Environmental, Safety and Health Standards Identification for Geothermal Energy

Report 6: Heat Stress

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March 1979

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Richland, Washington

FOREWORD

This report is the sixth in a series being prepared as part of the Department of Energy (DOE) project entitled "Environmental, Safety and Health Standards Identification for Geothermal Energy." This project is being performed for DOE by the Pacific Northwest Laboratory under Contract EY-76-C-06-1830^(a) and is cosponsored by DOE's Division of Operational and Environmental Safety and Division of Geothermal Energy.

Although a number of technical and institutional problems currently confront the industry which are impeding the development of geothermal energy, the scope of this project is limited to environmental and occupational health and safety considerations. Geothermal energy has been considered to be one of the cleaner and safer sources of power available to man. This attitude stemmed in part from a lack of knowledge about the various forms of geothermal energy, the environmental implications of various development options, and the health and safety hazards that geothermal development could pose. The environmental effects of existing developments have been localized and therefore not apparent to the general public, because all activities related to geothermal utilization are confined to the immediate vicinity of the energy source. The occupational hazards have not been widely investigated simply because of the limited number of geothermal developments. However, the world's demand for alternate sources of energy will necessitate the widespread use of geothermal energy, and when that happens, its effects on our environment and health must be clearly understood.

OBJECTIVE

The objective of this project is to identify and evaluate existing environmental, safety and health (ES&H) standards that may be applicable to problems and hazards in the geothermal industry. From this evaluation will come recommendations for the direct application or modification of existing standards or the development of new standards. More specifically, the individual objectives of the project are to:

(a) Battelle Memorial Institute operates Pacific Northwest Laboratory for the Department of Energy.

- identify and evaluate existing and potential ES&H problems in the geothermal industry that might be controlled by industry-wide standards
- determine the need for specific standards
- identify existing ES&H standards and determine their applicability to these needs
- identify needs that are not addressed by existing standards
- make recommendations for adoption or modification of existing standards or development of new standards.

The initial efforts on the project will be concentrated on those problems with the highest priorities; these include hydrogen sulfide emissions, brine disposal, blowouts, noise, subsidence and seismic effects of geothermal developments. The project is scheduled so that reports on the highest priority problems will be completed as soon as possible.

REPORTS

The ES&H problems briefly referred to above have been categorized into a number of topics that relate to specific problem areas. This categorization breaks the project down into manageable tasks, responds to the highest priority problems as early as possible, and corresponds to the general way in which the literature addresses these problem areas.

The reports scheduled for this project are listed below in their approximate order of completion:

- Report 1 Airborne Emissions
- Report 2 Liquid Waste Disposal/Water Pollution
- Report 3 Blowouts/Hot Water and Steam Releases
- Report 4 Subsidence and Induced Seismicity
- Report 5 Noise
- Report 6 Heat Stress
- Report 7 Sampling and Analyses
- Report 8 Falling Hazards
- Report 9 Electrical Hazards

Report 10 Heavy Equipment Operations
Report 11 Soil Effects and Land Use Planning
Report 12 Fire Hazards
Report 13 Construction
Report 14 Hazardous Substances
Summary Report

Reports 1 and 5 address both the environmental and the occupational safety and health aspects of airborne emissions and noise, respectively. Reports 2, 4, 7, and 11 are primarily directed at the environmental aspects of their respective topics. Reports 3, 6, 8, 9, 10, 12, 13, and 14 address primarily occupational safety and health aspects of their respective topics. Certain data and background information will have to be duplicated in some reports so that each report can stand alone.

SUMMARY

Heat stress may occur whenever an imbalance between body heat and heat loss to the environment causes the body to become burdened with excessive heat that it cannot lose to its surroundings. In the geothermal industry, heat-stress problems may arise from the extensive use of hot surfaces, steam and/or hot water. In addition, radiant heat problems may occur because of elevated temperature exposures.

Body temperature depends upon the balance between body heat and heat loss to the environment. If body core temperature rises 3 degrees above or falls 2 degrees below normal, performance may be impaired. Furthermore, if the thermoregulatory system, which constantly seeks to maintain a normal temperature range, does not function properly or is overburdened, heat-related symptoms, such as heat stroke, heat exhaustion and heat cramps may result.

