CDC Workplace Safety and Health ™

# NIOSH HEALTH HAZARD EVALUATION REPORT:

## HETA #2002-0284-2908
## Capitol Heat & Power
## Madison, Wisconsin

## June 2003

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

# PREFACE

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

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

# ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Erin Snyder and Jeffrey Nemhauser of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Ann Krake of HETAB, DSHEFS. Desktop publishing was performed by Ellen Blythe. Review and preparation for printing were performed by Penny Arthur.

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

## Highlights of the NIOSH Health Hazard Evaluation

## Evaluation of Heat Stress and Noise Exposure in Capitol Heat and Power Plant Workers

On July 30, 2002, NIOSH representatives conducted a health hazard evaluation to investigate employee concerns about exposure to heat stress and excessive noise levels during power plant operations.

### What NIOSH Did

- We monitored the heart rates of some workers during their shifts.
- We monitored noise exposures among some workers.
- We monitored the temperature in several work areas throughout the plant.
- We monitored noise levels throughout the plant.
- We interviewed workers about health effects they have experienced that could be related to high temperatures.
- We reviewed workplace illness and injury logs.
- We weighed some employees before and after their shift to see if they had lost weight; we also checked the urine of employees before and after their shift to see if they had become dehydrated.

### What NIOSH Found

- The heart rate of one worker was high enough to indicate an increased risk for heat-related illness.
- One worker was exposed to noise that exceeded the NIOSH recommended exposure limit (REL) of 85 A-weighted decibels [dB(A)].
- Noise greater than 85 dB(A) was found in various areas of the plant, including: near the turbines, the fans, the condenser water pumps, and the chillers.
- None of the workers interviewed expressed concerns related to heat stress.
- None of the employees monitored showed signs of dehydration.

### What Capitol Heat & Power Managers Can Do

- Train employees to recognize the dangers of working in extreme heat and to protect themselves from over-exposure.
- Maintain accurate records of any heat-related illnesses and note the indoor and outdoor temperatures and work conditions at the time.
- Improve the hearing conservation program to include annual audiometric testing and training for all power plant employees.
- Clearly identify (*or* post signs in) those areas with high noise where hearing protection should be worn.
- Emphasize continuing education programs to ensure all employees potentially exposed to hot environments and high noise levels stay current on these issues and prevention information.
- Improve communication with employees concerning health and safety issues.

### What the Capitol Heat & Power Employees Can Do

- Frequently drink small amounts of cool water or other caffeine-free liquids throughout the work shift.
- Eat meals during breaks to replace minerals and electrolytes lost in sweat.
- Maintain awareness of and report to management any indication of heat-related illness among yourself or your co-workers.
- Take breaks as needed in the cooled break room or control room.
- Wear hearing protection in those areas designated as high noise areas.

**What To Do For More Information:**
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513/841-4252 and ask for HETA Report # 2002-0284-2908

# Health Hazard Evaluation Report 2002–0284-2908
# Capitol Heat & Power
# Madison, Wisconsin
# June 2003

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## SUMMARY

On June 7, 2002, the National Institute for Occupational Safety and Health (NIOSH) received a request to conduct a health hazard evaluation (HHE) at the Capitol Heat & Power (CHP) plant in Madison, Wisconsin. The requestor cited concerns regarding worker exposure to heat stress and noise during power plant operations. Health concerns listed on the HHE request included lethargy and flu-like symptoms.

Two NIOSH industrial hygienists and a NIOSH medical officer visited the power plant to conduct an industrial hygiene and medical survey from July 29 through August 1, 2002. Monitoring of employee heart rates, skin temperature, and exposure to noise was conducted over two 8-hour shifts. Environmental temperatures during the same period were recorded in the facility using wet bulb globe temperature (WBGT) monitors. Workers' pre- and post-shift body weights were recorded to assess dehydration, a measure of heat strain. Private interviews were conducted with workers to gather information about health symptoms and concerns.

Indoor WBGT measurements ranged from 64.9 degrees Fahrenheit (°F) to 88.9°F, and outdoor WBGT measurements ranged from 73.8°F to 93.6°F. Workload categories (*light, moderate, heavy,* or *very heavy*) based on activity were assigned to each monitored employee and compared to the screening criteria in the American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Values (TLVs®). When compared to this screening criteria, results indicated that none of the five monitored workers were exposed to excessive heat stress conditions during the NIOSH survey. Heart rate monitoring data for the five consenting CHP employee participants did show that one employee had a heart rate in excess of the recommended ACGIH criterion, indicating an increased risk for heat strain.[1] None of the six workers interviewed reported health symptoms related to heat exposure at work, nor did any experience a weight loss of greater than 1.5 percent (%) of their pre-shift weight over the course of their shift.

NIOSH investigators targeted various areas within the power plant to monitor for noise. Sound levels were consistently greater than 85 A-weighted decibels [dB(A)] in the areas near the turbines and in the chiller basement near the condenser water pumps. In addition to the area noise measurements, five employees were monitored for personal noise exposure. In one instance, noise exposures exceeded the NIOSH Recommended Exposure Limit (REL) of 85 dB(A). Two employees spent most of their time exposed to noise levels between 70 and 80 dB(A), and two others spent most of their day exposed to noise levels between 70 and 90 dB(A).

In response to employee concerns, air samples for bromine were taken at the pellet storage tank and near the cooling tower. Colorimetric readings from the bromine detector tube did not indicate a presence of bromine at detectable levels.

NIOSH investigators observed that communication between CHP management and employees was a problem at the time of this survey. There appeared to be a lack of regular, ongoing communication and training regarding health and safety issues within the plant.

NIOSH investigators concluded that there is a potential for heat stress conditions to exist in the plant; one monitored worker showed signs of heat strain on the day of the survey. A plan to increase awareness of heat exposure should be implemented. Noise levels recorded in the plant indicate that a hearing conservation program is necessary for all employees.

Communication between employees and management needs to be improved, especially in the areas of health and safety training and responsibilities.

Keywords: SIC 4939 (Combination Utilities, Not Elsewhere Classified), coal-fired power plant, heat stress, heat strain, noise, bromine

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# INTRODUCTION

On June 7, 2002, the National Institute for Occupational Safety and Health (NIOSH) received a request to conduct a health hazard evaluation (HHE) at the Capitol Heat & Power (CHP) plant in Madison, Wisconsin. The employee requestors cited concerns regarding heat stress and noise exposure during power plant operations. Health concerns listed on the HHE request included lethargy and flu-like symptoms.

From July 29 through August 1, 2002, two NIOSH industrial hygienists and a NIOSH medical officer visited the power plant to conduct an industrial hygiene and medical survey. Monitoring of employee heart rates, skin temperature, and exposure to noise was conducted during two 8-hour shifts. Environmental temperatures during the same period were recorded in the facility using wet bulb globe temperature (WBGT) monitors. Private interviews were conducted with workers to gather information about health symptoms and concerns. Workers' pre- and post-shift body weights were recorded. Discussions were held with management representatives concerning hazard communication and employee training for heat stress awareness and other applicable programs, including hearing conservation. In addition, NIOSH investigators collected air samples for bromine in response to a verbal request from the requestor; concern for adverse health effects related to bromine exposure did not appear on the original written HHE request. An interim letter dated August 27, 2002, was sent to the HHE requestors, the union representative, and management representatives summarizing the NIOSH investigation and findings as of that date.

# BACKGROUND

The CHP plant was built nearly a century ago and is located several blocks from the Capitol building in downtown Madison, Wisconsin. The power plant provides heat, electricity, and air conditioning to 10,000 employees working in nine municipal buildings, including the Wisconsin State Capitol building. The power plant houses two generators, four absorption chillers, three cooling towers, four boilers, and various other equipment. Two boilers are coal-fired, while the other two are gas-fired; during the time the NIOSH survey was conducted, one of each type was in use.

The power plant operates twenty-four hours a day, seven days a week. First shift runs from 10:00 p.m. until 6:00 a.m; second shift begins at 6:00 a.m. and ends at 2:00 p.m., and third shift is from 2:00 p.m. until 10:00 p.m. At the time of the NIOSH site visit, the plant employed 14 men who performed a variety of tasks. Among the employees, there were eight plant operators working one of three 8-hour shifts, rotating six days on the job followed by four days off. Two operators work on each shift. Operators at CHP are responsible for operating the boilers and the coal/ash unloading system. In addition to these tasks, operators make hourly rounds within the plant to monitor water quality and temperature and to collect coal samples. The remainder of the shift is spent either in the control room or at a desk in the generator area. In general, the duties of the operators do not involve heavy physical exertion.

The remaining staff at the plant consists of two maintenance mechanics, an assistant, and a heating, ventilation, and air conditioning (HVAC) specialist, each of whom work only second shift. The plant superintendent and the plant assistant superintendent also work only second shift. The tasks of the maintenance and HVAC personnel vary greatly and are assigned on the basis of overall energy needs and required maintenance schedules. The duties of these employees typically involve more physical exertion and require that more time be spent out on the plant floor (and less time in the control room) as compared to the operators.

# METHODS

# Industrial Hygiene

## *Physiological and Personal Monitoring*

### Skin Temperature and Heart Rate

To assess the heat stress-related physiological effects of working at CHP, NIOSH investigators measured skin temperature and heart rate on consenting employees on July 30, 2002, during the second and third shifts (between the hours of 6:00 a.m. and 10:00 p.m.). Skin temperature readings were obtained at 1-minute intervals using a Mini-Mitter Mini-Logger® Series 2000 monitor (Mini-Mitter Company, Inc., Bend, Oregon). Skin temperature sensors were attached to the torsos of participating employees; the recording device, which weighs approximately 4 ounces, was worn clipped to the belt. The Mini-Logger is capable of measuring skin temperatures between 86-108 degrees Fahrenheit (°F) and readings have been validated to be accurate to within plus or minus (±) 0.18°F. Heart rates of participating employees were measured with the Polar® chest band heart rate monitor. This device measures the wearer's heart rate at 1-minute intervals and can record heart rates up to 250 beats per minute (bpm). It has been shown to be accurate to within ±1 beat per minute.

### Noise

NIOSH investigators quantified employee exposure to noise by use of the Quest® Electronics Model Q-300 Noise Logging Dosimeter (Quest Technologies, Oconomowoc, WI). Dosimeters were attached to the belt of participating employees and a small remote microphone was fastened to the shirt at a point mid-way between the ear and the outside of the employee's shoulder. Dosimeters were worn for the entire shift; employees typically do not leave CHP for lunch breaks. At the end of the shift, each dosimeter was removed and the information was downloaded to a personal computer for interpretation with QuestSuite for Windows® computer software. The dosimeters were calibrated before and after the work shift according to the manufacturer's instructions.

