

## Chapter 10

### Thermal Stress

#### Heat stress

Working in hot conditions puts stress on our body's cooling system. When the heat is combined with other stresses such as physical labor, loss of fluids, fatigue or preexisting medical conditions, it may lead to heat-related illness, disability and even death. This can happen to anybody--even the physically fit. The body is always generating heat and passing it to the environment. The harder the body is working, the more heat it has to lose. When the environment is hot or humid, is near a source of radiant heat (for example, a furnace or the sun), the body must work harder to get rid of its heat. If the air is moving (for example, from fans) and is cooler than the body, it is easier for the body to pass heat to the environment. Workers over 40 should be more careful because of a reduced ability to sweat.

Hot work environments can be managed with an effective program including but not limited to;

- Industrial hygiene monitoring program
- Work/rest regiments
- Ventilation
- Fluids for worker hydration
- Employees trained in the signs and symptoms of heat stress
- Use of appropriate clothing and PPE

The American Conference of Industrial Hygienist (ACGIH) TLV booklet is a good source to acquire better understanding of thermal stress and was used as a reference for this chapter. It also contains more information on heat stress factors such as metabolic rates that can assist in heat stress monitoring.

#### Acclimatization

If an employee is not used to working in the heat, it can take a week or two to get acclimatized or used to the heat. If they were ill or away from work for a week or so they can lose their acclimatization.

## Signs, Symptoms, Prevention and Treatment

Signs & Symptoms	Cause	Symptoms	Treatment	Prevention
<b>Heat Rash</b>	Hot humid environment; plugged sweat glands.	Red bumpy rash with severe itching.	Change into dry clothes and avoid hot environments. Rinse skin with cool water.	Wash regularly to keep skin clean and dry.
<b>Sunburn</b>	Too much exposure to the sun.	Red, painful, or blistering and peeling skin.	If the skin blisters, seek medical aid. Use skin lotions (avoid topical anesthetics) and work in the shade.	Work in the shade; cover skin with clothing; wear suntan lotions with a sun protection factor of at least 15. People with fair skin should be especially cautious.
<b>Heat Cramps</b>	Heavy sweating drains a person's body of salt, which cannot be replaced just by drinking water.	Painful cramps in arms, legs or stomach which occur suddenly at work or later at home. Cramps are serious because they can be a warning of other more dangerous heat-induced illnesses.	Move to a cool area; loosen clothing and drink cool salted water ( 1 tsp. salt per gallon of water) or commercial fluid replacement beverage. If the cramps are severe or don't go away, seek medical aid.	When working in the heat, workers should put salt on their food (if on a low-salt diet, this should be discussed with a doctor). This will give the body all the salt it needs; don't take salt tablets.
<b>Fainting</b>	Not enough blood flowing to the head, causing loss of consciousness.	Sudden fainting after at least two hours of work; cool moist skin; weak pulse.	Fainting may be due to a heart attack or other illness. <b>GET MEDICAL ATTENTION.</b> Assess need for CPR. Move to a cool area; loosen clothing; make person lie down; and if the person is conscious, offer sips of cool water.	Reduce activity levels and/or heat exposure. Drink fluids regularly. Workers should check on each other to help spot the symptoms which often precede heat stroke.
<b>Heat Exhaustion</b>	Inadequate salt and water intake causes a person's body's cooling system to start to break down.	Heavy sweating; cool moist skin; body temperature over 38°C; weak pulse; normal or low blood pressure; person is tired, weak, clumsy, upset or confused; is very thirsty; or is panting or breathing rapidly, vision may be blurred.	<b>GET MEDICAL AID.</b> This condition can lead to heat stroke, which can kill. Move the person to a cool shaded area; loosen or remove excess clothing; provide cool water to drink (salted if possible); fan and spray with cool water.	Reduce activity levels and/or heat exposure. Drink fluids regularly. Workers should check on each other to help spot the symptoms which often precede heat stroke.
<b>Heat Stroke</b>	If a person's body has used up all its water and salt, it will stop sweating. This can cause body temperature to rise.	High body temperature (over 41°C) and any one of the following: the person is weak, confused, upset or acting strangely; has hot, dry, red skin; a fast pulse; a headache or dizziness. In later stages, a person may pass out and have convulsions.	<b>CALL AMBULANCE.</b> This condition can kill a person quickly. Remove excess clothing; fan and spray the person with cool water; offer sips of cool water if the person is conscious.	Reduce activity levels and/or heat exposure. Drink fluids regularly. Workers should check on each other to help spot the symptoms which often precede heat stroke.

Effective engineering controls that reduce heat exposure to employees are the first line of defense when protecting workers. Below is a list of engineering, administrative, and personal protective clothing controls.

