

**CHAPTER 17**  
**HEAT STRESS**

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## Chapter 17

### HEAT STRESS

#### I. Introduction

Heat stress (also known as “thermal strain”) is a variety of health-related illnesses caused by excessive exposure to heat on the human body. Heat stress is a combination of heat generated by the human body and heat gained from the environment. In mining, environmental heat stress is caused by hot weather, working in the sun, near underground hot strata, furnaces, kilns or other heat sources. Heat stress also depends upon the type of clothing worn (especially protective clothing), humidity in the environment, and the miner’s work load. These factors affect miners’ deep body temperature, heart rate, sweating and sweat evaporation rate.

Heat stress increases the risk of accidents and heat-related illnesses or injuries. Miners who take medications that regulate blood pressure, thyroid, or kidney function are especially at risk. Drinking caffeinated beverages increases risk because they act as a diuretic. Heat-related illnesses include heat collapse (fainting), heat fatigue, heat rash, heat cramps, heat exhaustion, and heat stroke. Heat exhaustion can lead to heat stroke, a medical emergency that can rapidly lead to death. Each of these conditions can be prevented by appropriate engineering controls, as well as acclimatization (climatic conditioning), frequent rest breaks, adequate water intake (with electrolytes), and responsible supervision.

This chapter provides background information and a screening method for evaluating potential heat stress conditions at mines. Based on the results of an inspector’s screening survey, further evaluation may be required by the District Health Specialist or Industrial Hygienist, or by MSHA Technical Support.

#### II. Definitions

**Acclimatization** - The time period required for a person to adjust to environmental working conditions. When a miner has not worked under heat stress conditions in 2 weeks or more, heat acclimatization usually takes 5 to 7 days. Employees should work 50% of the workload the first day back and gradually work up to 100% on the last day. Miners who are not acclimated or are physically unfit are more at risk for heat stress than acclimatized, fit miners.

**Deep Body Temperature** - A measurement of the body core temperature, which is the temperature of the internal organs of the human body. Normal body core temperature is 37° C (98.6° F). Various organizations of health scientists (including NIOSH, WHO, and ACGIH)<sup>1</sup> recommend that the deep body temperature, when exposed to prolonged heat and work, should not exceed 38° C (100.4° F).

**Dry Bulb Temperature** - The ambient air temperature reading on a dry bulb thermometer. A dry bulb thermometer is an ordinary mercury thermometer and is not dependent on humidity.

**Electrolyte** - Any substance which changes into an ion when dissolved in a solution. Salts essential to the human body are electrolytes and are lost when sweating. Both water and electrolytes must be replaced to avoid or relieve heat stress.

**Globe Temperature** - The air temperature inside a hollow metal or thin copper globe that is painted black. The globe temperature is measured by a thermometer inside the center of the globe. The globe temperature measures the effect of direct exposure to radiant heat, such as the sun. In direct sunlight the globe temperature may be as much as 30° F higher than the Dry Bulb Temperature.

**Heat Cramps** - Painful muscle spasms that occur among those who sweat profusely in heat and drink large quantities of water, but do not adequately replace the body's salt loss. Drinking large quantities of water tends to dilute the body's fluids, while the body continues to lose salt. Shortly thereafter, the low salt level in the muscles causes painful cramps. The affected muscles may be part of the arms, legs, or abdomen, but tired muscles (those used in performing the work) are usually the ones most susceptible to cramps. It can occur despite drinking large quantities of liquids, since water, sodas and alcoholic beverages generally lack the needed salts (electrolytes). Lightly salted liquids or sports drinks can relieve or prevent these cramps.<sup>2</sup> Salt tablets irritate the stomach and should not be used.

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<sup>1</sup> National Institute for Occupational Safety and Health, World Health Organization (United Nations), and American Conference of Governmental Industrial Hygienists.

<sup>2</sup> CAUTION: Persons with heart problems or those on a low sodium diet who work in hot environments should consult a physician about what to do under these conditions.

**Heat Exhaustion** - A condition caused by the loss of large amounts of fluid by sweating, sometimes with excessive loss of salt. A miner suffering from heat exhaustion still sweats but experiences extreme weakness or fatigue, nausea, or headache. The victim may vomit or lose consciousness. Skin is clammy and moist, complexion is pale or flushed, and body temperature is normal or only slightly elevated. Resting in a cool place and drinking an ample supply of water or sports drinks will usually lead to recovery.<sup>2</sup>

**Heat Rash (Prickly Heat)** - Heat rash is likely to occur in hot, humid environments where sweat is not easily removed from the surface of the skin by evaporation and the skin remains wet most of the time. The sweat ducts become plugged, and a skin rash soon appears. Miners can help prevent this condition by resting in a cool place part of each day and by regularly bathing and drying the skin.