Noise exposures were compared to three different reference values: the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL), the OSHA Action Level (AL), and the NIOSH Recommended Exposure Limit (REL). The OSHA PEL and AL use 90 A-weighted decibels [dB(A)] as a criterion value with a 5 dB exchange rate.[2] These two OSHA Standard values differ in their associated threshold levels, set at 90 dB(A) for the PEL and 85 dB(A) for the AL.[2] The NIOSH criterion is 85 dB(A) with a 3 dB exchange rate and an associated threshold of 80 dB(A).[3]

## *Environmental Monitoring*

### Heat

WBGT measurements were recorded at continuous one-minute intervals using RSS-214 WiBGeT® instruments (Imaging & Sensing Technology, Horseheads, New York). These instruments were used to monitor conditions in the control room, the chiller basement, on the operator's desk in the generator area, near boiler #3, and outside the power plant near the front entrance of the building. The WiBGeT instrument takes three different readings: (1) a dry bulb temperature, accurate to within ± 0.5°F (measuring ambient air temperatures between 32°F and 150°F); (2) a natural wet bulb temperature (a measurement that accounts for the effects of evaporative cooling); and (3) a black globe temperature (a measurement that estimates radiant [infrared] heat load). Thus, the WiBGeT measures not only air temperature, but also accounts for air velocity, humidity, and sources of radiant heat. The various values are then combined and reported as a WBGT index which serves as a measure of the environmental contribution to heat stress expressed in °F.

### Noise

A Quest model 2400 (Quest Technologies, Oconomowoc, Wisconsin) sound level meter set for A-scale, slow response, was used to measure noise levels within the power plant. Readings were recorded while the hand-held instrument was carried throughout the power plant.

**Bromine**

Telephone discussions with the requestor prior to the NIOSH site visit revealed an additional concern not identified on the original HHE request. The requestor indicated a concern regarding respiratory exposure to bromine from pellets used at CHP. Bromine pellets for water treatment are dispensed into a feeding tank for the cooling towers. Ambient levels of bromine were measured using a Dräger™ pump with a colorimetric detector tube. Air is drawn manually through the tube with a bellows-type pump and the resulting length of the stain in the tube (produced by a chemical reaction with the sorbent) is proportional to the concentration of bromine. The minimum detectable concentration of the Dräger™ tube was 0.3 parts per million (ppm).

## Medical

A medical evaluation consisting of interviews, review of available records, and biological monitoring for fluid loss was conducted by a NIOSH medical officer in concurrence with the monitoring conducted by the industrial hygiene team.

### *Employee and Management Interviews*

Information concerning the plant, the nature of the work there, and various health and safety issues was obtained from pre-site visit interviews with the requestor. Interviews with management representatives and the plant superintendent conducted at the time of the site visit provided additional information.

Confidential interviews were held with all available consenting employees during the site visit. Workers were asked about personal health concerns, symptoms, or medical conditions that they believed to be related to their workplace exposures. Workers were asked to describe the methods used to self-monitor their health when working under hot conditions, about any personal history of heat-related illness, and about their normal job tasks and activities. Questions concerning the type and amount of fluid and food consumed during work were also included in the interview (**Appendix A**).

### *OSHA Logs*

Copies of the OSHA Log and Summary of Occupational Injuries and Illnesses (200 and 300 Logs) dating back to 2000 were provided to the NIOSH medical officer at the time of the HHE site visit. The logs were reviewed for evidence of heat-related illnesses.

### *Biological Monitoring for Fluid Loss*

Degree of dehydration or loss of body fluid (usually in the form of sweat) was determined among CHP employees by use of two complementary techniques: (1) pre- and post-shift weight measurements and (2) measurement of urine specific gravity. Seca Travelite™ digital scales, accurate to within ±0.1 pound (lb) with a range of up to 330 lbs, were used to measure participating workers' weights both before and after their shifts. Urine was collected from participating employees before and after their work shift; a refractometer was used to measure the specific gravity of each collected sample.

# EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the 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 even though 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 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 which potentially increases 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 RELs,[4] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[5] and (3) the U.S. Department of Labor, OSHA PELs.[2] Employers are encouraged to follow the NIOSH RELs, the ACGIH TLVs, the OSHA PELs, or whichever are the more protective criteria.

OSHA requires an employer furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). However, an employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

## Heat (Hot Environments)

A requirement for normal function of the human body is that the core body temperature (CBT) be maintained within an acceptable range of about 98.6°F +/- 1.8°F. Maintaining this internal body temperature balance requires a constant exchange of heat between the body and the surrounding environment. The total amount of heat that must be exchanged is related to the total amount of heat produced by the body (metabolic heat) and the heat gained from the environment (if any).[6] Heat exchange with the environment is a function of both environmental and individual factors. Environmental factors affecting heat exchange include ambient air temperature and humidity, air velocity, and radiant temperature. Individual factors that serve to increase or decrease a person's ability to exchange heat with the environment include skin temperature, the rate of sweat evaporation, and the characteristics of the clothing being worn.

In addition to the above, there are also a variety of human health factors that can serve to adversely affect the normal body mechanisms used to cope with increases in heat. A person's general state of health may thus contribute to the development of a heat-related illness. The ability to perspire normally, for example, is critical to regulating CBT. Skin disorders or medications that interfere with normal sweating mechanisms will compromise the body's ability to cope with increases in heat. Other conditions, such as heart disease, lung disease, and poorly-controlled diabetes, may not only compromise intrinsic cooling mechanisms, but may themselves be aggravated by increases in temperature, further worsening a person's state of health.

Other conditions may affect temperature regulation by altering the CBT. Obese individuals will tend to expend greater amounts of energy (as compared to less obese individuals performing a similar task), thereby serving to further increase their CBT. Obesity also reduces the rate of heat loss from the body. Taken together, these two factors contribute to an overall heat gain and an increased risk for the development of heat-related illness among obese individuals. Viral infections and diarrhea not only impair regulation of CBT, but they can (and often do) predispose a person to dehydration. Finally, prescription and over-the-counter medications as well as illegal street drugs and alcohol can affect the body's responses to heat. Alcohol consumption has been associated with heatstroke because it interferes with nervous system function and hormonal regulation of fluid balance.[6] Any of these factors may thus contribute to the onset of a heat-related illness and should ideally be taken into consideration when deciding on control measures or when situating workers within a workplace.[7]

The loss of fluids from the body (dehydration) is an important factor in the development of heat-related illness. Weight loss (or gain) over a few hours may reflect changes in extracellular fluid volume. Extracellular fluid volume is lost through the skin as a result of perspiration and also through the lungs. A body weight loss greater than 0% but less than or equal to 1.5%, as compared to an individual's pre-activity weight, is indicative of mild dehydration. A body weight loss of greater than 1.5% as compared to an individual's pre-activity or pre-shift weight, is suggestive of a larger loss of extracellular fluid volume, and therefore a greater potential risk for an individual to develop heat strain.

Specific gravity, a measure of urine concentration, can also be used to determine the degree to which someone may have lost body fluids. Specific gravity is an estimate of the number of particles dissolved in the urine. Urine having a lower specific gravity (i.e., more dilute) tends to be characteristic of well-hydrated persons because there is an excess of water being passed in the urine relative to the number of particles. Urine with a higher specific gravity (i.e., more concentrated) indicates a person who is excreting less water; a relatively greater number of particles are therefore dissolved in the urine.

## *Human Health Effects of Heat Exposure*

### Chronic Effects

Prolonged increases in CBT and chronic exposures to high levels of heat stress are associated with disorders such as temporary infertility (male and female), elevated heart rate, sleep disturbance, fatigue, and irritability. During the first trimester of pregnancy, a sustained CBT greater than 102.2°F may endanger the fetus.[5] One or more occurrences of heat-induced illness can result in temporary or permanent loss of the ability to tolerate heat stress.[7, 8]

### Acute Effects

More acute signs of serious heat exposure include (in increasing order of severity) skin disorders (heat rash, hives, etc.), heat syncope (fainting), heat cramps, heat exhaustion, and heat stroke. It should be recognized that not all workers will develop each condition in order; some may have a more serious health effect without ever showing less severe signs of heat stress.

#### *Heat Syncope (Fainting), Heat Cramps, and Heat Exhaustion*

Heat syncope occurs due to a shunting (movement) of blood to the skin and away from the central organs of the body, including the brain. As CBT rises, blood vessels in the skin dilate (widen) in order to facilitate cooling of the body. When blood passes through the skin near the surface of the body, the body is cooled as heat is transferred to the surrounding environment. An individual may not have sufficient blood volume, however, to adequately fill both the dilated blood vessels in the skin and their central organs (such as the heart, lungs, and brain). Inadequate blood flow to the brain results in fainting. This condition most often occurs in persons who stand in place for extended periods of time in hot environments.

Heat cramps, typically occurring in the muscles of the body engaged in strenuous work, are due to fluid and electrolyte imbalances created by heavy sweating. Heat cramps and heat syncope often accompany heat exhaustion, a condition characterized by weakness, fatigue, confusion, and nausea. The symptoms of heat exhaustion are caused by volume depletion (dehydration), sodium (salt) loss, and elevated CBT (greater than 100.4°F). Individuals performing strenuous activity in hot conditions and without adequate water and electrolyte (salt) intake are most at risk for developing this condition. Heat exhaustion may lead to heat stroke if the patient is not quickly cooled and given water or other liquids.

### *Heat Stroke*

Heat stroke may be most readily distinguished from heat exhaustion by the absence of perspiration. Whereas persons suffering from heat exhaustion maintain the ability to sweat, heat stroke victims do not. Thus, while victims of heat exhaustion or heat stroke may both present with mental status changes and nausea, the person with heat stroke will have hot, dry skin. In cases of heat stroke, CBT may exceed 106°F. Convulsions (seizures) may occur as a result of heat stroke, and death can result from damage to the brain, heart, liver, or kidneys.[9] Heat stroke is, therefore, a life-threatening emergency requiring immediate medical attention.

# Heat Stress and Heat Strain Prevention Guidelines

Heat stress is defined as a person's exposure to all combined sources of heat (both internal and external), minus any heat that may be lost from the body to the environment. Heat generated by the body as a result of exercise or work as well as heat gained from the environment may both contribute to heat stress exposure. The physiological response to heat stress exposure is defined as heat strain.