### **Engineering Controls**

- Control the heat at source through the use of insulating and reflective barriers (insulate furnace walls).
- Exhaust hot air and steam produced by specific operations.
- Reduce the temperature and humidity through air cooling.
- Provide air-conditioned rest areas.
- Reduce physical demands of work task through mechanical assistance (hoists, lift-tables, etc.).

### **Administrative Controls**

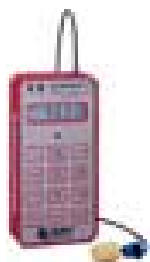
- Schedule hot jobs to cooler times of the day.
- Work/rest regimen.
- Make available cool drinking water or other fluids for workers and remind them to drink a cup every 20 minutes.
- Assign additional workers or slow down work pace.
- Make sure everyone is properly acclimatized.
- Train workers to recognize the signs and symptoms of heat stress.
- Pregnant workers and workers with a medical condition should discuss working in the heat with their doctor.

### **Clothing & PPE**

- Light clothing should be worn to allow free air movement and sweat evaporation.
- Outside, wear light-colored clothing.
- In a high radiant heat situation, reflective clothing may help.
- For very hot environments, air, water or ice-cooled insulated clothing should be considered.
- Vapor barrier clothing, such as acid suits, greatly increases the amount of heat stress on the body, and extra caution is necessary.

### **Monitoring Equipment**

Two commonly used monitoring tools are the Wet Bulb, Globe Temperature (WBGT) device and the personal heat stress monitor. The WBGT offers a useful index of environmental contribution to heat stress. It is influenced by air temperature, radiant heat and humidity. It can be used to determine heat stress exposure before it occurs. Personal heat stress monitors indicate body core temperature. The heat stress monitor in the example below uses an ear lug device to calculate body core temperature. The heat stress monitor gives a reading of heat stress exposure during or after the exposure has occurred.



Personal Heat  
Stress Monitor



Wet Bulb, Globe  
Temperature Monitor

### Wet Bulb, Globe Temperature (WBGT)

The WBGT uses three sensors (sensor array) to take measurements which compute the WBGT index; wet bulb thermometer, globe temperature, and dry bulb thermometer. The WBGT index is an accepted method of determining the heat stress level imposed on an individual in a given environment. Although the formulas for the WBGT index are included in this chapter, the WBGT monitor will give an index reading temperature that can be useful in determining the potential for heat stress exposure. The ACGIH screening criteria for heat stress exposure table is included as well. The values from the WBGT can be compared to this table to determine an appropriate work/rest regimen.

The WET BULB THERMOMETER gives an indication of the effects of humidity on an individual. Relative humidity and wind speed are taken into account by measuring the amount of evaporative cooling taking place at a thermometer covered with a moistened wick.

The GLOBE THERMOMETER gives an indication of radiant heat exposure to an individual due to either direct light or hot objects in the environment. This is accomplished by placing a temperature sensor inside a blackened copper sphere and measuring the temperature rise.

The DRY BULB THERMOMETER measures the ambient air temperature. This measurement is used in the outdoor WBGT calculation when a high solar radiant heat load may be present.

The WBGT uses the wet bulb and globe temperatures readings to monitor the indoor environment. Outdoor measurements include the dry bulb temperature reading where a high solar radiant heat load may be present. The WBGT index is a weighted average of these measurements according to these formulas:

$$\text{WBGT indoor} = 0.7 \text{ wet bulb} + 0.3 \text{ globe}$$

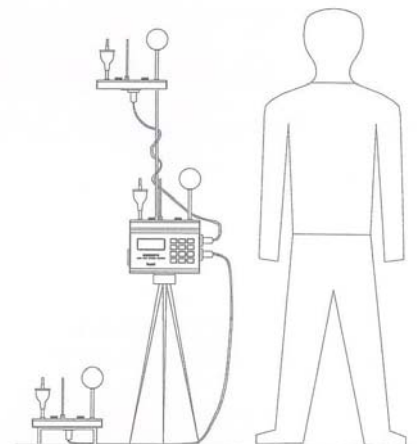
$$\text{WBGT Outdoor} = 0.7 \text{ wet bulb} + 0.2 \text{ globe} + 0.1 \text{ dry bulb}$$

## Monitoring with a Wet Bulb, Globe Temperature (WBGT)

Some WBGT units are available with more than one sensor array. These can be used to monitor more than one area at a time or used together at ankle, abdomen, and head height when the temperature in an area is variable (see illustration). When used in a temperature variable environment the WBGT can weight or average the readings. Most WBGT units can be set to automatically weight the readings together using formula below.