Currently, no recognized consensus exists for a heat-stress standard, although several permissible exposure limits have been recommended. Of the many indices developed, those discussed in the following three documents represent guidelines from which a standard may eventually develop:

- Occupation Exposure to Hot Environments⁽¹⁾
- "Recommendations for a Standard for Work in Hot Environments"⁽²⁾
- Threshold Limit Values (TLV) for Physical Agents.⁽³⁾

Each document refers to the Wet Bulb Globe Temperature (WBGT) as the index used for measuring the environmental factors that influence the dissipation of body heat. However, the documents vary in their use of other factors such as workload, work-rest regimen, air velocity, employee training and monitoring.

A personal monitoring device has advantages over the WBGT because it considers individual differences in work rate, clothing and other factors. Difficulties, however, with wearer acceptance and location of the device are still unresolved; therefore, further research is needed to develop personal monitoring devices.

Since little epidemiological evidence exists that relates human exposure to environmental measurements, more effort is needed to gather this information. Until further research is completed, the American Conference of Governmental Industrial Hygienists (ACGIH) TLV on heat stress should be applied to exposure evaluations at geothermal sites. The Threshold Limit Values assume that nearly all acclimated, fully clothed workers with adequate water and salt intake should be able to function effectively under given working conditions without exceeding a deep-body temperature of 38°C.

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INTRODUCTION

This report is the sixth in a series aimed at identifying the environmental and occupational safety and health issues related to geothermal energy development, evaluating the existing standards applying to those issues, and recommending that existing standards be adopted or modified or that new ones be established. This report discusses only those issues and standards related to heat stress.

Heat stress may occur whenever the body is burdened with excessive heat that it cannot lose to its surroundings. Consequently, the work environment plays an important role in predisposing the individual to heat-stress effects. Geothermal energy sites are potential sources of increased heat exposures to which employees may be exposed. For instance, geography is crucial since some sites, as in the Imperial Valley, California, are subject to extreme summer temperatures. Large volumes of steam, hot surfaces, and piping, which are present in this industry, are also potential problem areas. The metabolic rate of a worker may also be high, as in well drilling where the worker not only produces significant metabolic heat but is also exposed to direct sun. In addition, workers may wear heavy clothing, such as coveralls, which lessens cooling by air movement. All factors considered, a potential exists for heat-stress problems at geothermal sites.

CONCLUSIONS AND RECOMMENDATIONS

Although most people agree that an occupational heat-stress standard is necessary to protect workers from heat-exposure problems, no conclusive evidence exists that will support the specific provisions necessary to meet this mandate. The greatest need is for epidemiological studies that address the problems involved in correlating exposure data with standards requirements. As a result, this report fully supports the recommendations of the Occupational Safety and Health Administration (OSHA) Standards Advisory Committee on heat stress, which urges an epidemiological approach.⁽²⁾

Further research on heat-stress monitoring methods is definitely needed. Inherent shortcomings, such as relating laboratory results to industrial experiences, occur when attempting to relate environmental factors to individual body-heat load. It is strongly recommended that more effort and research be directed into the development of a low-cost, effective personal monitoring device, such as that suggested by Lutz and Coker.⁽⁴⁾

Until an acceptable heat-stress standard is in effect, it is questionable whether any single set of criteria should be declared applicable to the geothermal industry. Since the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV) For Physical Agents⁽³⁾ is the prescribed standard for many Department of Energy (DOE) contractors, it should be acceptable to use these values in evaluating worker exposures at geothermal sites. However, this document only provides guidelines for evaluating heat stress and controlling overexposures by specified work-rest regimens. Supplementing the heat-stress TLV's with the information provided by the NIOSH Criteria Document⁽¹⁾ and the OSHA Standards Advisory Committee Recommendations⁽²⁾ on acclimation, medical surveillance, engineering control, and employee training is recommended for the geothermal industry.