**Heat Stroke** - When the body's temperature regulatory system is overtaxed or fails and the body core temperature rises above 40° C (104° F). **This is a medical emergency and can result in death within minutes if not treated.** A heat stroke victim's skin is hot, usually dry, and red or spotted. The victim may be mentally confused, delirious, or possibly in convulsions or unconscious. First aid efforts include lowering the body temperature by loosening tight clothing, removing the victim to a cool area, and placing the victim in cool water or sponging the body with cool water.<sup>3</sup> **Seek medical attention immediately.**

**Wet Bulb Temperature (Natural Wet Bulb Temperature)** - The air temperature measured by a thermometer whose mercury bulb or other sensing element is covered with a sleeve or wick soaked in water. As the water evaporates, the wet bulb temperature drops below the dry bulb temperature and the wet bulb temperature approximates the evaporative cooling effect of perspiration on the human body. The wet bulb temperature helps assess heat stress under conditions where radiant heat and air velocity are not important factors. A temperature of 28°C (82.4°F) is the upper limit for moderate physical work; but when the wet bulb temperature increases, physical performance may decrease.

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<sup>3</sup> CAUTION: Persons with heart problems or those on a low sodium diet who work in hot environments should consult a physician about what to do under these conditions.

**WBGT (Wet Bulb Globe Temperature) Index** - A calculated number that indicates the combined effects of air temperature, direct radiant heat source, and the evaporative cooling effect of perspiration in contact with moving air. The WBGT is used for indoor and outdoor exposures with and without solar load. The two formulas for calculating the WBGT Index are in Section III below.

### III. Exposure Limits

MSHA has no standards or regulations that specifically address heat stress and that can be cited for enforcement purposes. However, 30 CFR §§ 56/57.20002 requires mine operators to make sufficient potable (drinkable) water available to miners, and 30 CFR §§ 56/57.15006 requires operators to provide equipment to protect miners from hazards in the work environment. 30 CFR Parts 46 and 48 require appropriate hazard training for all miners. 30 CFR §§ 56/57.18010 requires that an individual capable of providing first aid be available on all shifts.

The American Conference of Governmental Industrial Hygienists (ACGIH) published Threshold Limit Values (TLVs<sup>®</sup>) for Heat Stress in 1999.<sup>4</sup> The TLVs<sup>®</sup> shown in Figure 17-1 are based on the **WBGT Index**. For MSHA, the WBGT Index is the simplest and most suitable method used to measure heat stress. MSHA personnel can use these TLVs<sup>®</sup> as a reference to evaluate the hazard and to make heat stress control recommendations to prevent heat-related illnesses. See Section VI.B of this Chapter. WBGT indices are based on the following formulae:

**Formula 1** - Outdoors with solar load [i.e., in direct sunlight]:

$$\text{WBGT} = 0.7 \text{ NWB} + 0.2 \text{ GT} + 0.1 \text{ DB}$$

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<sup>4</sup>1999 TLVs<sup>®</sup> and BEIs<sup>®</sup> - Threshold Limit Values for Chemical Substances and Physical Agents [and] Biological Exposure Indices, Heat Stress, Table 1, p.135.



**Formula 2** - Indoors or Outdoors with no solar load:

$$\text{WBGT} = 0.7 \text{ NWB} + 0.3 \text{ GT}$$

where: WBGT = Wet Bulb Globe Temperature Index  
 NWB = Natural Wet-Bulb Temperature  
 DB = Dry-Bulb Temperature  
 GT = Globe Temperature

The following **work-rest cycles** apply to a 5-day work week and 8-hour work day, which includes a short morning and afternoon break and a longer lunch break. They also assume that cool drinking water is available for drinking about one cup every 15 - 20 minutes. These values are intended to be applied to the hottest one hour of exposure if the exposure is continuous. If the exposure is intermittent, these values are intended for the hottest two continuous hours.