## *Heat Stress Guidelines*

Heat stress indices have been developed by various agencies as guidelines to protect workers from developing heat-related illnesses in the occupational environment. The World Health Organization, for example, concluded that "it is inadvisable for CBT to exceed 38 degrees Celsius (°C) (100.4°F) or for oral temperature to exceed 37.5°C (99.5°F) in prolonged daily exposure to heavy work and/or heat."[10] According to NIOSH (1986 *Revised Criteria*), a CBT of 39°C (102.2°F) should be considered reason to terminate exposure even when CBT is being monitored.[7] While this does not mean that a worker with a CBT exceeding those levels will necessarily experience an adverse health effect, research has shown that workers with elevated CBTs are at increased risk both for developing a heat stress illness and for experiencing unintentional injuries due to the detrimental effects of heat on higher brain functions, including reasoning and judgment.[7]

Also included in the 1986 *Revised Criteria* are graphs of metabolic heat (generated by a worker) plotted against WBGT indices. Guidelines based on these graphs indicate combined levels of heat exposure that should not be exceeded.[7] Using these graphs, NIOSH developed two sets of recommended limits (see **Appendix B**), one for acclimatized workers (REL) and one for non-acclimatized workers (Recommended Alert Limit [RAL]). No employee should be exposed to metabolic and environmental heat combinations exceeding the applicable Ceiling Limits (C) shown in the REL or RAL without being provided (and properly using) appropriate and adequate heat-protective clothing and equipment.[7]

## *ACGIH Criteria*

ACGIH criteria for heat exposures (like the NIOSH Revised Criteria) are to be used only when WBGT indices are available for the particular work area of concern. Use of either the NIOSH or the ACGIH criteria requires professional judgment and a heat stress management program to ensure protection for each worker in each heat stress situation.

The ACGIH TLV for heat stress attempts to provide a framework for the control of heat-related disorders within the workplace. For surveillance purposes, a documented pattern of workers exceeding the TLV is sufficient indication of the need to control occupational exposure to heat. On an individual basis, the TLV represents the point at which a worker must cease exposure until complete recovery is achieved. Although the risk for unintentional injuries may increase with increasing levels of heat stress, it is important to note that the TLV is not specifically directed at controlling these.[1]

The ACGIH screening criteria (see **Appendix C**) may be used to create a work-rest regimen designed to maintain CBTs below the recommended limits for both acclimatized and non-acclimatized employees. ACGIH-suggested work-rest cycles are designed to enable a majority of workers to continue working without a substantial increase in the risk of experiencing an acute adverse health effect.[1, 5] The ACGIH TLV screening criteria assume as a reference an adequately hydrated, unmedicated, healthy worker wearing light-weight, summer-type clothing. For other than light-weight, summer-type clothing, the WBGT indices in the appropriate work/acclimatization categories must be lowered. The criteria cannot be used for employees wearing encapsulating suits or garments that are impermeable or highly resistant to water vapor or air movement. Further assumptions made by this model include an 8-hour work day (with two 15-minute breaks, and a 30-minute lunch break), and a 5-day work week; it is further assumed that the worker has access to a rest area with temperatures the same as, or lower than, those in work areas and at least some air movement. Given these assumptions, the TLV is the WBGT index to which such an individual may be repeatedly exposed without experiencing adverse health effects.

### ACGIH Definition of Heat Strain

According to the ACGIH, excessive heat strain, and the indication that work should be discontinued, may be marked by one or more of the following criteria:

- For individuals with normal cardiac performance, a persistent heart rate over several minutes that is greater than (>) 180 bpm minus their age in years.
- For any individual, a recovery heart rate > 110 bpm at 1 minute following peak work effort.
- For non-acclimatized personnel, CBT > 38.0°C (100.4°F); for medically fit, heat-acclimatized personnel, CBT > 38.5°C (101.3°F).

The risk for developing a heat-related illness is increased under the following conditions:

- If a worker has profuse, sustained sweating over several hours in the workplace.
- If a worker experiences a weight loss over a shift in excess of 1.5% of their pre-shift body weight.
- If a worker has a 24-hour urinary sodium excretion of less than 55 millimoles.

Workers exhibiting the above findings who develop heat-related illness may become disoriented, confused, dizzy, or lightheaded. They may exhibit a relatively sudden onset of unexplained irritability, or may complain of severe fatigue, or flu-like symptoms. Although none of these findings alone are specific for heat-related illness, any worker manifesting these signs or symptoms, particularly those working under high heat stress conditions, should be removed for rest in a cool location with rapidly circulating air. Immediate emergency care and medical attention may be necessary. If sweating stops and the skin becomes hot and dry, emergency care with hospitalization is essential for a favorable outcome.[5]

## *OSHA Standard*

OSHA does not have a specific heat stress standard. However, the OSHA technical manual, Section III, Chapter 4, *Heat Stress*,[11] provides investigation guidelines that approximate those found in the ACGIH 1992–1993 *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*. Acceptable levels of exposure to heat are enforced by the Secretary of Labor under the General Duty Clause of the Occupational Safety and Health Act of 1970 [Public Law 91-596, section 5(a)(1)].[2]

## Noise

Noise-induced hearing loss is an irreversible condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise-induced hearing loss is caused by damage to nerve cells in the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[12] While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is gradual. Typically, it begins to develop at 4000 or 6000 Hertz (Hz) and spreads to lower and higher frequencies (the hearing range is 20 Hz to 20000 Hz). Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have still higher frequency components.[13]

The dB(A) is the preferred unit for measuring sound levels to assess work noise exposures. The dB(A) scale is weighted to approximate the sensory response of the human ear to sound frequencies near the threshold of hearing. The decibel unit is dimensionless, and represents the logarithmic relationship of the measured sound pressure level to an arbitrary reference sound pressure (20 micropascals, the normal threshold of human hearing at a frequency of 1000 Hz). Decibel units are used because of the very large range of sound pressure levels which are audible to the human ear. Because the dB(A) scale is logarithmic, increases of 3 dB(A), 10 dB(A), and 20 dB(A) represent a doubling, tenfold increase, and 100-fold increase of sound energy, respectively. It should be noted that noise exposure expressed in decibels cannot be averaged by taking the simple arithmetic mean.

The OSHA standard for occupational exposure to noise (29 CFR 1910.95)[2] specifies a maximum PEL of 90 dB(A) for a duration of 8-hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship, or exchange rate. This means that a person may be exposed to noise levels of 95 dB(A) for no more than 4 hours, to 100 dB(A) for 2 hours, etc. Conversely, up to 16 hours exposure to 85 dB(A) is allowed by this exchange rate. The duration and sound level intensities can be combined in order to calculate a worker's daily noise dose according to the formula:

$$\text{Dose} = 100 \text{ X } (C_1/T_1 + C_2/T_2 + ...C_n/T_n),$$

where $C_n$ indicates the total time of exposure at a specific noise level and $T_n$ indicates the reference duration for that level as given in Table G-16a of the OSHA noise regulation. During any 24-hour period, a worker is allowed up to 100% of his daily noise dose. Doses greater than 100% are in excess of the OSHA PEL.

The OSHA regulation has an additional AL of 85 dB(A); an employer shall administer a continuing, effective hearing conservation program when the 8-hour TWA value exceeds the AL. The program must include monitoring, employee notification, observation, audiometric testing, hearing protectors, training, and record keeping. All of these requirements are included in 29 CFR 1910.95, paragraphs (c) through (o). Finally the OSHA noise standard states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels.

NIOSH, in its Criteria for a Recommended Standard,[3] and the ACGIH[5] propose exposure criteria of 85 dB(A) as a TWA for 8 hours, 5 dB less than the OSHA standard. The criteria also use a more conservative 3 dB time/intensity trading relationship in calculating exposure limits. Thus, a worker can be exposed to 85 dB(A) for 8 hours, but to not more than 88 dB(A) for 4 hours or 91 dB(A) for 2 hours.

## Bromine

Bromine is a dark brown corrosive liquid, commonly used as an additive in gasoline, dyes and pharmaceuticals.[14] At CHP, solid bromine pellets are used in the water purification system for the facility's three cooling towers. Dermal exposure to liquid bromine can cause an acne-like rash and it is a severe dermal and mucous membrane irritant. Symptoms and signs of systemic bromine exposure include dizziness, headache, cough, diarrhea, and abdominal pain.[15]

Although the odor threshold for bromine is 0.05 ppm, the NIOSH REL is 0.1 ppm. Thus workers may notice a detectable odor before being overexposed.[14] The OSHA PEL and ACGIH TLV are also 0.1 ppm;[2,5] the immediately dangerous to life and health (IDLH) value for bromine is 3 ppm.[16]

# RESULTS

## General Workplace Observations

Based on information collected through informal interviews and at the opening and closing conferences with management and labor representatives, NIOSH investigators identified problems with management-labor communication at the time of this survey. The parties responsible for implementing employee health and safety training programs were not readily identifiable. This has resulted in a lack of both proper employee training and an apparent absence of safety programs at CHP in several areas including some not specifically mentioned in this HHE request.

## Industrial Hygiene

### *Physiological and Personal Monitoring*

Five CHP employees consented to participate in personal monitoring of skin temperature and heart rate during the course of their work shifts.

#### Heart Rate and Skin Temperature

Heart rate monitoring data for the five consenting CHP employees are shown in **Table 1**. Of the five employees, one displayed an elevated heart rate in excess of the recommended ACGIH criterion of 180 bpm minus his age in years.[1] This employee's heart rate exceeded the recommended criterion for more than 5% of his work shift.

Skin temperature measurement results are not included in this report. No evaluation criteria exist for these measurements, and skin temperatures are influenced by environmental conditions thereby decreasing their accuracy. Rather, in this report, heart rate and WBGT measurements, which do have established criteria, are used to determine heat strain.

#### Noise

The five employees who participated in heat stress monitoring also were monitored for noise exposure during the NIOSH survey. The comparisons of these employees' exposures and the evaluation criteria are shown in **Table 2**. The average daily noise exposures at CHP were below the OSHA criterion for all five employees monitored. In no instance was the OSHA criterion exceeded for any of the monitored employees. Employees #4 and #5 had daily noise exposures at the NIOSH REL of 85 dB(A). However, there were occasions during the day of the survey when all employees had high exposures to noise, indicated as *max level* in **Table 2**. The real-time noise exposures were plotted and are shown in **Figures 1–5**, where the PEL is defined as the average A-weighted noise level during the period of monitoring based on a 5 decibel exchange rate and a 90 dB(A) threshold. When the exchange rate is 3 decibels and the threshold is 80 dB(A), the value is defined as the REL.