STATEMENT OF THE PROBLEM

Heat-stress problems in the geothermal industry are similar to those of many other industries, such as food processing and paper manufacturing, since the heat-stress potential correlates with the extensive use of hot surfaces (pipes, vessels, equipment), steam and/or hot water. Radiant heat problems occur, as in the metal industry with its foundries and smelters, because of elevated temperature exposures.

Whereas heat loss from hot surfaces and piping is common in general industry, the geothermal industry tries to insure minimum heat loss. Therefore, insulation becomes extremely important in preserving heat enthalpy. A resultant benefit accrues from insulation: reduced radiant heat to the worker's environment with a lower risk of accidental burns.

Two of the greatest concerns of potential heat exposure in the geothermal industry involve maintenance personnel and the drilling operations. Maintenance personnel often spend a significant amount of time in areas where other workers are normally not present. Consequently, these areas may be confining, have little or no ventilation and have an elevated temperature. Also, these employees often perform operations that require substantial work output, thus increasing their metabolic rate and adding to their total body-heat burden. In combination, the above factors may produce a stressful situation.

Drilling operations present additional heat-related considerations. Not only may the work load vary from moderate to heavy, but clothing such as overalls is also required, which lessens cooling by air movement. Gloves must be worn when handling the pipe and equipment. Venting steam and/or gases that may be present on the platform increase exposure to heat and higher humidity. Normally, little protection from the sun is afforded.

Geothermal geography is also related to heat-stress potential. For instance, summer temperatures in the Imperial Valley, California, often exceed 100°F (37.8°C), which may result in difficulties in reducing a person's total heat load. However, chances are that the employees in this area are acclimated to high temperatures, which reduces the possible effects. Nevertheless, these

temperatures are an important consideration for an unacclimated worker who suddenly begins work in the area. In reality, heat-related problems are more likely in a cooler setting where occasional increased temperatures occur than in a hotter environment. For instance, exposure to heat during vessel entry or pipe repair at the Geysers may be more stressful to personnel than that which would result during similar work in the Imperial Valley. However, heat stress will increase at the sudden onset of increases in climatic temperatures or humidity regardless of whether prevailing temperatures in the region are high or moderate.

The human organism is the best indicator of heat stress because a person's deep-body temperature is the result of the balance between the organism's total body heat and that of its environment. The body's core temperature as recommended by the World Health Organization (WHO) and the National Institute of Occupational Safety and Health (NIOSH) should not exceed 100.4°F (38°C). As long as this criterion is met and the worker's water and salt intake is adequate, no physiological impairment is expected. However, to monitor all potentially exposed employees is impractical. So, we must measure the forces that affect body temperature and attempt to predict outcomes from these external measurements.

PHYSIOLOGICAL EFFECTS OF HEAT STRESS

The core temperature in man fluctuates only a few degrees, centering around a normal temperature of 98.6°F (37°C). If core temperatures exceed 38.0°C, workers should not be permitted to continue their work.^(2,3) Beyond this temperature, the probability of health hazards increases significantly. Whether damage may ensue depends on a number of complex variables. Of major importance is the functioning of the thermoregulatory system, which constantly seeks to maintain this narrow temperature range. If the system does not function properly or is overburdened, heat-related symptoms will result.

Body temperature depends upon the balance between body heat and heat loss to the environment. Even at rest, we produce metabolic heat by oxidizing food elements, which maintains core temperatures well above that of the surrounding air. Problems begin when the environmental temperature approaches normal body temperature and heat loss becomes increasingly difficult. The thermodynamic processes that govern heat interchange between the body and its environment are represented by the equation:

$$S = M + R + C - E$$

where

S is the rate of storage (change in intrinsic body heat), BTU/hr

M is the rate of metabolism (heat produced within the body), BTU/hr

R is the rate of radiative heat gain (or loss), BTU/hr

C is the rate of convective heat gain (or loss), BTU/hr

E is the rate of evaporative heat loss, BTU/hr.