**Light work** includes sitting or standing to write or control machines.

**Moderate work** includes walking with moderate lifting or working with hand tools.

**Heavy work** includes digging, shoveling, or heavy lifting.

<b>Figure 17-1. Examples of Permissible Heat Exposure TLVs®</b> (Values are given in WBGT°)			
<b>Work-Rest Regimen</b>	<b>Work Load</b>		
	<b>Light °C (°F)</b>	<b>Moderate °C (°F)</b>	<b>Heavy °C (°F)</b>
Continuous Work	30.0 (86)	26.7 (80)	25.0 (77)
75% work - 25 % rest, each hour	30.6 (87)	28.0 (82)	25.9 (78)
50% work - 50 % rest, each hour	31.4 (89)	29.4 (85)	27.9 (82)
25% work - 75 % rest, each hour	32.2 (90)	31.1 (88)	30.0 (86)

**Note:** The TLVs<sup>®</sup> in Figure 17-1 assume that workers are acclimatized, fully clothed (e.g., lightweight pants and shirt) with adequate water and salt intake, and able to do the indicated level of work without exceeding a deep body temperature of 38° C (100.4° F). For unacclimatized workers performing a moderate level of work, TLVs<sup>®</sup> should be reduced by approximately 2.5° C (4.5° F).

Subtract the following from the TLVs<sup>®</sup> in Figure 17-1 to adjustments for clothing wear:

<b>Figure 17-2. WBGT° Correction Factors for Clothing</b>	
Summer work uniform	0° C (0°F)
Cotton overalls	2° C (4°F)
Winter work uniform	4° C (7°F)
Waterproof suit	6° C (11°F)

#### IV. Screening and Surveying Equipment

##### A. Sling Psychrometer

This is a hand-held instrument consisting of two thermometers mounted side-by-side on a narrow support. The support is connected to a handle by a swivel. One thermometer measures the dry bulb temperature while the other measures the wet bulb temperature. By reading both thermometers, the sling psychrometer can determine relative humidity using the chart supplied with the instrument. However, for heat stress screening, only the wet bulb thermometer is used.

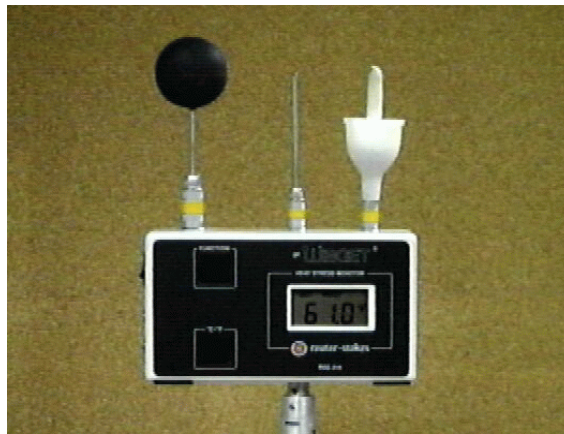


Figure 17-3. Sling Psychrometer

**B. Metrosonics (Reuter-Stokes) Model 213 \*Mini-Wibget®**

This electronic heat stress monitor has the same dry bulb and wet bulb thermometers that comprise the sling psychrometer, as well as a globe thermometer. This instrument measures all three temperatures. It simultaneously calculates the WBGT heat index and displays the reading digitally. It is recommended, however, only for outdoor use. See paragraph V.B. for indoor WBGT Index estimates.

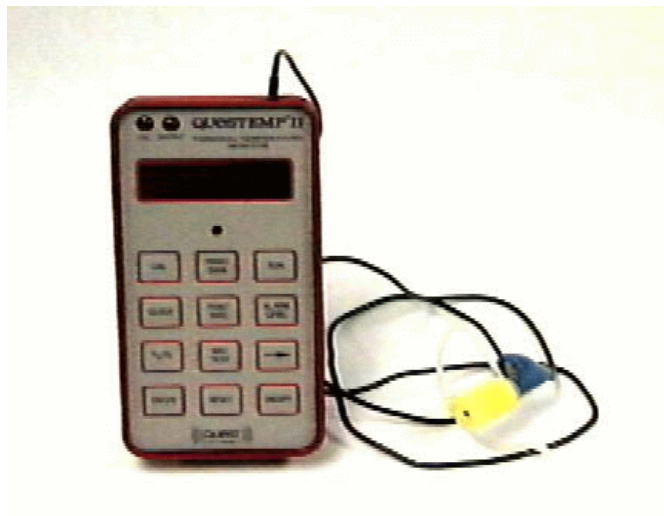
\* No longer made replaced by IST, Model 214.



**Figure 17-4. Mini-Wibget®**

**C. Personal Heat Stress Monitor**

This instrument continuously measures the human body temperature using a sensor inside an ear plug inserted in the miner's ear canal. It has an alarm which warns the user that the body temperature has risen above a "safe" level. This is a more precise way to determine the heat hazard level to which a miner is exposed than using an environmental air temperature instrument. It is particularly useful for a miner who is enclosed in a protective suit which increases heat stress substantially. Although inspectors are not provided these instruments, Technical Support personnel may use them during an industrial hygiene survey.



