considered as more representative of minimum exposure levels for the workers and job titles sampled. During the follow-up survey no refuse was being burned in the boiler, minimal work involving potential fly ash exposures was performed, and workers at the power plant have, by the nature of the design of the RDF handling system for charging the boiler, few opportunities for exposure to the refuse dust itself. Repair work on the RDF Bin was performed with the bin empty. The total workforce was also quite small and the number of workers in any one job title was limited, providing fewer opportunities for exposure monitoring.

Arsenic exposures were not identified during the activities conducted by the workers during the survey. This metal was of interest based upon a trade journal article indicating that arsenic was found in high concentrations in coal fired boiler deposits.[21]

Coal dust and crystalline silica exposures were low, with one exception, during the follow-up survey. This is probably influenced by the fact that no coal was received or dumped in the coal yard during the days of sampling. The one coal handler having an elevated crystalline silica exposure and an overexposure to coal dust was performing clean-up in the #5 belt passageway underneath the coal hopper house. He was observed to be wearing a nuisance dust respirator. The coal handlers also reported that the coal dust exposures occurring during coal car dumping within the coal hopper house were severe enough to seriously impair vision. No opportunity to observe this occurred during the survey, but the configuration of the structure, the absence of dust controls, and the amounts of dust removed from surfaces during clean-up (a unit train of 55 coal cars had just been unloaded the previous week, thus clean-up was going on during the survey) indicated that high dust exposures were possible. The coal dust and crystalline silica exposures documented in this study should be considered representative of the low end of possible exposures encountered by the coal handlers.

Exposures to respirable fly ash and silica exposures associated with the fly ash were very limited. Table X presents one worker having a work assignment involving the fly ash handling equipment, and this task was of limited duration. His exposure was negligible for crystalline silica and the respirable dust exposure was 0.3 mg/m^3. One should be cautioned that comparison of fly ash exposures to nuisance dust criteria may not be appropriate in view of the fact that the ash may contain more toxic materials such as trace metals that would necessitate the application of more stringent exposure criteria. Also a dust must meet a certain set of criteria specified by the ACGIH (presented in Table III) before it can be generally considered to be a nuisance dust.

Although carbon monoxide exposures were a concern in the coal yard in association with operation of the thaw shed and the front-end loaders, the thaw shed was not in use, preventing evaluation or observation of its operation. Limited long-term detector tube sampling in the front-end loader cab did not reveal any detectable carbon monoxide exposure in the cab. Based upon this finding, no further samples were obtained in the front-end loader cab.

Potential heat stress exposures appear to be one of the most serious health hazards present at the plant. Heat stress measurements (WBGT readings) obtained at numerous locations throughout the plant identified areas well in excess of recommended levels for continuous strenous labor. Some of these areas met or exceeded the heat levels permitting continous light work. This applied to acclimatized as well as unacclimatized workers. Heat levels measured in the steam vaults exceeded those that could be safely entered by any individual regardless of acclimitization or level of work effort required. Variation in heat stress levels was observed with the change in seasons, however for some locations the radiant heat load contribution (infrared energy from hot equipment and surfaces indicated by globe temperature) from surrounding surfaces was such that outside air temperature and air movement would have little influence on the WBGT values. The number of locations measured within the power plant during both July 1986 and January 1987 that remained at or above a WBGT value of 80°F was four out of twenty-one (20%). Some additional hot work areas were measured during the January survey, and these would most likely have increased values during warmer seasons.

The absence of a hot work environments program places workers at increased risk of heat related illness or death if work in some of the identified areas were to be required. An extreme hot work environment encountered on occasion by the power plant personnel is found in the below street steam vaults. The plant has adopted a policy of shutting off the steam to the vault and allowing it to cool down before anyone is permitted to enter the vault. Throughout the power plant itself there was little opportunity to observe work in the hot areas of the facility. The types of work performed could easily range from very light, such as walking through an area to read gauges, to heavy, such as major maintenance repair work or equipment installation and replacement. Heat illness is something that does not take an entire workshift to develop. At high temperatures, the body's compensatory mechanisms for eliminating excess heat are quickly overwhelmed and life threatening situations can develop in only a few minutes.

Personal noise exposure sampling revealed that about 30 percent of those monitored had exposures that would require implementation of a hearing conservation program (exposure at or above 85 dB(A)). About 71 percent encountered maximum noise level at some time during the sampling period at or in excess of 95 dB(A). Several areas of the plant were designated as manadatory hearing protection areas, however compliance was observed to be poor and the designations and locations of the signs relied very heavily on conscientious cooperation on the part of all workers and visitors passing through the area. Discussions concerning the patchwork of designated hearing protection areas raised the possibility that entire plant floors where high noise areas are present require hearing protection.

The plant had no formal respiratory protection program in place. The presence of disposable nuisance dust respirators, chemical cartridge respirators, disposable chemical vapor respirators, and self-contained breathing apparatus (SCBA) necessitates such a program. Instances of improper wearing of respirators (e.g. bearded workers), improper respirator storage, and the absence of a regular inspection and periodic training by designated workers in the use of SCBAs was noted.

The quality of chemical storage areas varied throughout the plant. Storage below the turbine hall in the basement had the largest concentration of chemicals present. Adjacent to this area, old and discontinued chemicals were stored in drums. On the main floor chemicals used in analyzing boiler water were located both in a small lab and haphazardly inside of the water analysis panel. Compressed gas cylinders were stored outside of the plant in a cylinder storage shed, but had not been chained in place. Large quantities of sulfuric acid (500 gallons) and chlorine (1 ton cylinder) were stored outside of the plant by the cooling towers for use as biocides in the towers. It was in this area that an accumulation of water beneath the sulfuric acid storage tank was noted during the initial survey. This had been drained by the time of the follow-up survey. This area was located outside of the plant where the SCBA respirators were stored.

One item of concern mentioned by the requestors was the presence of polychlorinated biphenyl (PCB) containing transformers in the basement of the plant. These were no longer in use, were marked as PCB containing along with a warning, had not been involved in a fire, and did not present any visual evidence of damage or leakage. No repairs or modifications were reported to have been performed on the units and they had been targeted for removal and disposal by the power plant management. They were not located in an area that presented a high degree of risk from mechanical damage to the transformers. These units were not considered to present a significant health risk in their present configuration.

The plant offered periodic medical examinations, however they sought input from NIOSH in identifying elements for inclusion in the exams. Most workers currently use their own personal physicians for concerns involving work related injuries or illnesses, and the plant does not maintain any occupational medical records on the workers. Periodic medical surveillance that would be warranted for workers at the plant may include baseline and periodic audiograms, determination of a worker's ability to wear respiratory protection, fitness for work in hot and dusty environments, regular surveillence of workers involved with asbestos work, and baseline blood lead determinations.

Hearing protection, respiratory protection, hazard communication, hot work environment and medical surveillance programs all require incorporation of worker training programs. Initial and periodic training provides the workers not only with an understanding of the necessity and proper operation of the respective programs, but also encourages greater individual involvement in protection from occupational hazards through the proper use of engineering controls, administrative programs, work practices, and when necessary through the proper use of personal protective equipment. Periodic industrial hygiene surveys to evaluate worker exposures to various contaminants and agents encountered at the plant also provide valuable information for development and modification of various control measures and industrial hygiene/occupational health programs at the facility.

VIII. SUMMARY AND CONCLUSIONS

The industrial hygiene surveys conducted at the Ames Municipal Power Plant identified potential health hazards from noise, heat, asbestos, coal dust, and crystalline silica. The only "overexposure" documented was to coal dust in the coal yard. Exposures to a variety of metals including cadmium, chromium, lead, and nickel were very low or non detectable. Factors contributing to the low metals exposures may include the low percentage of refuse used as fuel (15% maximum) compared to coal, enclosed refuse handling and feed systems to the boiler, and possibly the fact that during the survey no refuse was being burned as part of the fuel supply. The absence or necessity for improvement, of personal protective equipment programs, chemical storage and hazard communication program, asbestos operations and maintenance program, hearing conservation program, hot work environments program, and considerations for medical surveillance are discussed.