Heat storage is either positive or negative, depending on whether heat is being stored or depleted. As the rate of storage (S) increases, body temperature rises and compensating mechanisms attempt to increase the cooling rate. Metabolism (M) is positive and depends upon the individual's work load and energy output. Heat load will seldom exceed 1200 BTU/hr, regardless of the task, if rest breaks are regularly taken. Radiant heat (R), a form of electromagnetic energy which passes through the air without heating it, may be either positive or negative: positive if radiating surfaces are hotter than the body

surface and negative if the environment is cooler than the body surface temperature. Convective heat gain or loss (C) is similarly dependent upon the surrounding air temperature. Convective heat is a function of the temperature gradient between the skin and the ambient air and air movement past the surface. Evaporative heat loss (E), which is a cooling mechanism based on the skin and the air, is negative since evaporation will always result in heat loss.

In addition, heat exchange occurs during conduction, where heat is transferred to or from the body, to or from a material in direct contact with it, and during respiration, which warms and saturates the respired air to the temperature of the lungs' air passages. Simply stated, the physiologic control of blood flow from heat-production sites in muscles and deep tissues to the cooler body surface, where heat dissipates through radiation, convection and evaporation, regulates body temperature. Environmental factors that inhibit the body's ability to relieve excess heat shift the heat equation toward storage (S). Normally, however, conduction heat loss does not contribute significantly to temperature regulation.

Excessive body heat produces reactions in human beings. Since heat stress produces cardiovascular strain that increases demands on blood flow, physical performance may be affected. When muscles do not receive enough blood, work output should be reduced or overstrains, which increase the probability of accidents, may occur.

Excessive heat also affects psychological performance since learning ability, skilled task performance, and other jobs involving sensorimotor coordination may deteriorate. Also, people exposed to excessive heat often complain of fatigue.

In addition to the effects produced in the organism by excessive heat, a danger exists where contact with hot pipes, molten metal, steam, and related equipment may occur. Combined, these factors produce an environment where the probability of accidents increases.

Heat combined with other factors (such as carbon monoxide, drugs, noise, and bacteria) may also produce undesirable effects. Since noise and heat may be encountered concurrently in the geothermal industry, the chance of accidents increases when subjects perform at the same noise level but with an elevated temperature.

Medical considerations involve physiological responses to heat stress such as elevated skin temperatures with resultant pain and tissue damage and/or elevated body temperatures with the subsequent syndromes of heat exhaustion, heat cramps, and heat stroke. These responses vary according to the imbalance between environmental and body temperature. For clarity, the common forms of heat-associated physical disorders are described below.

HEAT STROKE

This is the most serious disorder that results from exposure to excessive heat. When heat stroke occurs, a complete breakdown in the body's thermoregulatory system results, causing sweating to cease, the skin to become hot and dry, and the internal body temperature to rise drastically. If not treated, the individual may become unconscious or die. The patient must be promptly removed to a cool area and measures must be taken to cool the body by wetting the clothes, vigorous fanning, and other means.

HEAT EXHAUSTION

The major difference between heat exhaustion and heat stroke is that sweating still occurs. The disorder results from the significant loss of body fluids and salts. Extreme weakness and nausea may be experienced, and unconsciousness can ensue. The patient should rest in a cool place and replace the lost liquids and salts. Effects are not permanent.

HEAT CRAMPS

This disorder results when large quantities of water are drunk in a hot environment without replacing lost salts. Consequently, muscle spasms may occur because of the imbalance of electrolytes in the body. Salted liquids, tablets, or intravenous saline solutions will relieve cramps.

FAINTING

At first glance, this disorder may appear mild compared to those listed above, but it may lead to a serious accident, especially if the affected

employee were to fall from his work position. A worker who has fainted should be removed from the area, his clothing loosened, and his feet elevated. Since fainting is common in unacclimated workers, the worker should be acclimated before returning to work. The NIOSH Criteria Document proposes specific acclimation regimens for unacclimated employees and for employees who have lost acclimation during nine or more days leave or four days sick leave.⁽¹⁾ Unacclimated employees begin with 50% of the anticipated workload and exposure time on the first day, followed by daily 10% increments building up to 100% total exposure on the sixth day. Employees who have lost acclimation begin with 50% of the anticipated total exposure on the first day, followed by 20% increments building up to 100% total exposure on the fourth day. This NIOSH procedure is recommended as a guide for acclimation regimens in the geothermal industry.