**Figure 17-5. Personal Heat Stress Monitor**

## **V. Screening and Surveying Procedures**

When potential heat stress conditions are encountered, a screening survey should be conducted. Environmental heat stress should be checked at least every  $\frac{1}{2}$  hour during the hottest part of each work shift, particularly during the hottest months of the year.

### **A. Screening with the Sling Psychrometer**

A sling psychrometer may be used to determine the Natural Wet Bulb Temperature (NWB).

1. Make sure the mercury column in the wet bulb thermometer does not contain any gaps (air bubbles). If it does, shake the thermometer vigorously to get the mercury back into a continuous column.
2. Thoroughly saturate the wick sleeve of the wet bulb thermometer, using clean (preferably distilled) water, at least one-half hour before reading the temperature. Make sure the wick is clean and completely covers the mercury reservoir at the bottom of the thermometer, plus about one additional bulb length.

3. Position the psychrometer at chest height in the area where the miner is working. If this is not possible, position it in an area representative of the miner's heat exposure.
4. Expose the thermometer only to natural air movement. Do not swing or whirl it.
5. Allow 5 minutes for the psychrometer's mercury level to stabilize. Then record both the dry bulb and wet bulb temperatures and the time of the reading.

**B. Measuring the WBGT (Wet Bulb Globe Temperature) Index with the Mini-Wibget<sup>®</sup>**

Note: The Mini-Wibget<sup>®</sup> must not be exposed to temperatures above 65° C (149° F).

1. Use a vane anemometer or other wind measurement instrument to determine air movement. The air flow must be at least 100 feet per minute for the Model 213 Mini-Wibget<sup>®</sup> to be accurate.
2. Push the wet bulb sensor and the globe sensor into the sockets indicated by the symbols on top of the instrument case. Looking at the display, the globe will be on the left and the wet bulb on the right.
3. Place a clean cotton wick over the element of the wet bulb sensor that has a sponge at the base of the water reservoir area. Fill the reservoir with distilled or demineralized water.
4. Turn the instrument on by pushing the on/off switch on the front of the instrument. Hold or place the instrument approximately 4 feet (1.2 meters) above the ground and at least 18 inches (60 cm) from any person for at least 3 minutes before taking readings.
5. Read the display when the number has stabilized. The reading is the WBGT Index.
6. When finished for the day, empty the Wet Bulb reservoir. See appendix A for maintenance and battery replacement instructions.

**Note:** The Mini-Wibget<sup>®</sup> is recommended only for outdoor use since it calculates the WBGT Index from the outdoor formula (Formula 1 in Section III above). However, it can be used indoors to roughly approximate the indoor WBGT Index.

### C. Instructions to the Miner

1. Explain to the miner what you are doing, what the instrument does, and the reason for the survey (i.e., the heat stress hazard). If available, issue a Miner Health Hazard Information Sheet or Card.
2. Emphasize the need for the miner to continue to work in a routine manner and report to you any unusual occurrences during the survey period (such as unusual changes in temperature).

### D. Determining the Level of Hazard

In general, the higher the speed of the wind or ventilation air flow, the faster that water (or perspiration) will evaporate, and the lower the wet bulb temperature (or skin temperature) will be as compared to the dry bulb temperature. The difference may be as much as 30° F. Similarly, perspiration evaporates faster as air speed increases. This lowers the body's skin temperature and, indirectly, deep body temperature. However, the human body may not be adequately cooled by the evaporation of perspiration when the environmental air temperature is above 35° C (95° F), regardless of wind speed.

1. Using a **Sling Psychrometer**:
  - a. If the Natural Wet Bulb (NWB) Temperature exceeds 24.5° C (76° F), **contact the district health specialist or industrial hygienist as soon as possible.**
  - b. Provide the dry bulb (DB) temperature reading as well as an estimate of the miner'(s') workload when exposed to the heat. When the NWB exceeds 24.5° C (76° F), the risk of heat injury to the miner increases as the difference decreases between the NWB and DB temperatures. When the air has nearly 100 % humidity

and there is no air movement, the wet bulb temperature will be approximately the same as the dry bulb temperature.

2. Using the **Mini-Wibget**<sup>®</sup>:
  - a. Read the WBGT Index from the digital display.
  - b. Use Figure 17-1 to determine the TLV for the miner's workload and work/rest cycle being followed. Subtract any clothing factor (use Figure 17-2) from that TLV.
  - c. Compare the WBGT Index with the TLV. If the TLV is exceeded in any two consecutive measurements, inform the mine operator that work conditions should be modified through use of recommended engineering or administrative controls or personal heat-protective equipment.