IX. RECOMMENDATIONS

A. Hot Work Environments and Heat Stress:

Heat:

The control of heat can be approached by addressing the various components which contribute to heat stress.[22]

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), and 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.[9]

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.[9] Salt supplementation of the normal diet is rarely required except possibly for heat-unacclimatized individuals during the first 2 or 3 days of heat exposure. Generally recommending increased salt intake, even for those who watch their own salt consumption, is not warranted. Salt tablets can irritate the stomach and should not be used.

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.[9]

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.[9]

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.

The practice of shutting off the steam supply to steam vaults to allow a cool-down period prior to working in them should be continued. Considering the extremely high temperatures present in the vaults, this approach probably represents the best, and possibly the only pratical way that work may be performed safely in the steam vaults.

B. Chemical Contaminants:

The potential chemical contaminant exposures of greatest concern from this investigation appeared to be asbestos, coal dust, and crystalline silica. Further exposure monitoring to characterize contaminant levels during activities involving these contaminants will futher define the hazard and also provide information concerning the effectiveness of control measures in use.

Adherence to proper maintenance and use of engineering controls and work practices as well as containment measures and proper personal protective equipment usage will prevent unnecessary asbestos exposures. Implementation of a complete asbestos operations and maintenance program is essential.

Exposures to coal dust and crystalline silica are primarily associated with work in the coal yard in association with rail car dumping, coal handling, and clean-up procedures. Half-mask dust cartridge respirators are preferrable to using the currently available nuisance dust respirators for workers required to do jobs in dusty areas. Removal of workers from the areas of dust generation during railcar dumping until the dust has settled would reduce exposures. Wet cleaning procedures and regular house keeping will also reduce reintrainment of settled dust. Enclosure of transfer points and dumping bins would reduce the number of sites that permit fugitive dust emissions into the surrounding equipment and building areas. This would also serve to reduce housekeeping requirements. Application of a dust suppressant to the coal itself as it is stored may also present an option for consideration in controlling coal dust. Crystalline silica content appeared to be uniform in bulk samples of the coal dust, fly ash, and refuse dust, suggesting that activities involving exposure to these latter two dusts also utilize appropriate dust suppression techniques and personal protective equipment.

C. Chemical Storage:

Chemical storage in the back of the water panels should be discontinued. At the time of the study this area had become a haphazard storage location for a variety of chemicals. Implementation of a hazard communication requires clear labelling on all chemical containers, both large and small. Efforts should be undertaken to remove old and discontinued chemicals stored in the basement of the power plant. Emergency response personnel should be acquainted with the location, identity, and quantities of hazardous chemicals stored throughout the plant.

D. Respiratory Protection:

A respiratory protection program in accordance with the OSHA respiratory protection standard, 29 CFR 1910.134, should be implemented. This would include provisions for training, determination of medical fitness for respirator use, individual respirator issuance, fit testing, respirator maintenance, inspection, and storage. Disposable respirators for acid gases and organic vapors should not be re-used indefinitely once opened. The sorbent material will continue to absorb contaminants and water vapor from the surrounding atmosphere once the respirator is put into use. Disposable sorbent (air purifying respirators for chemical contaminants such as acid gas and organic vapors) should be replaced on a weekly basis for workers having a need to use them in the Demineralizer Area. More frequent replacement may be necessary if there is a lot of water vapor in the area. Respirators should be stored in clean, sealed containers in a clean uncontaminated area between uses.

Half-mask respirators equipped with dust cartridges are recommended over the nuisance dust respirators for coal handlers in the coal yard. These respirators would provide better protection to the coal handlers, but vigilance is necessary to keep the respirators clean and the cartridges would need to be changed daily or more frequently if dustier conditions prevail.

The presence of SCBAs in the plant necessitates incorporation of the same elements of a respiratory protection program for these devices plus regular inspection, on a monthly basis, of the units and periodic use of the equipment by personnel authorized to use these devices. Additionally, since the SCBAs may be used under conditions immediately dangerous to life and health (such as a chlorine tank repair), provisions for standby personnel, and direct and continuous communication with the worker, and the use of safety harnesses and safety lines must be provided.

A large portion of the stress of wearing respiratory protection is borne by the worker's cardiovascular system. Medical fitness determinations addressing the suitability of the individual to use respirators is recommended. The suggested frequency of such determinations, barring a change in health status which would necessitate interim testing, is as follows: For most working conditions requiring respirators, every 5 years for workers under 35 years of age, every 2 years for workers aged 35-45, and every 1-2 years for workers over 45; For strenous work conditions requiring SCBA usage, evaluations should be conducted every 3 years for workers under 35, every 18 months for workers age 35-45, and annually for workers over 45.[23] Respiratory protection cannot be worn by bearded workers, since the beard is one item that prevents obtaining a satisfactory seal of the respirator facepiece to the worker's face. Leakage around the edges of the respirator negates the use of the respirator. Periodic fit testing of the workers to evaluate respirator fit and protection factors is also required.

The presence of several chemicals in large quantities, specifically sulfuric acid (500 gallons) and chlorine (a 1 ton cylinder), necessitate an emergency response program addressing measures to be taken in the event of an uncontrolled or accidental release of the material. Local emergency response personnel should be knowledgeable of the chemical hazards present at the plant, their location, and the quantities.

E. Monitoring for Trace Metals:

Exposures to trace metals did not appear to be a problem, however due to the dynamic nature of the refuse content and the fact that very little refuse was handled during the survey, periodic evaluations of worker exposures to the metal cadmium, chromium, nickel, and lead should be undertaken. Target job categories or titles would include those involving handling refuse dust and fly ash. A trade journal article identified arsenic deposits on boiler tubes as a potential health hazard encountered by personnel working inside the boilers.[21] Management should consult the OSHA arsenic standard, 29 CFR 1910.1018 prior to initiating work on the boiler tubes. An initial measure to be taken would be collection of the deposits from the tubes and having them analyzed for arsenic compounds prior to the initiation of the work, if this is feasible. This would help determine whether a potential hazard is present from arsenic.

F. Noise:

Worker noise exposures demonstrated the need for improvement in the plant hearing conservation program. Compliance with the wearing of hearing protectors in posted hearing protection areas was observed to be poor. Discussion with management representatives concerning the posting of high noise areas and mandatory hearing protection areas resulted in a recommendation that high noise areas be designated by floor in the power plant, rather than localized areas since some locations had numerous entry points and workers could easily enter or pass through the areas without being informed of the need for hearing protection. This approach would simplify the need for workers to be continuously donning hearing protection. Worker education and management support for the program should also be increased. Personnel passing through high noise areas should also be required to wear hearing protection, regardless of how long they intend to be in the area. Ear muffs are issued to the workers for use in conjunction with their hard hats. One problem with use of this type of hearing protection is that when safety or prescription glasses are worn with the muffs, the temple bars of the glasses breaks the seal of the muffs around the ears, negating the effectiveness of the ear muffs. In this instance, in-the-ear hearing protection is more effective.

The railcar vibrator located in the coal hopper house, although not in use during the time of the survey, reportedly generated tremendous noise levels. Since the coal handlers had some of the higher noise exposures without operation of the vibration unit, workers in this area may need to wear both ear plugs as well as ear muffs.