HEAT RASH

When sweat is not easily removed from the skin by evaporation, the ducts may become plugged, causing the sweat glands to become inflamed and a rash to develop. Frequent bathing is important to prevent this condition.

MONITORING EQUIPMENT

Two types of monitoring equipment are used to evaluate the effects of heat stress. Measuring devices such as the Wet Bulb Globe Thermometer are used to evaluate the influence of environmental factors; personal monitoring devices are used to measure workers' deep-body temperature. These devices are discussed separately below.

MEASURING DEVICES

The four environmental factors that influence the rates of heat transfer between man and his surroundings are air temperature, air velocity, humidity, and thermal radiation. To arrive at an estimate of heat stress, monitoring equipment must be used to measure these four variables.

Generally, the Wet Bulb Globe Temperature (WBGT) is considered the simplest and most suitable technique to measure the environmental factors. The devices required for a WBGT are a wet-bulb (natural) thermometer, a dry-bulb thermometer (when used outdoors in the sunshine), and a globe thermometer (see Figure 1).

The wet-bulb temperature is obtained by exposing a sensor wetted with distilled water to natural air movement, which depresses the wet-bulb thermometer. The dry-bulb temperature may be obtained from a common glass thermometer, or from a bimetallic, thermocouple, resistance, or thermistor thermometer, all of which measure the air temperature as defined by convection. The globe thermometer is a thin-walled copper sphere with the bulb of a thermometer or other sensor located at its center. The outer surface of the bulb is painted flat black, allowing the device to measure radiant heat as the temperature rises as a result of the heat being absorbed by the bulb's black surface. Radiant heat is a function of the gradient from the radiant temperature of the environment to skin temperature, such as the temperature difference one would perceive when standing close to a hot water radiator. These three measurements form the equation for WBGT:

$$\text{WBGT} = 0.7 \text{ WB} + 0.3 \text{ GT (Indoor measurements)}$$

FIGURE 1. Wet Bulb Globe Thermometer

or

$$\text{WBGT} = 0.7 \text{ WB} + 0.2 \text{ GT} + 0.1 \text{ DB (Outdoors-in-sunshine measurements)}$$

where

WB is the natural wet-bulb temperature

GT is the globe-thermometer temperature

DB is the dry-bulb temperature.

Electronic instruments are now available that combine dry-bulb, wet-bulb, and globe temperatures and indicate a direct readout of WBGT (see Figure 2). These instruments are compact and only one reading is necessary. They may also be used with a strip-chart recorder for time studies.

An even simpler modification of the WBGT instrumentation is the wet-globe thermometer, a simple hand-held device that makes a single measurement (see Figure 3). The instrument exchanges heat with the environment by convection, radiation, and evaporation; however, some investigators have reported weaknesses in this device as the relative values of the three components of heat transfer from the wet globe and the human body may vary considerably.

Other devices may be used to measure environmental factors, such as psychrometers, hydrometers, anemometers, pyrometers and radiometers. However, for assessment of the WBGT, these instruments are unnecessary.

FIGURE 2. Wet Bulb Globe Temperature Index Instrument
(Photograph courtesy of Bendix Corporation)

FIGURE 3. Wet Globe Thermometer

PERSONAL MONITORING DEVICES

A personal monitoring device is a more useful approach for properly evaluating human heat-stress exposures than measuring devices that correlate environmental factors with heat stress. Lutz and Coker⁽⁴⁾ have presented the latest advance in heat-stress measurement, based on the development of a warning device that is placed in the worker's ear. The device senses the ear canal temperature that is correlated with deep body temperature. This approach has several advantages over the Wet Bulb Globe Temperature index. The WBGT measures environmental factors, but does not account for individual differences in work rate, clothing, degree of acclimation, and other factors. Measurement of deep body temperature eliminates many of the variables involved with WBGT readings since a major problem with heat stress is a person's inability to recognize the early warning signs.