## *Environmental Monitoring*

### Heat

WBGT measurements taken during the survey are presented in **Table 3**. Indoor WBGT measurements ranged from approximately 64.9°F to 88.9°F, and outdoor WBGT measurements ranged from 73.8°F - 93.6°F.

Using the WBGT data, workload categories (*light, moderate, heavy,* or *very heavy*) based on activity were assigned to each monitored employee and compared to the screening criteria in the ACGIH TLVs. Plant operators were classified as engaging in a *light work load*, while the maintenance and HVAC personnel were classified as having *moderate work loads*. All participating employees were acclimatized to the work environment according to both NIOSH and ACGIH criteria. When compared to the ACGIH screening criteria, our results indicate that none of the monitored workers were exposed to excessive heat stress conditions during the NIOSH survey.

### Noise

The results of power plant sound level measurements (presented in **Table 4**) reference the plant layout provided by management in which the main employee entrance is located at the south side of Building A. Sound level meter measurements were consistently greater than 85 dB(A) in the areas near the turbines and in the chiller basement near the condenser water pumps. Ten of the thirty measurements exceeded 85 dB(A).

### Bromine

Air samples for bromine were taken at the pellet storage tank and near the cooling tower. Colorimetric readings from the bromine detector tube did not indicate a presence of bromine in detectable levels (< 0.3 ppm).

# Medical

Six CHP employees consented to participate in confidential interviews, pre- and post-shift measurement of weight, and collection of urine samples for the measurement of specific gravity before and after their work shift.

## *Interviews*

Although none of the employees interviewed reported ever having been dehydrated while at work, three of the six did report having had symptoms in the past that may have been consistent with overexposure to heat. One employee had an episode of lightheadedness while working inside a boiler approximately one year prior to the NIOSH site visit. Another employee reported feeling lightheaded and having had muscle cramps at work in the past, although he was unable to characterize the circumstances surrounding the episode. A third employee suffered a loss of consciousness at work and was subsequently transferred to the hospital approximately ten years prior to the NIOSH site visit. He denied further episodes of loss of consciousness since that time. One employee reported a history of heat-related illness in the remote past, prior to his employment at CHP.

All employees reported consuming fluids during the course of their work shift, although several noted that colas or coffee were their beverages of choice. Each employee reported drinking water as needed during their shift. The majority of employees eat during their shift, some taking a light snack and others eating a more full meal.

Each of the employees noted that when they felt themselves becoming 'overheated,' they would find a cool place to sit down and drink fluids. None of the employees, however, reported taking their own temperature or pulse as a means of assessing their level of heat stress.

### *OSHA Logs*

A review of the OSHA 200 and 300 Logs dating back to 2000 did not reveal evidence of heat-related illnesses among employees working at CHP.

### *Biological Monitoring for Fluid Loss*

#### Weight Loss and Urine Specific Gravity

Of the six employees who participated in pre- and post-shift weight measurements, four actually gained weight over the course of their shift. Another employee stayed the same weight and one other lost one pound. Urine specific gravity was essentially unchanged for each of the six participants from the beginning of their work shift until the end. Taken together, these data would indicate a low risk for heat- related illness among the employees surveyed at the time of the NIOSH site visit.

# DISCUSSION

## Heat Exposure

The environmental heat measurements recorded at CHP on the day of the NIOSH survey indicate that there is a potential for heat stress conditions to exist in the plant. Several work locations throughout the plant (coal bunker, near the boilers and in the chiller basement) are areas of potentially excessive heat. Daily tasks performed by CHP employees require that time be spent in areas throughout the plant, and thus it is imperative that a heat stress prevention program be developed to include all employees regardless of job description.

## Noise Exposure

Both personal and area noise measurements were taken during the NIOSH survey at CHP. Area noise measurements were high enough to warrant the implementation of a hearing conservation program, including the use of hearing protection devices by all employees in those areas near the turbines, the fans, the chillers, and the condenser water pumps. NIOSH recommends that hearing protection devices be worn whenever noise levels exceed the NIOSH REL of 85 dB(A), regardless of exposure time.[3] It is recognized that hearing protection devices may be less effective than the noise reduction ratings (NRR) that are assigned to them.[17] The use of hearing protection devices is subject to many problems, such as discomfort, incorrect use with other safety equipment, dislodging, deterioration, and abuse.[18] They also perform differently in workplace settings as compared to the laboratories where the NRRs are determined.[19,20] NIOSH acknowledged this problem in its original criteria document on occupational noise exposure.[17] The document recommends medical surveillance in the form of audiometric testing for all employees whose occupational noise exposure is controlled by personal protective equipment.

# CONCLUSIONS

At the time of this survey, none of the participating CHP employees developed significant heat strain based on the results of heart rate, weight loss, or urine specific gravity monitoring. However, physiological monitoring indicated one employee did experience heat strain on the day of the site survey. NIOSH investigators have concluded that heat stress is a potential hazard at CHP, particularly on those days when high environmental temperatures may increase the indoor temperatures experienced by workers. The potential for developing heat stress is further enhanced if workers do not take full advantage of the cooled break room or control room as well as replenish fluids lost through sweating during their work activities.

Bromine samples were taken at the pellet storage tank and near the cooling tower. Colorimetric readings from the bromine detector tube did not indicate a presence of bromine in detectable levels.

The average daily noise exposures at CHP were below the OSHA criterion for all five employees monitored. In no instance was the OSHA criterion exceeded for any of the monitored employees. Area noise measurements are high enough to warrant the implementation of a hearing conservation program, including the use of hearing protection devices by all employees in those areas near the turbines, the fans, the chillers, and the condenser water pumps.

# RECOMMENDATIONS

Based upon the measurements and observations made during the NIOSH survey, a number of recommendations are suggested to improve the working environment for Capitol Heat & Power employees.

## Training & Communication

Perhaps the most important recommendations from the NIOSH survey stem from needed improvements in communication and training. Communication between management and employees should focus on the exchange of concerns about environmental conditions and potential exposures in the plant.

1. The state government agencies responsible for implementing health and safety programming should be identified and this information should be clearly communicated to all employees.

2. A health and safety committee should be formed. Committee members should represent both management and employees equally. A committee leader should be chosen to act as a liaison between management officials and other employees within the plant who do not actively participate in committee discussions. The focus of this committee should be the exchange of ideas regarding health and safety issues and concerns, especially training.

3. Employees should be trained in accordance with all applicable OSHA standards, including, but not limited to, hearing conservation and hazard communication.

## Heat Stress

An effective heat stress management program is essential to ensure adequate protection for employees against heat stress and strain. The following recommendations (in addition to Appendix D) are provided to help management and employees work together to create an effective heat stress program:

1. Management should ensure that all employees potentially exposed to hot environments receive continuing education covering heat stress and heat stress prevention on at least an annual basis. A good heat stress training program should emphasize (at a minimum) the following::

- Knowledge of the hazards of heat stress.

- Recognition of predisposing factors, danger signs, and symptoms.

- Awareness of signs and symptoms of heat related illness and first-aid procedures for treatment.

- Employee responsibilities in avoiding heat stress.

- Knowledge of medical conditions that may increase the risk of heat-related illnesses.

- Dangers in using drugs, including therapeutic ones, and dangers of the use of alcohol before or during work in hot environments.

- Preventive measures that can be taken to reduce heat stress.

2. Management should maintain accurate records of any heat-related illness events (separate and apart from the OSHA 300 Logs) and note the environmental and work conditions at the time of the illness. Such events may include repeated accidents, episodes of heat-related disorders, or frequent health-related absences. Job-specific clustering of specific events or illnesses should be followed up by industrial hygiene and medical evaluations.

3. During particularly hot weather, the following information should be reinforced and the recommended behaviors strongly encouraged:

- Thirst is a poor guide in fluid replacement. Workers should be encouraged to drink water (approximately 8 fluid ounces) every 15 to 20 minutes. The water should be cool (50°F–60°F). Drinking from disposable cups or personal containers is preferable to drinking directly from water fountains. Workers should drink enough water each shift to prevent loss of body weight.[7] Beverages with a high sugar content (for example, sodas), caffeine (for example, colas, tea, or coffee), and alcohol should all be avoided; consumption of these products may result in worsening of dehydration.[21]

- Minerals and electrolytes lost in sweat are most readily replenished with a normal diet. Management, union officials, and co-workers should encourage workers to eat during their breaks.

- A cooled environment provides an important control in preventing an excessive rise in CBT. Workers should take advantage of the cooled break room or control room. Taking breaks out-of-doors, particularly during the warm summer months, may not provide sufficiently cool temperatures to facilitate a sufficient lowering of the CBT prior to a return to work. Man-cooling fans should not be used when temperatures (dry bulb) exceed 95°F.

- Pre-shift and post-shift weights should be about the same. Scales should be provided in the locker room so that workers may monitor their weight during the shift. If a worker loses weight during the course of a shift, he should stop work and slowly drink more fluids to replenish those that have been lost.

- Workers should be conscious of and monitor physiological responses to heat strain. Workers should know how to check their own pulse (or that of others) and monitor it during heavy work periods. Personal peak heart rates should not exceed 180 bpm minus the age of the worker in years, for more than several minutes in a row. Workers should consider creating a system whereby one worker can encourage another (their buddy) to rest, and to drink plenty of fluids; buddies should call for help if and when heat strain symptoms become apparent.

4. A written Heat Alert Plan (HAP) should be developed by management and union officials as a preventive measure to reduce heat stress when environmental temperatures rise at a rate in excess of the workforce's capacity to properly acclimatize, as defined below. A state of heat alert can then be declared to make sure that measures to prevent heat casualties will be strictly observed during a specified time period. HAPs take advantage of the weather forecast of the National Weather Service as a measure to prevent heat-related illnesses. Components of an HAP may include the following:

- Establishing criteria for the declaration of a heat alert. For example, a heat alert may be declared if the weather forecast predicts a maximum air temperature of 95°F (or above) or when the daily maximum temperature exceeds 90°F and is 5°F (or more) above the maximum reached in any of the preceding days. Use of continuous WBGT monitoring within the plant, especially when environmental temperatures rise above those encountered during the completion of this survey, can also serve as a guide to declaring a heat alert.

- Postponing tasks which are not urgent until the hot weather spell is over.

- Increasing the number of workers in each team in order to reduce each worker's heat exposure.

- Increasing rest allowances by using the ACGIH screening criteria and NIOSH guidelines. It should be emphasized that the ACGIH criteria and NIOSH guidelines are screening tools and individual schedules should be devised using physiologic monitoring. Using of a screening tool alone does not guarantee that heat stress will be prevented.