G. Asbestos:

The plant had begun to implement an Operations and Maintenance program for ACM within the plant. Determination and labelling of all ACM within the plant should be performed in order to permit easy identification of materials requiring special handling procedures. This would require labelling all insulation materials as either asbestos containing or asbestos free. A conservative approach to labelling materials of unknown composition is to classify them as ACM. Repair of existing insulation and coverings that are currently deteriorating will need to be completed as part of the implementation phase of the Operation and Maintenance program. Decommissioning of Boilers #5 & #6 in place necessitates a perpetual Operations and Maintenance program until the building and structures are razed or the ACM insulated equipment is removed. The purpose of this program is three-fold: (1) to clean up asbestos fibers previously released; (2) prevent future release by minimizing ACM disturbance and damage; and (3) to monitor the condition of ACM. Further information on this type of program may be obtained from the Region VII Regional Asbestos Coordinator, USEPA, 726 Minnesota Avenue, Kansas City, Kansas 66101; (913) 236-2838.

H. Worker Education:

A regular worker education program should be implemented that would incorporate training in hot work environments, hearing conservation, respiratory protection, hazard communication, asbestos containing materials, proper use of personal protective equipment, work practices, and personal hygiene. 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, lock-out and tag-out procedures, and personal hygiene to reduce their exposures to hazardous contaminants or conditions.

I. Medical Surveillance:

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 may encounter at this facility are high dust levels, toxic metals, use of respiratory protection, hot work environments, silica, asbestos, heavy manual labor, and height work.

Periodic medical surveillance should include audiometric testing, assessment of fitness for work in hot environments and using respiratory protection, and medical exams of asbestos workers. Recordkeeping is also an important part of any medical surveillance program. A successful health and safety program should include periodic reassessment of its effectiveness. This will include reveiwing of medical records; therefore, these documents should be well maintained. Each accident or illness should be promptly evaluated to determine the cause of the incident and to implement appropriate changes in the health and safety program. The program must be integrated with the industrial hygiene program, personal protective equipment program, and safety procedures.[24]

J. Miscellaneous:

The plant had implemented a tag-out procedure for repair of equipment. An additional component of this program should include a lock-out procedure to accompany tagging out the equipment.

Workers are currently given the option of laundering their coveralls at the plant or at home. Coveralls and uniforms should be laundered at the plant to avoid tracking contaminants into the workers' vehicles and homes.

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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 Ames Municipal Power Plant, Ames, Iowa
2. International Union of Electrical Workers, Local 234
3. NIOSH Regional Office
4. OSHA

For the purpose of informing the approximately 50 affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table I

Job Titles and Descriptions of Workers Participating in Exposure Monitoring

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

January 1987

Job Titles	Job Description and Examples
Power Plant Auxiliary Operator	Inspects and assists Plant Operator in the operation of power plant equipment; operates, lubricates, and inspects auxiliary power plant equipment; performs routine inspections of equipment; observes and records equipment operation parameters; tests various process water qualities; operates boiler bottom ash removal equipment and fly ash removal equipment.
Power Plant Fireworker (Fireman)	Operates control equipment in firing high pressure boilers. Uses stoker and pulverized coal burning equipment and observes burning conditions of burners when firing coal, gas, oil, RDF, or combination fuels. Operates soot blowers, fly ash removal equipment, boiler feed pumps, fans, pulverizers, and other boiler related auxiliary equipment. Operates pneumatic conveyors, feeders, and controls for burning RDF.
Coal Handler	Transfers coal from coal cars to storage bins and hoppers with mechanical conveyors and elevators; operates heavy equipment in moving caol cars and storing and reclaiming coal; hand shovels coal; keeps tunnels and gallerys clean.
Electric Technican	Installs, maintains, and tests electonic circuits such as high speed data and control systems, telemetering, communication, load control, protective relays and instruments. Performs maintenance, trouble shooting, and installation of a wide variety of electrical and electronic systems.
Power Plant Maintenance Worker	Performs routine work of moderate difficulty in manual labor, including semi-skilled tasks. Assists in basic machine work, steamfitting, plumbing, trubine, boiler, and auxiliary equipment repair; repacks valves, may perform cutting and welding as required; uses hand tools to assist in repairing and maintaining plant machinery and equipment.
Power Plant Maintenance Mechanic	Performs work of moderate to considerable difficulty in skilled tasks in the maintenance and repair of mechanical equipment in electrical utility facilities. Performs machine work, steamfitting, plumbing, turbine, boiler, and auxiliary equipment repair; inspects and repairs ash handling equipment; performs welding tasks.
Instrument and Control Repairworker	Performs maintenance, trouble shooting, and installation of a wide variety of electrical and pneumatic systems. Performs routine inspections on power plant combustion control equipment, cleans and performs maintenance on such equipment; maintains flue gas analysis equipment, automatic control valves, and water testing equipment.
Custodian	Performs custodial care and maintenance of public buildings and grounds. Sweeps, mops, scrubs, waxes and polishes floors; disposes of trash and garbage; opens and closes buildings.

Table II

Metals Evaluated in Bulk Dust and Personal Exposure Samples

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

Element[1]	Symbol	Analytical Limits of Detection[2] LOD Initial	LOQ Follow-up	LOQ Filters
Aluminum	Al	10 ug/g	0.01(% by wt)	1.0 ug
Antimony	Sb	10	0.01	1.0
Arsenic	As	5.0	0.01	1.0
Boron*	B	10	--	-
Barium	Ba	1.0	0.01	1.0
Beryllium	Be	1.0	0.01	1.0
Calcium	Ca	5.0	0.01	1.0
Cadmium	Cd	1.0	0.01	1.0
Cobalt	Co	1.0	0.01	1.0
Chromium	Cr	1.0	0.01	1.0
Copper	Cu	1.0	0.01	1.0
Iron	Fe	1.0	0.01	1.0
Lanthanum	La	5.0	0.01	1.0
Lead	Pb	2.5	0.01	1.0
Lithium**	Li	--	0.01	1.0
Magnesium	Mg	1.0	0.01	1.0
Manganese	Mn	1.0	0.01	1.0
Molybdenum	Mo	1.0	0.01	1.0
Nickel	Ni	1.0	0.01	1.0
Phosphorus**	P	--	0.01	1.0
Platinum**	Pt	--	0.01	1.0
Selenium	Se	10	0.01	1.0
Silver	Ag	2.5	0.01	1.0
Strontium**	Sr	--	0.01	1.0

continued

Table II (continued)

Metals Evaluated in Bulk Dust and Personal Exposure Samples

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

Element(1)	Symbol	Analytical Limits of Detection(2) LOD Initial	LOQ Follow-up	LOQ Filters
Tin*	Sn	10	--	-
Tellurium	Te	10	0.01	1.0
Thallium	Tl	10	0.01	1.0
Titanium	Ti	10	0.01	1.0
Vanadium	V	10	0.01	1.0
Yttrium	Y	1.0	0.01	1.0
Zinc	Zn	1.0	0.01	1.0
Zirconium	Zr	10	0.01	1.0

1. The metals analyzed in the various bulk and filter samples are listed here along with their respective symbols. *: denotes metals analyzed only in the bulk samples obtained during the initial survey (July 1986). **: denotes metals analyzed in the bulk samples and filter samples collected during the follow-up survey (January 1987) but not in the initial bulk samples.
2. Analytical limits varied between the samples collected during the initial and follow-up surveys. The initial survey sample bulks limit of detection (LOD) are given in micrograms/gram of sample (ug/g); the follow-up survey bulks were given a limit of quantitation (LOQ) of 1 percent (0.01) by weight; and the LOQ for exposure samples collected on filters was 1.0 micrograms (ug) per filter. --: denotes metal not analyzed for the indicated sample set.

le III

Chemical Contaminant Exposure E[illegible]tion Criteria and Health Effects Summary

Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

Contaminant+	Recommended Exposure Limit++ (ug/m^3)	Source*	OSHA** (ug/m^3)	Symptoms***	Target Organs***
Arsenic and compounds (as As)	2 (15-min ceil)	NIOSH	10	Ulceration of nasal septum, dermatitis, gastrointestinal disturbances, peripheral neuropathy, respiratory irritation, hyperpigmentation of skin, [carcinogenic]	Liver, kidneys, skin, lungs, lymphatic system
Cadmium dust	Lowest Feas Limit	NIOSH	200	Pulmonary edema, dyspnea, cough, chest tightness, substernal pain; headache; chills, muscle aches; nausea, diarrhea; emphysema; proteinuria; anemia; [carcinogenic]	Respiratory system, kidneys, prostate, blood
Coal dust (respirable)	2000 (5% quartz)	ACGIH	2400	Coal worker's pneumoconiosis, progressive massive fibrosis	Lungs
Chromium (Cr)	1 (Note 1) 25 (Note 2)	NIOSH	500 (Note 3) 1000 (Note 4)	Respiratory irritation; nasal septum irritation; leukocytosis, leukopenia, monocytosis, eosinophilia; eye injury, conjunctivitis; skin ulcers, sensitization, dermatitis; lung cancer, histologic fibrosis of lungs; [Chromium VI carcinogenic]	Blood, lungs, respiratory system, liver, kidneys, eyes, skin
Lead (Pb)	<100 (Note 5)	NIOSH	50	Lassitude, insomnia, pallor, eye grounds; anorexia, weight loss, malnutrition, constipation, abdominal pain, colic; hypotension, anemia; gingival lead line, tremors, wrist paralysis	Gastrointestinal system, central nervous system, kidneys, blood, gingival tissue
Nickel (Ni)	15	NIOSH	1000	Sensitization dermatitis; allergic asthma; nasal cavities; pneumonitis, [carcinogenic]	Nasal cavities, lungs, skin
Respirable Dust	5000 (<1% quartz)	OSHA	5000	Long history of little adverse effect on lungs and does not 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
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 or compound with the elemental symbol or molecular formula in parenthesis.

++ Recommended exposure limits are given in micrograms per meter cubed (ug/m^3).

* NIOSH recommended exposure limits (RELs) are obtained from the NIOSH pocket guide to chemical hazards (reference 3) except for lead which was obtained from NIOSH testimony to the U.S. Department of Labor (reference 4). ACGIH criteria are obtained from the current Threshold Limit Values, (reference 5). All values are time weighted averages over an 8- (in the case of NIOSH criteria 8- to 10- hour) hour workshift, except for the ACGIH criteria, except where otherwise noted by a ceil (ceiling) notation. Lowest Feasible Limit denotes that exposures to potential occupational carcinogens should be maintained at the lowest levels feasible.

** OSHA permissible exposure limits (PELs) are given in ug/m^3 as for the RELs. OSHA PELs from reference m.

*** Symptoms and target organs listings obtained from reference 3. Description of nuisance dust criteria from the ACGIH TLVs for 1987-1988, reference 5. Symptoms of coal dust overexposure taken from reference 7.

Note 1 The 1 ug/m^3 REL for chromium is for carcinogenic chromium VI compounds.

Note 2 The 25 ug/m^3 REL for chromium is for noncarcinogenic chromium VI compounds.

Note 3 The 500 ug/m^3 OSHA PEL is for soluble chromic and chromous salts as chromium.

Note 4 The 1000 ug/m^3 OSHA PEL is for chromium metal and insoluble salts.

Note 5 The OSHA respirable crystalline silica PEL in ug/m^3 is calculated for each sample by the following formula: $\frac{10000 ug/m^3}{(\% SiO_2 \text{ in sample})+2}$ = PEL ug/m^3

Table IV

ACGIH and NIOSH Recommended Heat Exposure Limit Values

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

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 5.

** 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 5 and the NIOSH Occupational Exposure to Hot Environments Revised Criteria, reference 9.

Table V

Bulk Sample Asbestos Content in Percent by Volume

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

Sample Description/Location	% Asbestos by Volume* Amosite	Chrysotile
Insulation material on floor below leaking pipe; main floor, SW corner of Boiler #6	<1	10-20
Wet insulation obtained from above pipe, same location	ND	5-10
Settled dust on I-beam; S side of Boiler #5, first mezzanine level up from main floor	ND	ND
Loose material lying on floor; around Boiler #5, first mezzanine level:		
Cementitious type material-chunks	<1	ND
Soft, fibrous material	15-20	/5
Settled dust sample; N side of Boiler #6, NE corner stairs, below top walk-way	ND	ND
Settled dust; SW corner of Boiler #7, above pulverized coal inlets to boiler	ND	ND

* <: denotes less than 1%; ND denotes nondetectable; / denotes approximately

Table VI

Metal Content of Bulk Settled- and Process- Dust Samples

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

Sample Description	Metal Content, Percent By Weight[1]																		
	Al	B	Ba	Ca	Cu	Fe	La	Mg	Mn	Mo	Na	Ni	P	Pb	Sr	Ti	V	Zn	Zr
Initial Survey Bulks: July 1986																			
Settled dust, above Boiler #7 pulverized coal inlets	1.7	0.02	0.01	9.6	<0.01	4.5	*	0.41	0.11	ND	--	ND	--	<0.01	--	0.02	ND	0.12	ND
Settled dust, Boiler #7, top of soot blowers	0.41	<0.01	0.02	2.2	0.05	37	*	0.15	0.18	ND	--	0.02	--	0.02	--	0.03	ND	0.04	ND
Settled dust, top of Boiler #7, level 7.5	1.6	0.02	0.02	6.3	0.02	3.2	*	0.68	0.06	ND	--	0.01	--	0.01	--	0.08	ND	0.18	ND
RDF Bin dust, 7/86	0.56	<0.01	0.02	2.4	0.01	0.32	*	0.16	0.02	ND	--	ND	--	0.04	--	ND	ND	0.05	ND
Settled coal dust, Shaker House, 7/86	0.26	<0.01	0.04	0.53	ND	0.24	*	0.96	<0.01	ND	--	<0.01	--	ND	--	0.01	<0.01	<0.01	ND
Fly ash, ESP B1-4, boiler #8, 7/86	6.4	0.06	<0.01	17	0.01	3.5	*	3.1	0.02	<0.01	--	<0.01	--	0.02	--	0.16	0.01	0.10	0.02
Settled dust, top of boiler #8, level 9	1.7	0.02	0.03	6.9	0.03	2.1	*	0.81	0.04	<0.01	--	0.11	--	0.01	--	0.09	<0.01	0.25	<0.01
Settled dust, side of boiler #8, level 5	2.2	<0.01	0.02	6.6	0.02	3.5	*	0.78	0.06	<0.01	--	0.01	--	<0.01	--	0.02	<0.01	0.53	<0.01
Follow-up Survey: January 1987																			
Fly ash, ash silo	6.5	--	0.47	15	0.02	3.3	0.01	2.8	0.03	0.01	1.2	<0.01	0.47	0.08	0.03	0.48	0.01	0.08	<0.01
Fly ash going to silo	6.5	--	0.46	15	0.01	3.4	0.01	2.88	0.03	0.01	1.2	<0.01	0.43	0.08	0.31	0.43	0.01	0.07	<0.01
Coal from Coal Yard	0.28	--	0.03	0.75	<0.01	0.19	<0.01	0.14	<0.01	<0.01	0.02	<0.01	0.02	<0.01	0.01	0.02	<0.01	<0.01	<0.01
Refuse dust, RDF Bin	0.62	--	0.02	1.4	0.01	1.8	<0.01	0.13	0.03	<0.01	0.27	<0.01	0.08	0.09	<0.01	<0.01	<0.01	0.05	<0.01

1. See Table I for the elemental symbols of the various metals and the respective limits of detection. <0.01 denotes elements that may have been present below a quantifiable level. ND denotes that the metal, if present, was below the analytical limit of detection. * denotes that interference in the analysis prevented accurate determination of the metal. Metals not listed here but present in Table I were all below the analytical limits of detection, limits of quantitation, or interferences prevented an accurate determination. All values are percent by weight.