The device described by Lutz and Coker⁽⁴⁾ was designed to reduce the problem of wearer acceptance; that is, the device was intentionally made small, unobtrusive and easy to put on. It was also designed to detect the rise in core body temperature, regardless of work rate, without being affected by the external temperature. The ear canal was chosen as a suitable measuring site based upon past investigations. Experiments during which thermocouples

were placed against the tympanic membrane demonstrated that changes in internal body heat produced similar responses at the tympanum. However, this measurement is only favorable in a laboratory setup as the use of thermocouple probes in this manner causes discomfort and may injure the tympanic membrane.

Other experiments showed that a temperature gradient exists along the wall of the ear canal. Conclusions regarding the suitability of using the ear canal for measuring core-body temperature were considered impossible because of past evidence.⁽⁴⁾ The instrument, which was developed in an attempt to overcome the inherent problems in an ear canal system, consists of thermistors that are attached to an ear mold and placed in the ear canal. The thermistor resistance is converted to a voltage signal that is compared to a reference signal. Temperatures found by this device were compared to tympanic and rectal measurements. After testing, the conclusions were: 1) ear canal temperature change correlates well with deep body temperature, 2) the closer the device is to the tympanum the better the correlation, and 3) the device must be thermally insulated.

Other factors involved in measuring heat stress by personal monitoring are a determination of metabolic rate by observing the rate of oxygen consumption and by measuring the change in rectal temperature to indicate the rate of heat storage. This type of approach is suitable for laboratory situations where environmental and work factors may be closely controlled. However, these techniques could not be practically used in the field. Further research in the area of personal monitoring devices is desirable.

REVIEW OF EXISTING STANDARDS

At present, no recognized consensus exists for a heat-stress standard. Historically, permissible exposure limits for hot environment work have been recommended. In choosing indices to represent such exposures, the climatic factors--air temperature, wind velocity, humidity, and radiant heat--had to be considered. In addition, some attention was usually given to the workload since the metabolic rate was important in evaluating total body heat. While some limits were based on rather subjective data, others were expressed in terms of physiological impairment. All had difficulties and shortcomings. For instance, many were derived in the laboratory and did not relate well to industrial experiences.

The NIOSH Criteria Document confirms that no significant epidemiological studies have been made that adequately relate the health experience of workers to their heat exposures.⁽¹⁾ Some particularly hot industries have reported heat-related effects. One industry found that out of 23,000 coal miners, lost time was 63% greater where the miners worked at temperatures in excess of 80°F (26.7°C) than where the working temperature was 70°F (21.1°C) or less.⁽⁵⁾

This and other studies lacked morbidity and mortality reports, and no environmental measurements were conducted. The OSHA Standards Advisory Committee also recognized that little scientific heat-stress data is now available in general industry.⁽²⁾ The Committee strongly recommended that OSHA and NIOSH initiate epidemiological studies as soon as possible.

Probably the most knowledge gained in the past regarding the effects of heat on health has been from the military. Often, the effects have been chronic; for instance, brain disorders resulting from heat stroke in military trainees have been observed. Much of the data gathered via the military was based on an affected population consisting of young, physically fit individuals who did not represent the industrial work force. Also, to make measurements simple enough to be practical, assumptions had to be made that were unproven. Considering all the variables involved in determining heat-stress effects (see Table 1) this task continues to be difficult.

TABLE 1. Factors Important in Determining Exposure-Effects Relationships

<u>Environmental Factors</u>	<u>Human Factors</u>	<u>Job Factors</u>
Temperature	Age	Physical Load
Humidity	Sex	Mental Load
Wind	Health	Perceptual-Motor Load
Solar Radiation	Physical Fitness	Sensorimotor Load
Long Wave Radiation	Body Build	Complexity of Task
Dust	Acclimation	Duration of Task
Aerosols	Nutrition and Hydration	Skill Required
Gases	Motivation	
Fumes	Training	
Barometric Pressure	Physical Capabilities	
Clothing	Mental Capabilities	
	Emotional Stability	
	Ethnic Characteristics	