- Reminding workers to drink small amounts of water frequently to prevent dehydration and reminding workers to weigh themselves to maintain their body weight.

- Regular monitoring of the temperature and pulse of all employees during their most severe heat exposure period.

5. Management should develop and pilot an acclimatization program to decrease workers' risk of heat-related illnesses. Such a program involves exposing employees to work in a hot environment for progressively longer periods. The program should also permit self-limitation of exposures.

6. Management should institute pre-placement and periodic medical examinations of persons applying for or working in hot environments. The examination should be performed by a health care provider with knowledge of the health effects associated with work in hot environments. The examinations should be performed to assess the physical, mental, and medical qualifications of the individuals. The health care provider should update the information periodically for people working in hot environments and determine the capability of individuals to work in hot environments.

7. Management and employees should use the screening charts in Appendices B and C to help identify heat stress effects and heat strain factors.

## Noise

An effective hearing conservation program is essential to ensure adequate protection of employees against high noise levels. The following recommendations are provided to help management and employees work together to create an effective hearing conservation program; however, OSHA standard 29 CFR 1910.95 Occupational Noise Exposure should serve as the minimum requirement:

1. Hearing protection should be worn routinely while working in those areas where potentially high noise levels may be encountered during the course of the work shift. NIOSH investigators determined those areas to be near the turbines, the fans, the chillers, and the condenser water pumps.

2. Periodic noise monitoring should be conducted for routine (daily) noise exposure and also during completion of scheduled and unscheduled maintenance activities. This is especially important when there is a process change or addition to daily work tasks in the plant.

3. CHP management should implement an annual training program to educate employees in hearing loss prevention, hearing protection selection, and employee/management responsibilities.

4. Annual audiometric testing should be conducted for all employees whose occupational noise exposure is controlled by use of personal protective equipment. Testing should be performed to ensure that hearing protection is being worn correctly and is providing adequate protection against hearing loss.

5. Proper signs alerting workers to the need for hearing protection in all areas of high noise levels should be posted where they are clearly visible to employees.

## Miscellaneous

While conducting the industrial hygiene and medical survey, NIOSH investigators identified other health and safety concerns within the plant. Addressing these additional concerns can also serve to improve the health and safety of all employees.

1. Smoking should not be permitted in the CHP plant; smoking areas should be designated outdoors. Smoking cessation classes should be offered to the employees and incentives should be established to encourage workers to stop smoking.

2. All first aid and burn kits should be adequately stocked and routinely checked to maintain supplies for employees' use.

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**Table 1. Heart Rate Data**
**Capitol Heat & Power, HETA 2002–0284-2908**
**July 30, 2002**

| Worker | Sampling Time | Average Heart Rate (beats per minute) | HR > 180-age of worker (percent activity) |
|---|---|---|---|
| Employee #1 | 6 hr : 42 min | 71 | did not exceed |
| Employee #2 | 7 hr : 05 min | 52 | did not exceed |
| Employee #3 | 7 hr : 22 min | 82 | did not exceed |
| Employee #4 | 7 hr : 11 min | 94 | did not exceed |
| Employee #5 | 7 hr : 42 min | 76 | 08:52–09:10[a]<br>09:20–09:28<br>12:51–12:52<br>(5.2 %) |

[a] The heart rate for this Employee exceeded the maximum value (180 minus age in years) during each of these time periods.

**Table 2. Noise Dosimetry Data**
**Capitol Heat & Power, HETA 2002–0284**
**July 30, 2002**

| Job Title | Sample Time | OSHA action level[a] | OSHA PEL[b] | NIOSH REL[c] | Max Level[d] |
|---|---|---|---|---|---|
| Employee #1 | 6 hr : 42 min | 66.4 dB(A) | 53.1dB(A) | 76.5 dB(A) | 98.6 dB(A) |
| Employee #2 | 7 hr : 05 min | 74.8 dB(A) | 67.0 dB(A) | 80.6 dB (A) | 106.9 dB(A) |
| Employee #3 | 7 hr : 22 min | 73.3 dB(A) | 54.9 dB(A) | 79.0 dB(A) | 97.6 dB(A) |
| Employee #4 | 7 hr : 11 min | 82.2 dB(A) | 72.3 dB(A) | 84.9 dB(A) | 109.2 dB(A) |
| Employee #5 | 7 hr : 42 min | 81.4 dB(A) | 75.4 dB(A) | 85.3 dB(A) | 109.9 dB(A) |
| Evaluation Criteria | | 90 dB(A) | 85 dB(A) | 85 dB(A) | |

[a] Data collected with a 90 dB criterion, 80 dB threshold, and 5 dB exchange rate
[b] Data collected with a 90 dB criterion, 90 dB threshold, and 5 dB exchange rate
[c] Data collected with a 85 dB criterion, 80 dB threshold, and 3 dB exchange rate
[d] Maximum slow-response level measured during sampling period

**Table 3. WBGT Environmental Temperature Data**
**Capitol Heat & Power, HETA 2002–0284-2908**
**July 30, 2002**

| Location | WBGT Range (°F) | Sampling Time (time of highest temp) | Dry Bulb Range (°F) | Sampling Time (time of highest temp) |
|---|---|---|---|---|
| Boilers | 81.3 – 86.4 | 12:03 – 20:27 (18:13) | 90.9 – 99.1 | 12:03 – 20:27 (16:16) |
| Control Room | 64.9 – 67.3 | 7:02 – 11:33 (10:58) | 69.1 – 72.0 | 7:02 – 11:33 (10:51) |
| Chiller Basement | 79.3 – 87.4 | 11:36 – 14:50 (14:32) | 95.0 – 99.5 | 11:36 – 14:50 (11:38) |
| In-charge desk | 75.9 – 82.0 | 7:51 – 16:13 (14:41) | 84.4 – 96.4 | 7:51 – 16:13 (16:05) |
| Outside | 73.8 – 93.6 | 7:17 – 14:41 (14:02) | 75.6 – 100.4 | 7:17 – 14:41 (14:13) |
| Coal Bunker | 88.9 | 12:20 | 104.5 | 12:20 |

**Table 4. Sound Level Meter Measurements**
**Capitol Heat & Power, HETA 2002–0284-2908**
**July 30, 2002**

| Location | Sound Level dB (A) | Location | Sound Level dB (A) |
|---|---|---|---|
| 1. Northeast corner, Building B | 77.6 | 16. Employee entrance, Building A | 73.2 |
| 2. North stairwell, Building B | 79.3 | 17. Southwest corner, Building A | 83.3 |
| 3. Northwest corner, Building B | 73.5 | 18. South side, Building A, near fans | 88.0 |
| 4. Between boiler #1 (not running) & boiler #3 | 82.3 | 19. BFP-4 | 82.9 |
| 5. Between boilers #3 & #4 | 80.7 | 20. Storage room, basement | 76.2 |
| 6. Between boilers #4 & #2 (not running) | 81.2 | 21. CWP-1 | 88.5 |
| 7. Between boilers #1 & #2 (neither running) | 74.2 | 22. CWP-2 | 86.9 |
| 8. Southwest corner, Building B | 74.2 | 23. CWP-3 | 88.2 |
| 9. Control room | 65.2 | 24. CWP-4 | 86.0 |
| 10. Southeast corner, Building B | 75.8 | 25. CWP-5 | 88.3 |
| 11. Break room | 64.8 | 26. Stairwell, Chiller basement | 88.2 |
| 12. Near turbine #2 | 91.8 | 27. Chiller basement, between pipes | 88.4 |
| 13. Near turbine #1 | 92.6 | 28. Chiller basement, between pipes | 83.0 |
| 14. North stairwell, Building A | 84.3 | 29. Lake water pump | 78.1 |
| 15. In-charge desk | 82.2 | 30. Quincy QE-5 | 83.6 |