Table VII

Heat Stress Measurements

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

Measurement Location	Date	Measurements in Degrees F[1]				
		WBGT	GT	DB	WB	%RH
Sub-Basement, Boiler #8:						
Feed water pumps, E side	7/86	85	102	101	78	35
	1/87	72	93	92	63	18
Feed water pumps, W side	7/86	83	100	98	76	36
	1/87	70	89	86	61	20
E side, pulverizer #83	7/86	86	106	96	77	42
	1/87	72	94	84	62	27
Between pulverizers #83 and #83	7/86	88	110	106	78	28
	1/87	74	99	92	63	18
Basement of Boiler #8:						
W side, below Boiler #8	7/86	82	95	95	76	42
	1/87	66	82	79	60	30
NE corner, below Boiler #8	7/86	80	93	92	74	42
	1/87	65	81	80	58	24
Main Level (Turbine Floor):						
Catwalk W of Boiler #8	7/86	90	113	106	81	34
	1/87	80	105	99	69	20
Blowers #81 and #82	7/86	87	106	102	79	36
	1/87	72	94	88	62	20
Turbine Hall	1/87	66	81	80	60	29
Burner Level 84 (Bottom):						
E side of Boiler #8	7/86	88	109	102	79	36
	1/87	69	92	90	59	12
Center Coal Burner	7/86	88	108	107	80	30
	1/87	70	91	85	61	22
Burner Level 81:						
Center Coal Burner	7/86	89	108	107	81	32
	1/87	73	94	87	64	27

continued

Table VII (continued)

Heat Stress Measurements

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

Measurement Location	Date	Measurements in Degrees F(1) WBGT	GT	DB	WB	%RH
Burner Level 83:						
Center Coal Burner	7/86	88	106	105	80	33
	1/87	74	95	89	65	26
N side of Boiler #8	7/86	92	115	112	82	27
	1/87	74	97	90	64	22
Upper Air Heater	1/87	79	106	98	68	19
Burner Level 82 (Top):						
Center Coal Burner	7/86	88	107	106	80	32
	1/87	73	94	89	64	24
Seventh Floor:						
W soot blowers	7/86	93	117	116	82	23
	1/87	76	100	97	66	18
E soot blowers	7/86	92	116	115	82	24
	1/87	79	106	101	68	17
Coal Tripper Room	7/86	82	96	95	76	42
	1/87	66	80	76	60	38
N side of plant roof	7/86	84	101	97	77	39
SW Corner Evaporators and Deaerators:						
Deaerator GgT1-11	7/86	89	109	104	81	37
	1/87	78	100	98	69	20
Plant evaporator	7/86	88	104	103	80	36
	1/87	80	100	98	72	25
Hospital evaporator	1/87	82	110	97	70	25

continued

Table VII (continued)

Heat Stress Measurements

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

Measurement Location	Date	Measurements in Degrees F[1] WBGT	GT	DB	WB	%RH
Ninth Floor:						
Steam super heater	7/86	92	116	107	82	34
	1/87	82	110	104	70	17
Spray flow valves*	1/87	81	107	103	70	18
N pressure guage	7/86	93	118	114	82	25
	1/87	82	108	104	71	17
Outdoors and Steam Vaults:						
N plant entrance	7/86	78	91	88	72	45
	1/87	42	44	43	42	90
Seventh Street Vault: Inside vault	7/86	118	146	138	102	30
	1/87	128	188	145	126	60
Above ground (alley)	7/86	84	115	91	74	44
	1/87	54	72	56	49	60
Sixth Street Vault: Inside vault	1/87	99	98	98	89	70
Above ground (alley)	1/87	39	43	39	37	80
NIOSH Recommended Exposure Limit[2]:		80				

1. Values are presented in degrees fahrenheit. WBGT: wet bulb globe temperature; GT: globe temperature; DB: dry bulb temperature; WB: wet bulb temperature; RH: relative humidity in percent.
2. NIOSH limit is for acclimated, healthy, physically fit men engaged in moderate continuous physical activity. Reference 9.

Table VIII

Breathing Zone Asbestos Exposures

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

January 12-13, 1987

Date	Location[1]	Job Title	Sample Duration (minutes)	Fibers/cc[2] (Total)	Comments[3]
1/12	RDF Bin, Power Plant	Instrument Repair	468	0.004	Cellulose, Fibrous glass
1/12	Power Plant	Fireman C	473	0.01	Cellulose, TEM
1/12	Power Plant	Custodian	333	0.003	Cellulose
1/13	RDF Bin	Maintenance	445	---	Filter overloaded[4]
1/13	RDF Bin	Maintenance Mechanic	374	0.002	Plant matter, Fibrous glass
1/13	Power Plant	Fireman C	469	0.004	Cellulose, Fibrous glass, TEM
Evaluation Criteria: OSHA Permissible Exposure Limit				0.2	

1. RDF Bin: Refuse Derived Fuel Bin or Atlas Bin; Power Plant work area was primarily around Boiler #8.
2. Total fiber concentration is presented in fibers per cubic centimeter (cc) and is reported as asbestos fibers when analyzed by Phase Contrast Microscopy.
3. Comments present subjective observations by the analysts for each sample regarding the nature of the fibers present. Two samples were analyzed by Transmission Electron Microscopy (TEM) for fiber count and fiber identification. TEM analysis of Fireman C's sample for asbestos obtained on 1/12/1987 revealed the presence of chrysotile and amosite asbestos fibers ranging in width from less than (<) 0.01 to 0.3 micrometers (um) and length from <1 to 11 um. Total asbestos fiber concentration on the filter was 2727 fibers, or 0.02 fibers/cc. The second sample for Fireman C obtained 113/1987 had a very heavy particulate loading, but did not contain any detectable asbestos fibers. Note that TEM is capable of identifying asbestos fibers much smaller than those visible by Phase Contrast Microscopy and counted according to the "B" rules of NIOSH Method 7400(1).
4. The filter was to heavily loaded to permit analysis of the sample.

Table IX

Breathing Zone Exposures to Trace Metals

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

January 12-13, 1987

Sample Description				Contaminant Concentration in ug/m3[1]					
Date	Location	Job Title	Duration (minutes)	Al	Mg	Pb	Sr	Ti	Zn
1/12	Power Plant, Boiler #8	Auxillary Operator	472	129	56	2	6	9	2
1/12	Power Plant, Boiler #8	Fireman C	473	3	NQ	NQ	NQ	NQ	NQ
1/12	Fly Ash Silo	Maintenance	130[2]	388	171	6	18	29	7
1/12	Fly Ash Silo	Maintenance Mechanic	501	57	25	1	2	4	2
1/12	RDF Bin (outside bin)	Maintenance	444	9	3	NQ	NQ	NQ	2
1/12	RDF Bin (outside bin)	Maintenance Mechanic[3]	431	7	2	NQ	NQ	NQ	2
1/12	RDF Bin (outside bin)	Maintenance Mechanic	439	4	2	NQ	NQ	NQ	1
1/12	RDF Bin (escapeway)	Electrical Technican	409	4	2	NQ	NQ	NQ	1
1/13	Power Plant, Boiler #8	Auxillary Operator	429	210	83	3	8	11	4
1/13	Power Plant, Boiler #8	Fireman C	469	6	9	NQ	NQ	NQ	2
	RDF Bin (outside)	Maintenance	446	6	3	NQ	NQ	NQ	2
1/13	RDF Bin (outside)	Maintenance	477	5	3	NQ	NQ	NQ	1
1/13	RDF Bin (outside)	Maintenance	389	4	1	NQ	NQ	NQ	NQ
1/13	RDF Bin and Shop	Maintenance Mechanic	519	3	2	NQ	NQ	NQ	NQ
1/13	RDF Bin (escapeway)	Electrical Technician	360	3	NQ	NQ	NQ	NQ	NQ
Evaluation Criteria:[4]		OSHA		--	--	50	--	15000	--
		NIOSH		--	--	<100	--	--	--
		ACGIH		10000	--	150	10000	10000	10000
Analytical Limit of Quantitation in ug/filter (sample):				1.0	1.0	1.0	1.0	1.0	1.0

1. Metal concentrations are presented in micrograms per meter cubed of air (ug/m^3). Elemental symbols are as follows: Al= aluminum; Mg=magnesium; Pb= lead; Sr= strontium; Ti= titanium; Zn= zinc. NQ denotes samples where the particular metal, if present, was below the analytical limit of quantitation, less than (<) 1.0 ug/filter.
2. Worker was present for only a partial work shift.
3. Maintenance Mechanics were involved in some welding operations during the survey, however the work was performed primarily along the lower exterior of the RDF Bin.
4. Evaluation criteria sources are: OSHA General Industry Standards, reference 6; NIOSH Recommended Exposure Limits, reference 3; and the ACGIH Threshold Limit Values, reference 5. Criteria for Ti and Zn are for titanium oxide and zinc oxide dust, not the elemental metal as reported in the table.