The factors given above indicate the many indices that have been developed. No singularly good heat-stress standard exists. The current state-of-the-art can best be defined by analyzing and comparing three major documents from which a standard may eventually evolve:

- Occupational Exposure to Hot Environments, Criteria for a recommended standard, NIOSH, 1972.⁽¹⁾
- "Recommendations for a Standard for Work in Hot Environments." Proposed by the OSHA Standards Advisory Committee on Heat Stress, Draft 5 - January 11, 1974.⁽²⁾
- Threshold Limit Values for Physical Agents. Adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) for 1977.⁽³⁾

NIOSH CRITERIA DOCUMENT

The NIOSH Criteria Document⁽¹⁾ recommends that employee exposures to heat be controlled by compliance with prescribed work practices if the WBGT exceeds

79° F for men or 76° F for women. The document is especially applicable to the geothermal industry as a guide to acclimation and to medical and engineering procedures. A procedure for gradual acclimation of employees over a period of 6 work days and reacclimation of employees over a 4-day period is specified. The medical guidelines include predisposing factors, diagnostic criteria, medical effects of heat stress, and treatment methods. Under engineering control, the pros and cons of aluminum shielding and clothing in reducing radiant heat are discussed. Wet Bulb Globe Temperature monitoring procedures and equipment are described in detail.

OSHA RECOMMENDATIONS

The OSHA Standards Advisory Committee⁽²⁾ proposes permissible heat exposure values in °F, WBGT, which decrease as the employees' workloads increase. Selection of the appropriate metabolic rates is facilitated by over 50 examples of specific industrial operations that correspond to light, moderate, or heavy workloads. The document suggests that unacclimated employees be acclimated in accordance with a written policy that considers the conditions existing at the workplace. In addition, a number of criteria are suggested for engineering control, medical surveillance, and employee training. Elimination or reduction of heat by engineering controls like radiant heat shielding, evaporatively cooled or refrigerated supply air at work sites and local exhaust removal of steam are advised. Preemployment examinations, periodic checkups, and medical examinations as soon as possible after the occurrence of any heat illness are recommended. Proposed requirements include the training of personnel to understand the need for acclimation and salt and water replenishment, as well as to recognize heat disorder symptoms and first aid treatment.

ACGIH THRESHOLD LIMIT VALUES

The ACGIH standard⁽³⁾ suggests permissible heat-exposure values in °F, WBGT, for light, moderate, and heavy workloads. The values assume that employees are physically fit and acclimated. The document does not include guidance on how to acclimate personnel, nor does it include information on training employees, except that it encourages them to replenish water and salt loss.

EVALUATION OF EXISTING STANDARDS

Because of the similarities of the three documents reviewed above, they will be discussed together. By drawing upon each document's strong points, a meaningful guide for heat stress in the geothermal industry can be recommended.

WORKLOAD

The ACGIH and Standards Advisory Committee considered the employee's workload, since a higher metabolic rate produces increased body heat that must be dissipated. Three workload categories were described in terms of kilocaloric (kcal) output: light, moderate, and heavy. There are slight differences between the two documents as shown in Table 2.

TABLE 2. Workload Comparisons

<u>Workload</u>	<u>kcal/hr</u>	
	<u>ACGIH</u>	<u>Standards Advisory Committee</u>
Light	200 or below	200 or below
Moderate	200 to 350	201 to 300
Heavy	350 to 500	Above 300

In addition, ACGIH considered the work-rest regimen. They recommended that for each hour worked, the allowable WBGT temperature can increase as the percentage of work decreases (assuming the rest locations are at the same temperature as the work areas). The Standards Advisory Committee recommendation simply based an employee's thermal exposure on the hottest 2-hr period of the regular work shift. The NIOSH Criteria Document similarly defined exposure but related it to continuous exposure for 1-hr or intermittent exposure (no longer than 15 min without an interrupting interval in a cooler environment) for a period of 2-hr with time-weighting of the WBGT.