Figure 1. Employee #1
Capitol Heat & Power
HETA 2002-0284
July 30, 2002

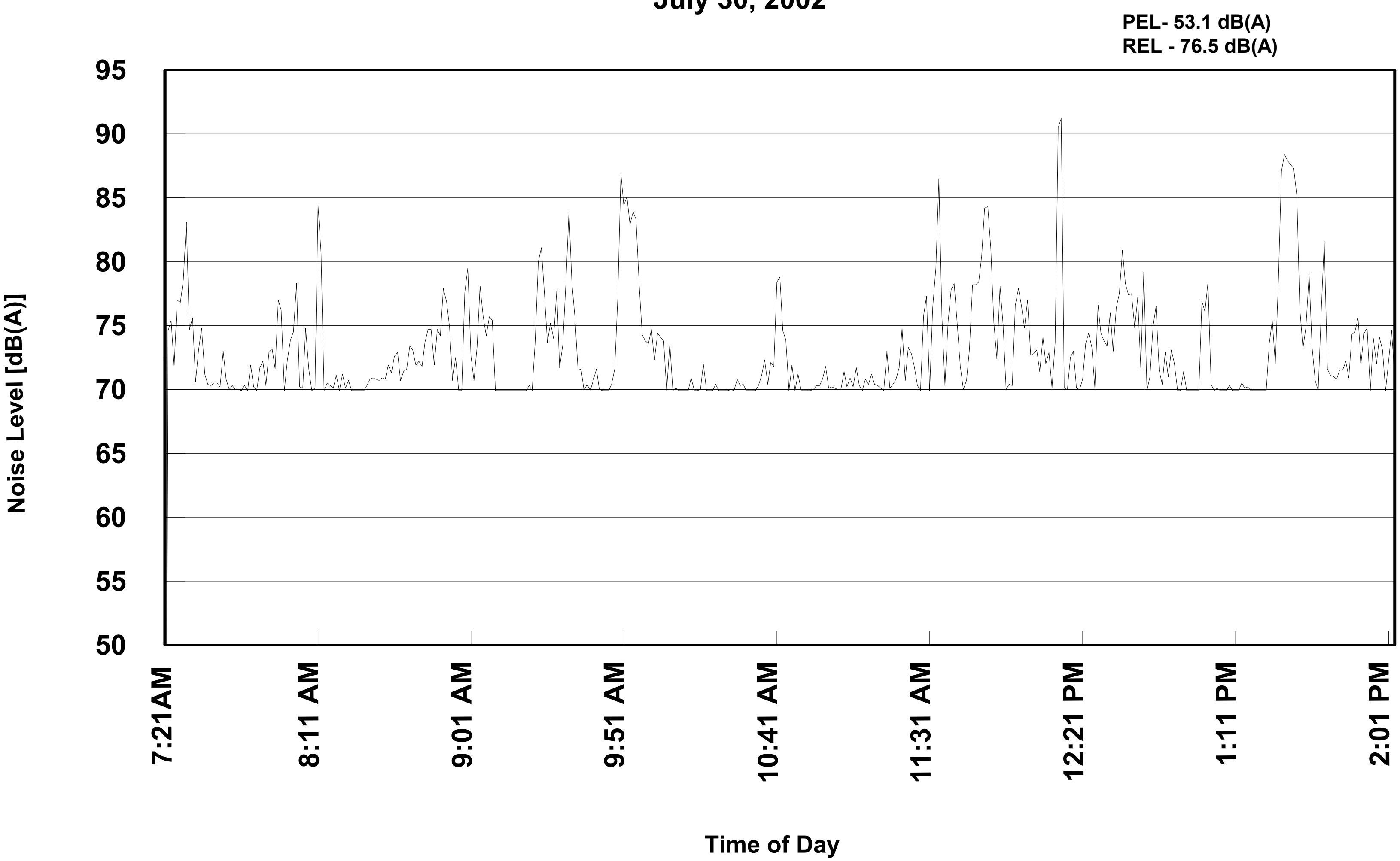
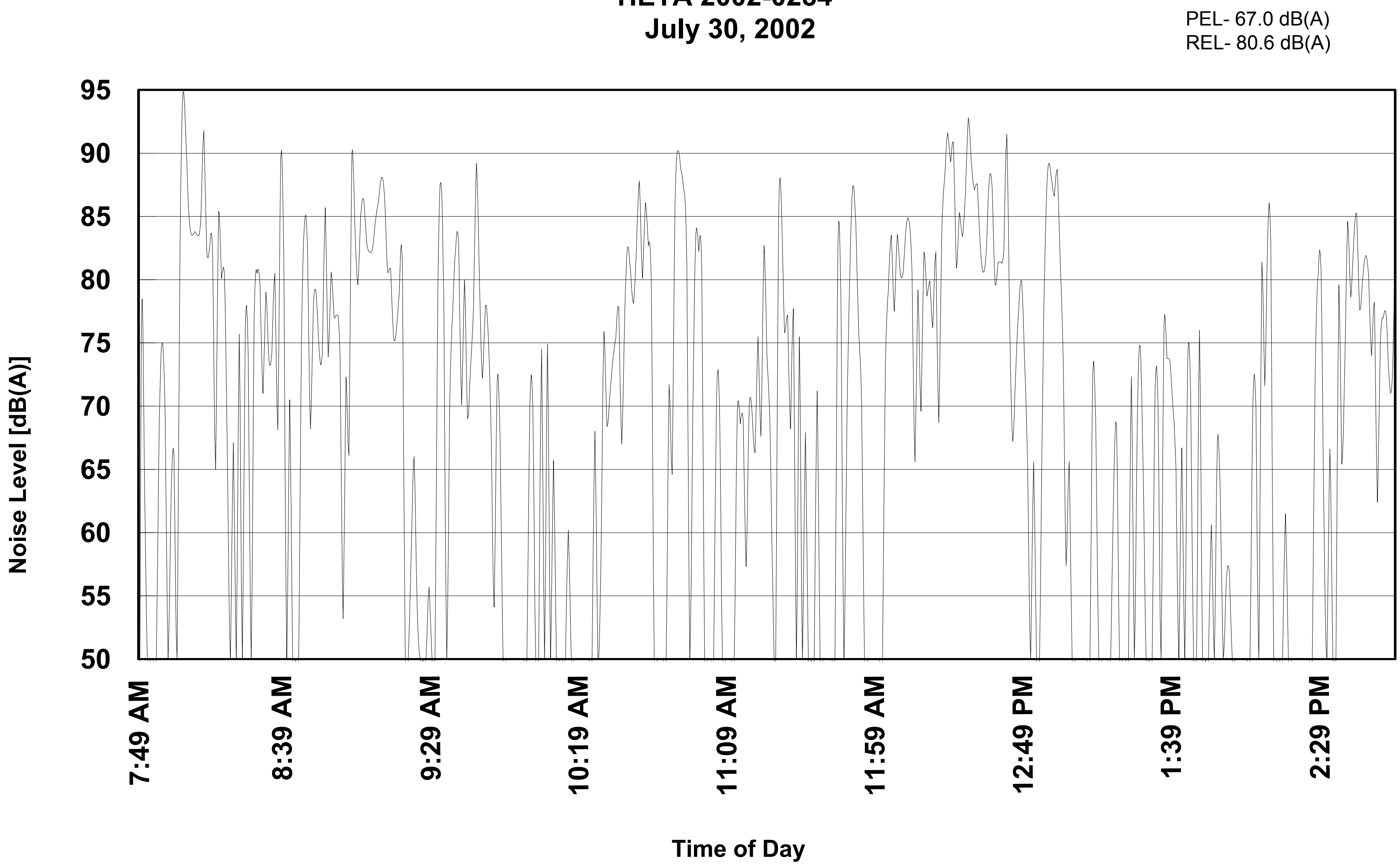