Table λ

Worker Exposures to Coal Dust* and Crystalline Silica

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

January 12-13, 1987

Sample Description[1]				Concentration mg/m3(2)			
Date	Location	Job Title	Duration	Quartz	Cristobalite	Resp.Dust	%SiO2
1/12	Coal Yard	Coal Handler	448	0.04	ND	3.4	1.2
1/12	Coal Yard	Coal Handler	428	Trace	ND	1.2	Trace
1/12	Coal Yard	Coal Handler	363	ND	ND	0.3	ND
1/12	Ash Silo	Maint.Mechanic*	488	ND	ND	0.3	ND
1/13	Coal Yard	Coal Handler	452	ND	ND	1.1	ND
1/13	Coal Yard	Coal Handler	665	ND	ND	0.6	ND
1/13	Coal Yard	Coal Handler	439	ND	ND	0.9	ND
Evaluation Criteria:[3]			OSHA	Note 1	Note 2	2.4	
			NIOSH	0.05	0.05	NA	
			ACGIH	0.1	0.05	2	
Analytical Limit of Detection per Sample:				0.015	0.015	0.01	

1. Sample duration is presented in minutes.
2. Concentrations are presented in milligrams per meter cubed of air (mg/m^3). Resp. Dust= respirable dust. %SiO2 indicates the percent of quartz in the individual sample. ND= nondetectable. Trace=trace amounts of the contaminant were present, but in insufficient quantities to be quantitated, generally less than about 0.03 mg/m^3.

*. This workers respirable dust exposure is for fly ash, not coal dust. Coal dust evaluation criteria is not applicable, and nuisance dust criteria (OSHA 5mg/m^3, respirable) may be inappropiate.

3. Evaluation criteria are obtained from the OSHA General Industry Standards, reference 6; NIOSH Recommended Exposure Limits, reference 3; and the ACGIH Threshold Limit Values for 1987-1988, reference 5.

Note 1. The OSHA respirable quartz permissible exposure limit (PEL) for each exposure must be determined using the following formula which incorporates the percent of crystalline quartz present in the sample into the calculation of the PEL. Respirable Quartz PEL (crystalline)= $\frac{10\ mg/m^3}{\%SiO_2 + 2}$

Note 2. To obtain the PEL for cristobalite, use 1/2 of the value calculated from the mass formula for quartz.

Table XI

Personal Full-Shift Noise Exposures

City of Ames Municipal Power Plant
Ames, Iowa
HETA 86-422

January 12-13, 1987

Sample Description				Results[1]			
				Dose			Maximum
Work Location	Job Title	Date	Duration (minutes)	Actual %	Projected %	Projected dB(A)	Level dB(A)
Power Plant	Auxiliary Operator	1/12	471	58	59	86	100
		1/13	480	42	42	84	100
Power Plant	Custodian	1/12	371	8	10	74	---
Coal Yard	Coal Handler	1/12	444	65	70	87	98
		1/13	417	51	58	86	97
Coal Yard	Coal Handler	1/12	422	22	26	80	---
		1/13	437	32	35	82	100
Coal Yard	Coal Handler	1/13	407	25	30	81	93
RDF (Atlas) Bin	Maint. Mechanic	1/12	436	40	44	84	101
		1/13	477	27	28	81	92
RDF Bin	Maint. Mechanic	1/12	444	29	31	82	97
RDF Bin	Maint. Mechanic	1/13	480	33	33	82	99
Ash Silo/RDF Bin	Maintenance	1/12	130*	13	47	85	96
		1/13	386	24	30	81	100
Evaluation Criteria:[2]		OSHA	480	100		90	
		NIOSH	480	100		85	

1. Results are presented as follows: Dose presents the percent of the total permissible 90 dB(A) OSHA time weighted noise exposure that the worker incurred over the time period of the work shift sampled (actual), percent that would have occurred if the worker had completed a full shift sampling period (projected), and the projected time weighted average noise exposure in dB(A). Maximum Level presents the maximum noise level encountered by the the worker over any one minute averaging period recorded by the noise dosimeter during the total sampling period. The maximum permissible noise level exposure is limited in the OSHA noise standard to 115 dB(A) for a period not to exceed 15 minutes.

*. Worker was present for only a portion of the workshift.

2. Evaluation Criteria are obtained from the OSHA General Industry Standards, reference 6; and the NIOSH recommended exposure limit is from reference 13.

FIGURE 1

THE BASIC OPERATION OF UNIT #8

ENERGY FLOW AND TRANSFORMATIONS

1. Coal is delivered to the Ames Municipal Power Plant by rail and truck. Belt conveyors transfer the coal to the coal bunkers within the plant.

2. The coal flows by gravity from the bunkers into the pulverizers which grind the coal into a dust that is finer than face powder. The primary air fan blows this dust into the boiler where it mixes with air and burns in suspension like a liquid fuel.

3. The boiler consists of many steel tubes filled with water. The heat of combustion boils the water, and steam is collected in the steam drum at the top of the boiler. The steam is further heated in the superheater before it is piped to the turbine. Unit #8 burns RDF as a supplemental fuel. Bottom ash is collected in the ash hopper at the bottom of the boiler and is flushed to the ash pond.

4. The turbine consists primarily of blades attached to a shaft. Steam flows against the blades causing the shaft to turn at 3600 RPM.

5. The generator and turbine are connected by a shaft. The rotating energy of the turbine is transformed into electrical energy by the generator.

6. The power transformer increases the generated voltage from 13,800 volts to 69,000 volts. From the power transformer the electrical energy goes to a substation for distribution to the consumer.

MAJOR ASSOCIATED EQUIPMENT

A. The cooling tower is used to provide a source of cool circulating water. This is done by moving air across the water that is falling through the cooling tower.

B. The exhaust steam from the turbine is admitted into the condenser where it is cooled and condensed by the circulating water. The condensate (water) is then pumped back towards the boiler.

C. Various steam heaters are used to reheat the water as it returns to the boiler from the condenser. The small amount of steam required by the heaters is obtained from different points in the turbine.

D. One of the heaters is called the "deaerator" because in addition to heating the water it removes air and other dissolved gases.

E. The hotside electrostatic precipitator eliminates 99.7% of the fly ash from the boiler flue gases by means of a 20,000 Volts DC electric field so that ash will not be emitted from the chimney.

F. The fly ash that is collected in the electrostatic precipitator hoppers is pneumatically conveyed to the fly ash silo where it is temporarily stored.