AIR VELOCITY

The Standards Advisory Committee discriminated between WBGT values in regard to air velocity. They allowed a greater WBGT when workers were in an area of high

air velocity (300 fpm or greater). Since a prime reason for choosing the WBGT is that air-velocity measurements are not necessary, this allowance for air-velocity is not entirely understandable. Evidently, the Committee felt that air velocity and evaporative and convective heat exchange (as it relates to physiological response) may be affected more than the instruments indicate. Regardless, the indoor air velocities in most industries are significantly less than 300 fpm, unless auxiliary ventilation is provided.

For comparative purposes, the continuous-work figures from the ACGIH table were chosen. Table 3 is intended to compare the actual allowable WBGT permitted under the three documents. The figures given for the Standards Advisory Committee are for low air velocity since they correlate more closely with the ACGIH figures. In areas of high air velocity (≥ 300 fpm), the Committee WBGT numbers should be increased by 4 to 5 degrees F. Since the Committee values are for the hottest 2-hr period of the work shift, it was deemed appropriate to compare these with the most stringent ACGIH TLV's. Ramsey has proposed other modifications to the values given in Table 3 that quantify some of the variables presented in Table 1.⁽⁶⁾

TABLE 3. Permissible Heat Exposure Values,
°F, WBGT

<u>Workload^(a)</u>	<u>ACGIH</u>	<u>Standards Advisory Committee</u>	<u>NIOSH Criteria Document</u>
Light	87	86	79
Moderate	80	82	79
Heavy	77	79	79

(a) As stated earlier, some differences do exist in the definition of workload. The NIOSH value of 79°F (26.1°C) is based upon a 2-hr, time-weighted average [76°F (24.4°C) for women].

ACCLIMATION

Both the NIOSH Criteria Document and the Committee address the subject of acclimation, while the ACGIH only states that "the recommended heat stress TLVs are valid for acclimated workers who are physically fit."⁽³⁾ The Criteria Document recommends specific time periods for acclimation, both for new employees and those returning after leave. The proposed recommendations by the Committee are similar, but not as detailed.

MEDICAL EVALUATION

The suggestions for medical evaluations are nearly identical in the Criteria Document and Committee proposals; however, the ACGIH does not discuss this matter. An important item in the Criteria Document stipulates that a person who has had first aid training be available to recognize signs and symptoms of heat stress. A similar requirement is contained in the Committee's report under "Work Practices."

EMPLOYEE TRAINING

Section 6 in the NIOSH Criteria Document and item (g) in the Standards Advisory Committee recommendations address the subject of employee training--an important factor in preventing heat-related disorders. As the previous discussion on environmental measurements indicates, predicting physiological heat stress as a response given the environmental factors is difficult. Consequently, worker education deserves special consideration. Any forthcoming standard should contain requirements concerning instruction in recognizing symptoms.

Another component of an adequate educational program is treatment methods. The ACGIH TLV only specifies water and salt supplementation, but appropriate clothing is also important. In connection with employee training, the U.S. Department of Labor's publication Hot Environments⁽⁷⁾ emphasizes the importance of employer-employee awareness in preventing heat stress. Without this awareness, the probability of heat-related problems is quite high due to the variation in worker susceptibility.

The Criteria Document suggests that a warning sign be posted near an area where environmental conditions exceed the allowable WBGT. This recommendation is not contained in the Committee's suggestions. The value of this type of warning for such a subjective disorder is suspect since the presence of the warning may produce stress and subsequent physiological reactions in the worker.

MONITORING

Monitoring requirements differ in the Criteria Document and the Committee recommendations. The Criteria Document simply requires "a WBGT profile" for each workplace during winter and summer. After initial measurements, monitoring shall be performed annually during July and August. The frequency of the measurements is less specific in the Standards Advisory Committee proposal: "The number and frequency of measurements shall be adequate to define the heat exposure of the worker."⁽²⁾ The proposal requires that measurements be conducted during the hottest 2-hr period of the work shift. If all work practices of the standard are implemented, workplace monitoring is not required.

The most important consideration in developing a heat-stress standard appears in the final section of the Committee's recommendations, which states that the initial standard be reviewed 3 years after its promulgation to judge its effectiveness. In addition, increased epidemiological studies were recommended to supply more adequate data on which to base future heat-stress standards.

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