**Figure 2. Employee #2**
**Capitol Heat & Power Plant**
**HETA 2002-0284**
**July 30, 2002**



## Figure 3. Employee #3
## Capitol Heat & Power Plant
## HETA 2002-0284
## July 30, 2002

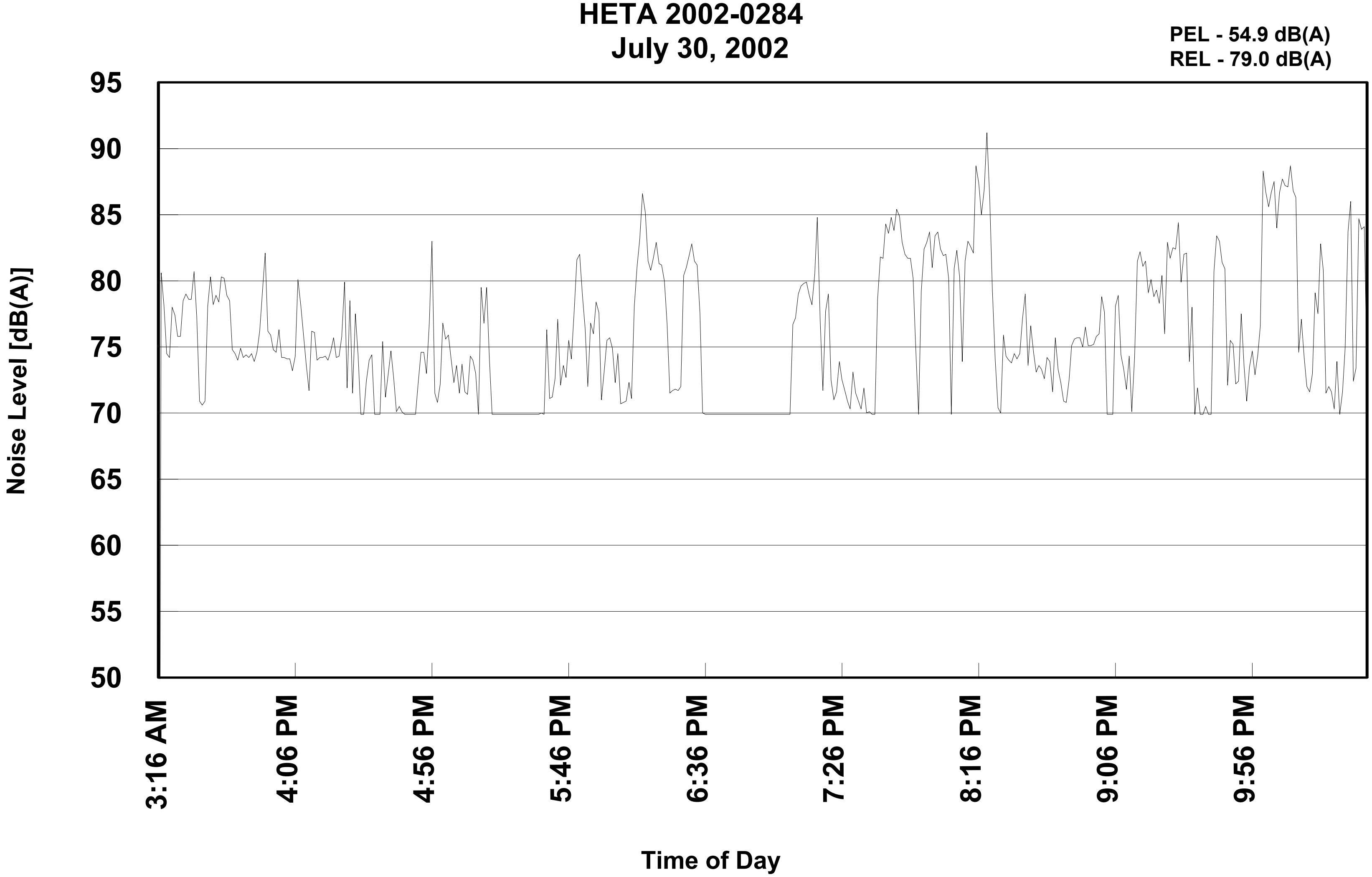


**Figure 4. Employee #4**
**Capitol Heat Power Plant**
**HETA 2002-0284**
**July 30, 2002**

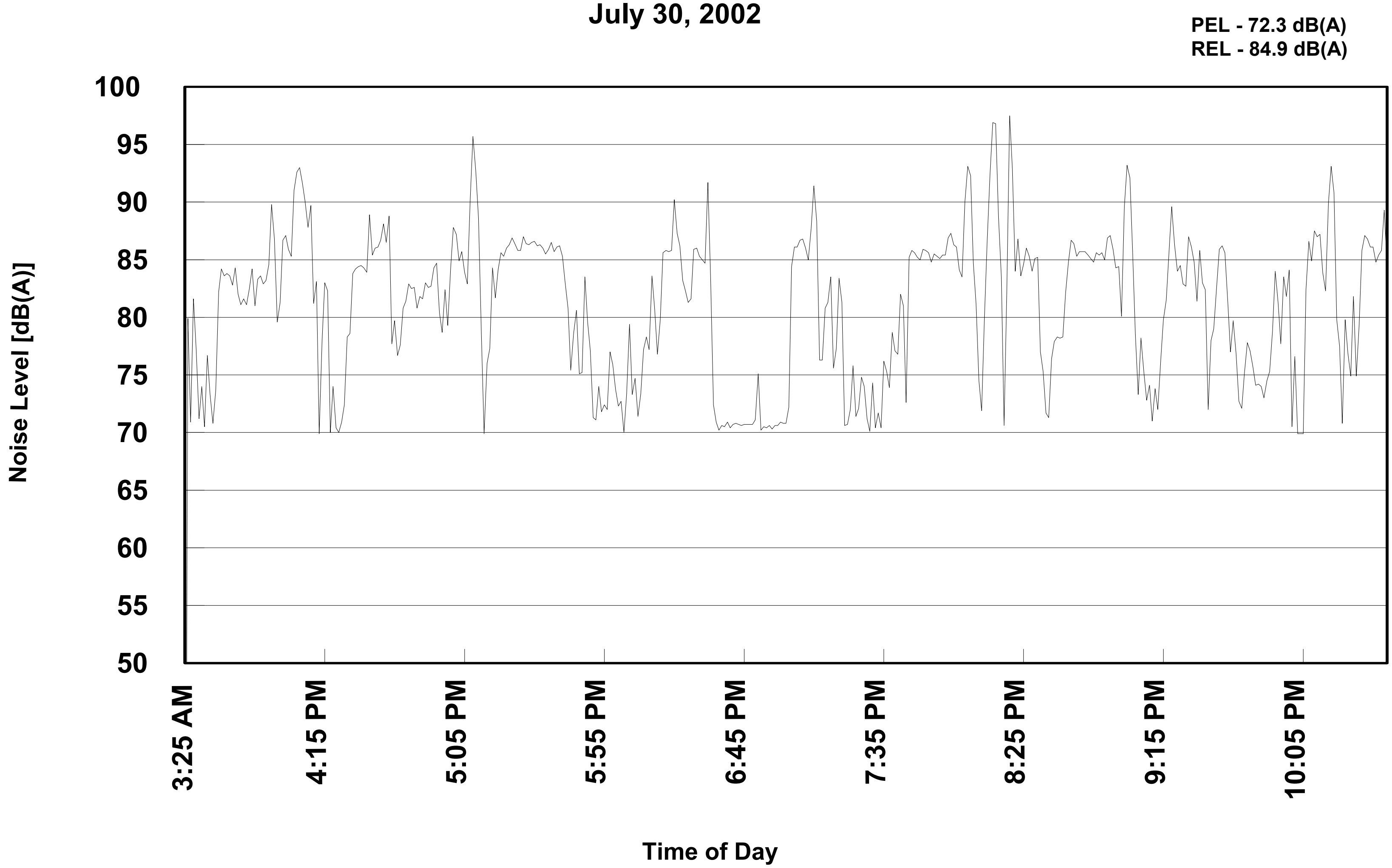
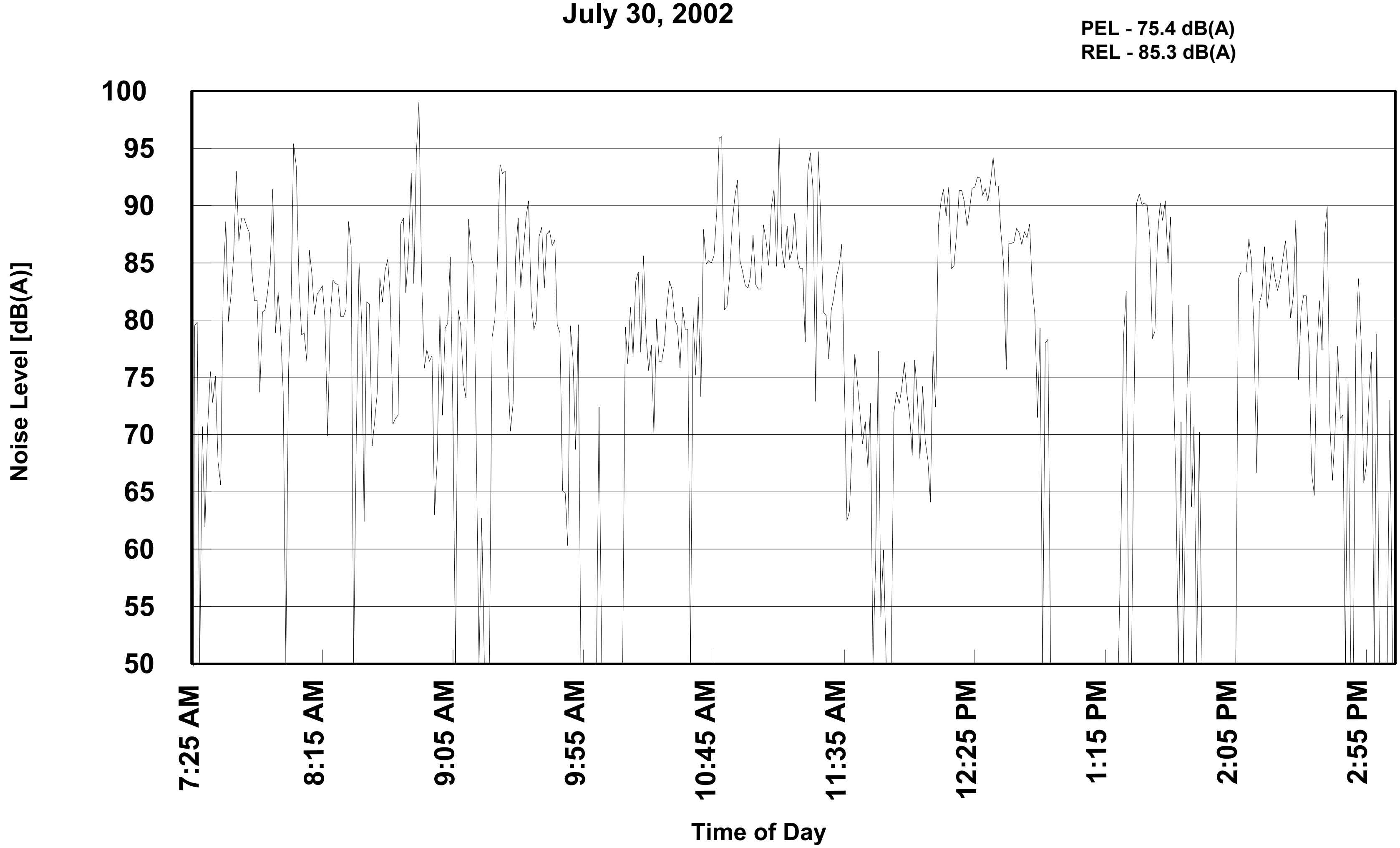


**Figure 5. Employee #5**
**Capitol Heat & Power Plant**
**HETA 2002-0284**
**July 30, 2002**



## Appendix A: Medical Interview Questionnaire

**Capitol Heat & Power**
**State of Wisconsin**
**Madison, Wisconsin**
**HETA 2002–0284**

Date:

Name:

Weight (in pounds)
- pre-shift:

- post-shift:

Urine specific gravity
- pre-shift:

- post-shift:

How much fluid did you drink during your shift?

What type(s) of fluid did you drink?

Did you eat during your shift?

How many times did you urinate during your shift?

How many times did you move your bowels during your shift?

How long have you worked for Capitol Heat & Power?

What is your job title?

What are your job duties?

What are your most physically demanding job duties?

What is your usual work schedule?  (Days per week; Hours per day; Shifts worked)

What type of fluid(s) do you drink at work?
- ☐ water
- ☐ electrolyte replacement drinks (e.g. Gatorade, PowerAde, All Sport, etc.)
- ☐ soft drinks: _______________
- ☐ beer
- ☐ coffee/tea
- ☐ milk
- ☐ other: ___________________

Have you ever run out of hydration fluids while on duty?

Have you ever had any symptoms of dehydration while on duty?
- ☐ lightheadedness
- ☐ fatigue
- ☐ fainting
- ☐ headache
- ☐ clammy skin

Have you ever had muscle cramps while on duty?

Have you ever had a skin rash while on duty?

Have you ever passed out or become dizzy or confused while on duty?

Have you ever had a doctor diagnosed heat-related illness that you reported to your supervisor or other management representative?

Do you have any chronic diseases that you see a doctor for?

- If yes, please list:

Do you take any medication for any illnesses or symptoms such as allergies, diabetes, heart disease, neurological disease, psychiatric disorder?

- If yes, what medication(s) do you take?

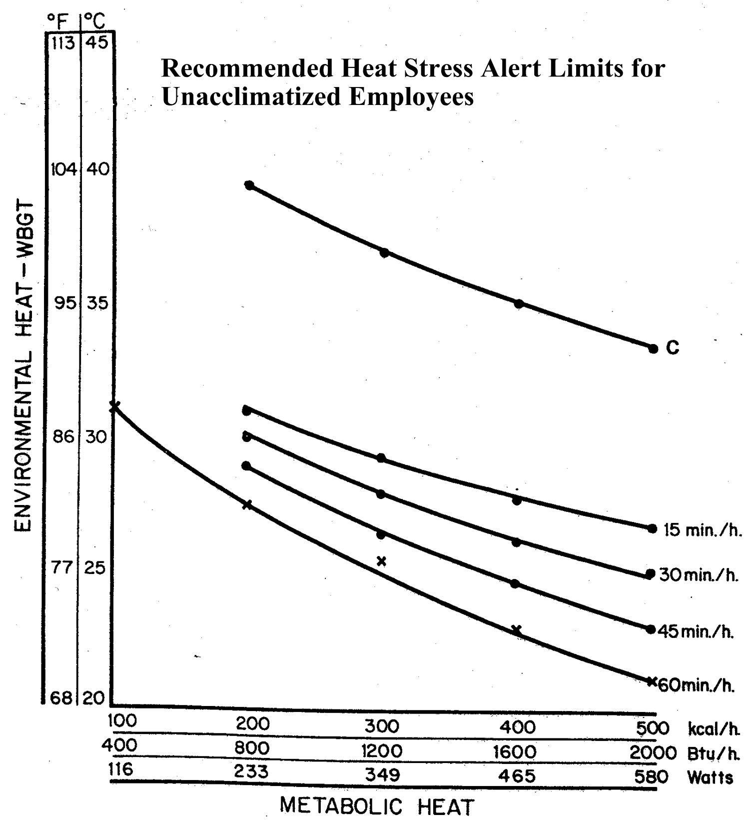
Do you monitor yourself to see if you are working too hard when it gets hot at work?