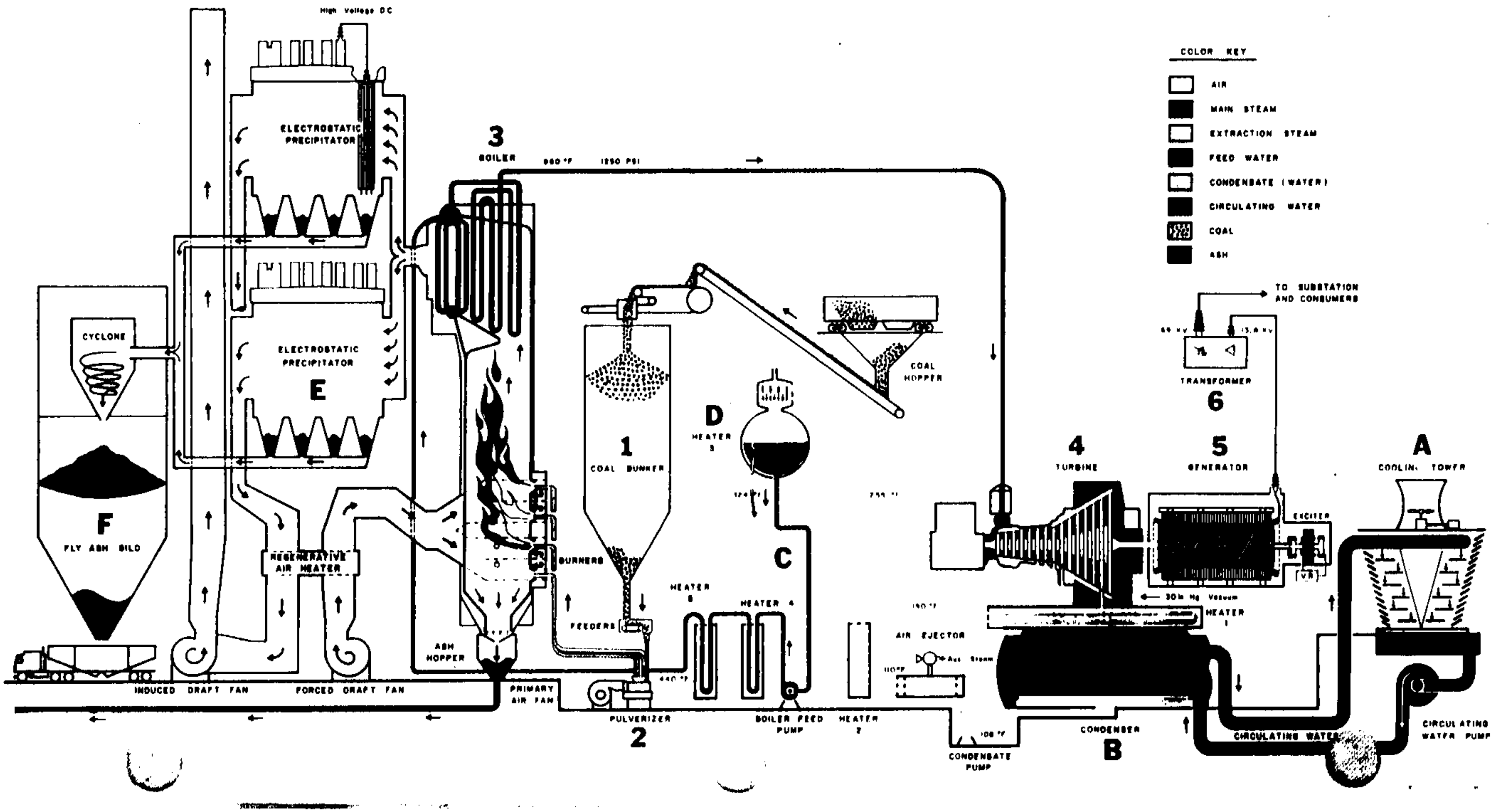
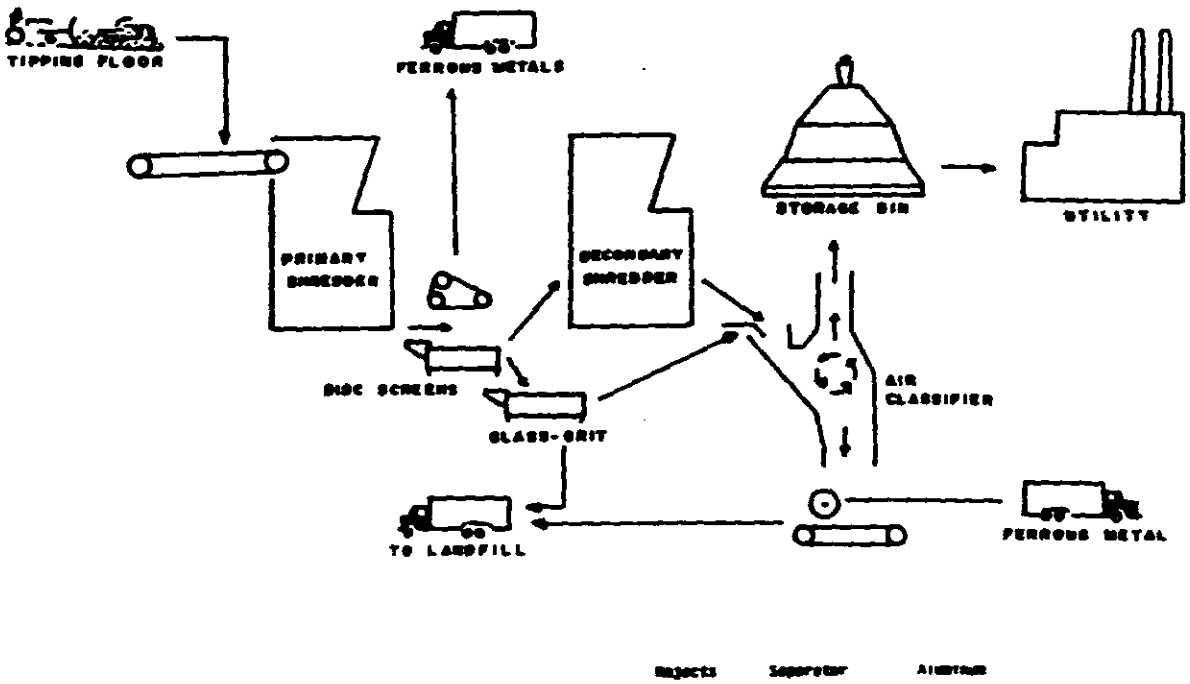


FIGURE 2

The Process



Tipping Floor

A sixteen thousand square foot floor with a ceiling 30 feet high holds the refuse of an entire county.

A mountain of garbage grows as the haulers bring in their daily loads for processing. Tennis rackets, old shoes, furniture, tree limbs, grapefruit rinds and countless other items find their way to the tipping room floor.

When a commercial refuse collection truck enters the tipping room, it rolls onto a scale that records the weight of the vehicle. The driver steps out of the truck and deposits a small plastic card into a readout machine that automatically subtracts the weight of the vehicle from the total weight on the scale.

The resulting figure (the weight of the refuse) appears in the control room on a digital readout machine that uses the information to determine the tonnage (or *mass flow*) that is processed.

When an automobile enters the plant, it is routed along a low cement wall that keeps it away from the commercial trucks. The driver then deposits refuse over the wall and drives away.

The "tipping fee" for commercial trucks is $3 per load. Automobiles pay 50¢. These fees are considered control or scale fees, intended more to keep the flow of traffic at a manageable level than to provide much revenue to the system.