**EXAMPLE:**

A miner is shoveling next to a crusher in the direct sun for 8-hour shifts, with only a 15-minute break in the morning and in the afternoon. A breeze is blowing much of the time on the mine property. A sling psychrometer indicates that between 12:00 noon and 4:00 pm, the average DB reading is 90° F and the NWB reading is 70° F. The crusher, however, allows little air movement to reach the shoveling miner, where the DB reading also averages 90° F, but the NWB reading averages 80° F. When the NWB is greater than 76° F, the risk of heat injury increases as the differences between the NWB and DB temperatures decrease. The inspector should contact the District health specialist for a follow-up survey with the WBGT the next day. Also, even though the miner was acclimatized, he complained of dizziness, rapid tiring, and extreme thirst.

**Immediate Action:** The miner is showing signs of heat exhaustion and should be treated immediately to avoid further complications such as heat stroke. Explain to the miner and to the mine operator the hazards of heat stress. The inspector should ensure that an adequate supply of potable drinking water has been provided as required by 30 CFR §§56/57.20002.



The following day the sling psychrometer indicates the same DB and NWB readings as the previous day. The Mini-Wibget<sup>®</sup> (which also measures globe temperature) shows a WBGT of 89° F for the shoveling miner.

**Calculation:** The miner is performing heavy work, and the work-rest regimen is continuous. From Figure 17-1, the TLV<sup>®</sup> is 77°. The miner is wearing bib overalls, and Figure 17-2 indicates that 2° should be subtracted from the TLV<sup>®</sup> to adjust for the additional heat load from clothing. The adjusted TLV<sup>®</sup> is therefore 75°F. The WBGT of 89° F exceeds the TLV<sup>®</sup> of 75°F.

**Action:** The operator must provide controls to lower the miner's heat load. This may be a change in the work-rest regimen, provision of shade or ventilation, or provision and use of a cooling vest. A citation for violation of 30 CFR §§56/57.15006 may be issued if the operator fails to provide adequate controls because a cooling vest could be used to reduce the heat load on the miner. Because the miner is in danger of heat exhaustion or heat stroke, an imminent danger order may also be considered. **Under these circumstances, it may be necessary to request a supporting survey from Technical Support.**

#### **E. Health Field Notes**

Record the following information in the health field notes:

1. The time the miner began and ended each task in each work area throughout the shift;
2. Temperature readings (from sling psychrometer) or WBGT readings during each task and the times of each reading;
3. Miner's name, job title, work location(s), shift hours per day, and days per week worked;
4. Type of clothing worn and any personal protective equipment (such as respirator, rain or slicker suit, chemical apron, or a cooling suit or vest);
5. Whether the miner was aware of the hazards of heat stress (indicating appropriate hazard training);
6. Availability of potable drinking water to the miner and approximate frequency and amount of liquids consumed during the shift;

7. Controls in use (such as air conditioning or work/rest cycles) with general description and whether or not they seem adequate;
8. Potential sources of heat stress (direct sun, kiln, etc.), a general description of these sources, number of persons affected, and possible additional control measures; and
9. Environmental conditions (such as wind conditions, temperature, humidity, or rain).

## **VI. Post-Inspection Procedures**

### **A. Review Health Field Notes**

Check that all the necessary information is included in the Health Field Notes. Refer to Chapter 21, Section V.

### **B. Report Writing**

Inspection reports should include a copy of the Health Field Notes, calculation worksheets, citation/orders, and any other supplemental information collected during the inspection.

**CHAPTER 17**  
**APPENDIX A**  
**Maintenance of the Mini-Wibget<sup>®</sup>**

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**Chapter 17**  
**Appendix A**  
**Maintenance of the Mini-Wibget®**

**A. Battery Replacement**

1. When the battery is low, a LO BAT (low battery) or --> indicator will appear in the upper left corner of the display. The instrument can be operated for 4 hours after the indication first appears.
2. Remove the four slotted screws on back of case; then remove the back half of the case.
3. Replace battery and reinstall back half of case. The instrument can use either a 9-volt alkaline battery (100 hours of life) or carbon-zinc battery (30 hours).

**B. Wick Replacement**

1. Replace the wick when it shows signs of discoloration. Remove it by pulling both the wick and sponge straight up over the sensor.
2. Install a new wick in reverse order of its removal. Dampening the sponge first will make it easier to install.
3. Wick life may be prolonged by washing both the sponge and wick in detergent solution and rinsing them several times with distilled or demineralized water.

**C. Calibration**

The instrument should be checked for calibration at least once a year. This requires the use of the Calibration Check Sensor, which comes with complete instructions for its use.

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