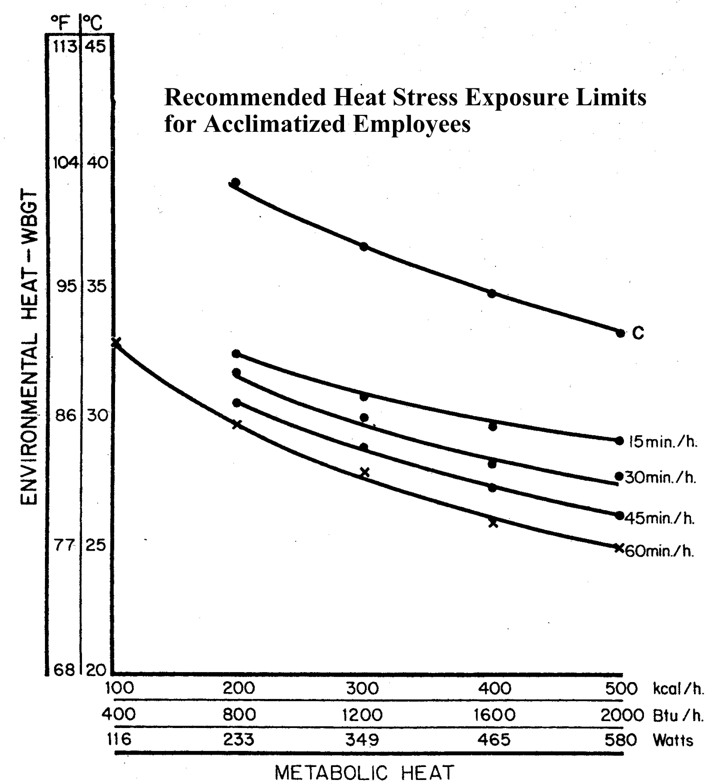
- If yes, how do you monitor to see if you are working too hard?

Do you exercise regularly when you are off work?

- If yes, what type of exercise?

**Appendix B: NIOSH Recommended Alert Limits (RALs) and Recommended Exposure Limits (RELs) for Heat Stress**



## Appendix C: ACGIH Screening Criteria for Heat Stress Exposure*

| | Acclimatized (WBGT values in °F) | | | | Unacclimatized (WBGT values in °F) | | | |
|---|---|---|---|---|---|---|---|---|
| **Work Demands** | **Light** | **Moderate** | **Heavy** | **Very Heavy** | **Light** | **Moderate** | **Heavy** | **Very Heavy** |
| **100% Work** | 85.1 | 81.5 | 78.8 | | 81.5 | 77.0 | 72.5 | |
| **75% Work; 25% Rest** | 86.9 | 83.3 | 81.5 | | 84.2 | 79.7 | 76.1 | |
| **50% Work; 50% Rest** | 88.7 | 85.1 | 83.3 | 81.5 | 86.0 | 82.4 | 79.7 | 77.0 |
| **25% Work; 75% Rest** | 90.5 | 87.8 | 86.0 | 85.1 | 87.8 | 84.2 | 82.4 | 79.7 |

Notes:
- See work demand categories table below.
- WBGT values represent thresholds near the upper limit of the metabolic rate category.
- If work and rest environments are different, hourly time-weighted averages (TWA) should be calculated and used. TWAs for work rates should also be used when the work demands vary within the hour.
- Values in the table assume 8-hour workdays in a 5-day workweek with conventional breaks as discussed in the Evaluation Criteria section of this report.
- Because of the physiological strain associated with Very Heavy work among less fit workers regardless of WBGT, criteria values are not provided for continuous work and for up to 25% rest in an hour. The screening criteria are not recommended, and a detailed analysis and/or physiological monitoring should be used.

The following work load categories, descriptions of work, and estimated energy expenditures help to estimate a conservative WBGT heat exposure limit for workers conducting these or similar jobs:

| Work Categories | Example Activities |
|---|---|
| **Resting** | Sitting quietly; Sitting with moderate arm movements |
| **Light (<200 kcal/hr)** | Sitting with moderate arm and leg movements; Standing with light work at machine or bench while using mostly arms |
| **Moderate (200–350 kcal/hr)** | Scrubbing in a standing position; Walking about with moderate lifting or pushing; Walking on level at 3.7 mph while carrying a 6.6 pound load |
| **Heavy (350–500 kcal/hr)** | Carpenter sawing by hand; Shoveling dry sand; Heavy assembly work on a noncontinuous basis; Intermittent heavy lifting with pushing or pulling (for example, pick-and-shovel work) |
| **Very Heavy (>500 kcal/hr)** | Shoveling wet sand |

* From American Conference of Governmental Industrial Hygienists (ACGIH®), *2001 TLV® and BEI® Documentation* and *2000 Supplement: Heat stress and strain: Documentation of TLVs® and BEIs®, 6th Edition*. Copyright 2000 and 2001, respectively. Reprinted with permission.

# Acclimatization

Workers who are suddenly exposed to hot work environments often develop symptoms of heat stress, including headaches, cramps, fatigue, and nausea. They may also experience increases in heart rate and core body temperature (CBT). With subsequent, repeated exposure to hot environments, however, there occurs a physiological adaptation such that workers may work in the heat with a decreased risk of developing heat-related illnesses. This adaptation is called acclimatization. Capitol Heat and Power (CHP) management should be particularly aware of an increased potential for heat stress following an abrupt rise in outdoor temperature, among non-acclimatized newly hired employees, and among personnel who have been absent from the work site for a number of days and would need to be re-acclimatized.

# Physiological Adaptations to Heat Exposure

The ability of a worker to acclimatize requires a normally functioning heart, lungs, and kidneys. The part of the brain responsible for regulating body temperature, the sweating mechanism, and the body's fluid and electrolyte balances must also be intact. Impairment or diminution of any of these functions may interfere with a person's ability to acclimatize or to perform more strenuous work in the heat once acclimatized.[1]

One important physiological change that occurs during acclimatization involves adaptation of the cardiovascular and peripheral vascular systems of the body. In response to an increase in CBT, the heart pumps more blood through the body at a faster rate than normal. As previously described, blood vessels throughout the body dilate in order to accommodate this increased blood flow. The microscopic blood vessels located in the upper layers of the skin also fill with blood and as an increasing volume of blood circulates closer to the surface of the skin, excess body heat is exchanged to the environment.[2] An acclimatized individual has the ability to facilitate this improved heat exchange without suffering from the condition known as heat syncope.

Acclimatized individuals differ from non-acclimatized persons in other respects. Acclimatized persons not only perspire more than non-acclimatized persons, they perspire more uniformly over their entire body surface. They also begin to sweat earlier than non-acclimatized individuals exposed to similar conditions. In addition, acclimatized individuals lose less salt through sweating and are therefore able to withstand greater water loss.[3] Overall, this results in both lower heat storage (a lower CBT) and a decreased work load on the heart.

# The Acclimatization Process - Exposure and Work

Consistent work at even a moderate pace in a hot environment generally results in the physiological changes that will substantially improve worker comfort and safety. Empirical data suggest that 95% or more of workers are able to adequately acclimatize to heat stress.[1] For people in good general health, exposure to heat only is not sufficient to induce physiological acclimatization; however, increasing one's metabolic rate while in a hot environment is required to properly acclimatize.

There are three phases to heat acclimatization. The first phase occurs with consecutive daily exposures to heat accompanied by a requisite rise in metabolic rate for 2 hours (for example, work activity, exercise) each day. During this initial exposure period, the body can achieve 33% of optimum acclimatization by the fourth day. The second, or intermediate, phase is marked by cardiovascular stability. By the eighth day of exposure, both skin surface temperature and CBT are lower, reaching 44% of optimum. Finally, during the third phase, the body responds by changing the chemical composition of both sweat and urine in order to conserve body fluids and restore electrolyte balance. By day 10, a person of good general health will have achieved 65% of their optimal acclimatization; by day 18, 93% of optimal acclimatization will be achieved; and by the end of the third week of heat exposure and work, a person should have attained approximately 99% of optimal acclimatization.[2]

Although a majority of individuals achieve a satisfactory level of acclimatization after working (or exercising) in a hot environment, there are several important features to keep in mind concerning this phenomenon. First, acclimatization at a certain temperature is effective only at that temperature; a person exposed to a higher level of heat stress will only be fully acclimatized at the lower level.[2] Second, whereas heat acclimatization for most individuals begins early in a period of working in the heat, it is also quickly lost if the exposure is discontinued. The loss of acclimatization begins when activity under heat stress conditions is discontinued, and a noticeable loss occurs after four days. An absence from work of more than seven days will return a worker to his or her physiological baseline; to regain the previous level of acclimatization, an individual will require up to three weeks of consecutive daily exposures to heat accompanied by the necessary rise in metabolic rate.[2] The physiological adaptations that are characteristic of heat acclimatization are generally recovered fairly rapidly after brief absences, however, so that workers who are off for two consecutive days will tend to return to their previous level of acclimatization one to two days after returning to the job.

Chronic illness, the use or misuse of some pharmacologic agents, a sleep deficit, varying degrees of malnutrition, and disturbances of water and electrolyte balance may each serve to reduce a worker's capacity to acclimatize. In addition, an acute episode of mild illness, especially those characterized by fever, vomiting, respiratory impairment, or diarrhea, may cause abrupt, transient loss of acclimatization.[1]

## Fluid and Electrolyte Balance

Dehydration, a common problem from working in the heat, is caused by losses of both fluid volume and sodium (salt) through sweat. This condition affects the ability of the body to regulate temperature and results in a rise of CBT.[4] Although it is necessary to sweat to facilitate cooling of the body, both fluid and salt losses must be replaced to prevent dehydration. Sweat production represents a large potential source of cooling if all the sweat is evaporated while at the same time serving as a source of progressive depletion of body water content. By weighing workers at intervals during the day (or at least at the beginning and end of the work shift) the amount of body water depletion, and thus, dehydration, may be estimated.

Under high heat and strenuous work conditions, individuals may produce between six and eight liters of sweat in a given work shift, and replacement of fluid loss under those conditions is usually incomplete. When the weight loss exceeds 1.5% to 2% of an individual's pre-activity or pre-shift body weight, heart rate and core body temperature increase and work capacity decreases. The ACGIH reports that an individual may be at greater risk for heat strain if weight loss is greater than 1.5% of pre-shift body weight.[2]

In addition to water, the other important component of sweat is salt (sodium chloride). In most circumstances, a salt deficit does not readily occur (even under high heat strenuous work conditions) because the typical American diet generally contains an excess of salt, enough to replace salt lost through perspiration. Eating during the shift should replace the elements lost by a worker through sweat. Workers on salt-restricted diets should explain their working conditions to their doctor and discuss the need for extra salt, especially if the workers are non-acclimatized.[1]

# References


1. NIOSH [1986]. NIOSH Revised Criteria for a Recommended Standard: Occupational Exposure to Hot Environments (Revised Criteria 1986). Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-113.

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