FIGURE 3

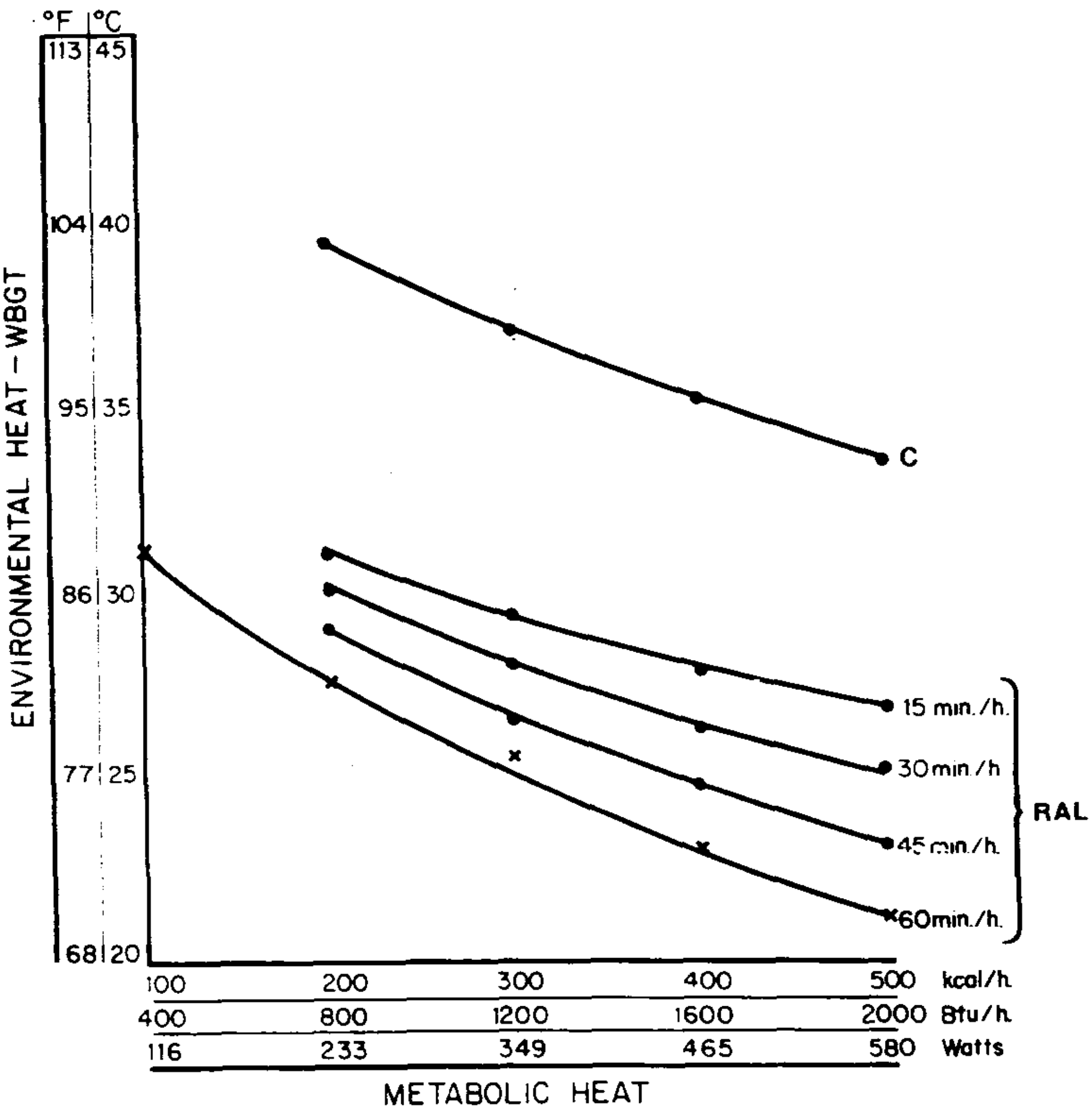


Figure 3. **Recommended Heat-Stress Alert Limits**
Heat-Unacclimatized Workers

C = Ceiling Limit
RAL = Recommended Alert Limit
*For "standard worker" of 70 kg (154 lbs) body weight and 1.8 m^2 (19.4 ft^2) body surface.

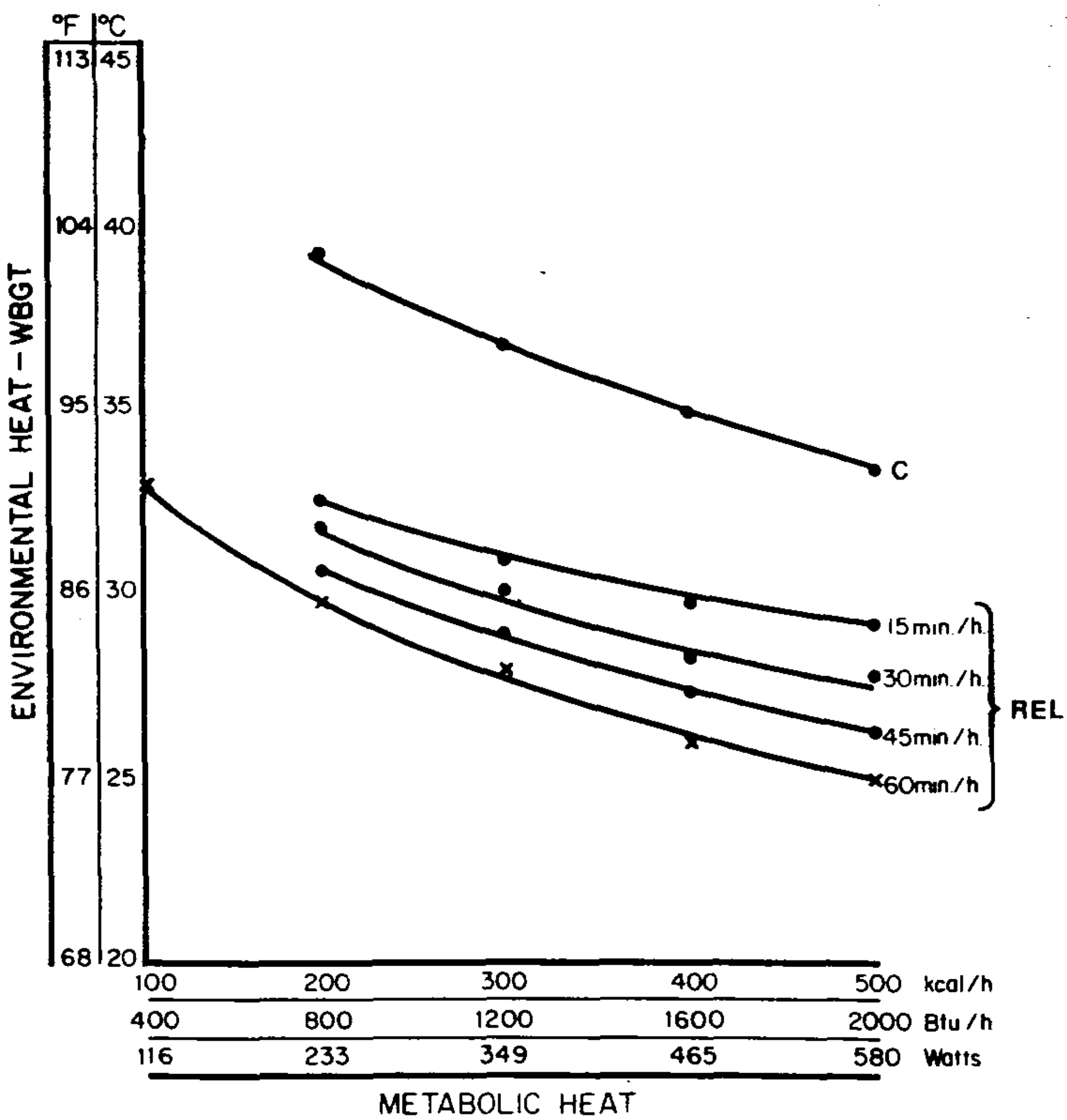


Figure 4. **Recommended Heat-Stress Exposure Limits**
Heat-Acclimatized Workers

C = Ceiling Limit
REL = Recommended Exposure Limit
*For "standard worker" of 70 kg (154 lbs) body weight and 1.8 m^2 (19.4 ft^2) body surface.