$$\text{WBGT} = \frac{(\text{WBGT}_{\text{head}} + (2 \times \text{WBGT}_{\text{abdomen}}) + \text{WBGT}_{\text{feet}})}{4}$$

4



### Basic Operating Instructions:

- Depending on the memory capabilities, you may need to clear the WBGT data from previous monitoring. The unit may append the data or start a new session.
- Place the WBGT at a height of 3.5 ft. for standing individuals or 2.0 ft. for sitting individuals. Tripod mounting is recommended to get unit away from anything that may block radiant heat or airflow.
- Fill the wet bulb reservoir with distilled water. After adding water or moving the unit to a new location, allow 10 minutes for the globe and wet bulb readings to stabilize.
- Set the instrument to WBGT-in for indoor application or WBGT-out for outdoor use.
- Start the unit's data recording for the monitoring session.

See the instruction book for the WBGT you are using for details on data logging, programming start and stop times, alarm options, data out-put, printing options, etc.

Because the WBGT is only an index of environment, the screening criteria are adjusted for the contributions of the work demands and clothing as well as state of acclimation. The following tables are used in conjunction with WBGT measurements to assess the work environment. Table 1 provides WBGT criteria suitable for screening purposes, table 2 provides additions to measured WBGT values for some clothing ensembles, and table 3 provides examples of activity levels. These values are based on preventing fit, acclimatized workers' core temperatures from rising above 38° C (100° F).

<b>Table 1. Screening Criteria.</b> All values in °C								
Work Demands	Acclimated				Un-acclimated			
	Light	Moderate	Heavy	Very Heavy	Light	Moderate	Heavy	Very Heavy
100% Work	29.5	27.5	26		27.5	25	22.5	
75% Work; 25% Rest	30.5	28.5	27.5		29	26.5	24.5	
50% Work; 50% Rest	31.5	29.5	28.5	27.5	30	28	26.5	25
25% Work; 75% Rest	32.5	31	30	29.5	31	29	28	26.5

<b>TABLE 2. Additions to measured WBGT values for some clothing.</b> All values in °C	
Clothing Type	WBGT Addition
Summer work uniform	0°
Cloth (woven material) overalls	+3.5°
Double-cloth overalls	+5°

<b>Table 3. Examples of Activity Categories</b>	
Categories	Example Activity
Resting	Sitting quietly
	Sitting with moderate arm movements
Light	Sitting with moderate arm and leg movements
	Standing with light work with machine or bench while using mostly arms
	Using table saw
	Standing with light or moderate work at machine or bench and some walking about
Moderate	Scrubbing in standing position
	Walking about with moderate lifting or pushing
	Walking on level at 6 Km/hr while carrying 3 Kg weight load
Heavy	Carpenter sawing by hand
	Shoveling dry dirt
	Heavy assembly work on a noncontinuous basis
	Intermittent heavy lifting with pushing or pulling (e.g., pick-and-shovel work)
Very Heavy	Shoveling wet sand

### Personal Heat Stress Monitor

The personal heat stress monitor described in this chapter uses an ear sensor to monitor body temperature. It is intended to alert the user that their body temperature has risen above the “safe” level and action should be taken to allow the body to cool. It does not replace the individuals own feelings and judgment.

The hypothalamus is located at the base of the brain. It is the body's temperature controller. The ear canal borders the hypothalamus and will track its temperature changes once the ear canal is isolated from the outside environment. The personal heat stress monitor's sensor is placed in a special ear plug to achieve the required isolation and monitor change in the body's temperature. It will set off an audible alarm in the ear when body temperature levels reach a preset limit. The recommended limit is 38° C by the World Health Organization (WHO). This limit has been accepted by the ACGIH. Closely monitored acclimated individuals may have a higher tolerance. If the alarm activates, take appropriate measures to allow the body to cool. Rest, lowering the work load, moving to a cooler environment, and drinking cool liquids are all methods to help cool the body and avoid heat related injuries.

#### **Basic Operating Instructions:**

- Explain the purposes of the personal heat stress monitor to the worker and that an audible alarm sounding indicates their body needs a cooling period.
- Turn on the monitor and check battery strength and clear old data if required.
- Calibrate the monitor by taking the worker's oral temperature and entering this "offset" temperature into the monitor.
- Place the sensor in a new ear plug and have the worker use slight pressure to roll the ear plug and insert it into the ear canal. Allow 5 minutes for temperature to stabilize. Only ear plugs designed for the sensor should be used.
- Place the personal heat stress monitor on the worker's belt or other location so the cord to the ear piece will not interfere with the work being performed.

After use, many personal heat stress monitors allow for the data to be printed out or down loaded to analyze the worker's heat exposure. See the instruction book for the personal heat stress monitor you are using for details on data logging, programming start and stop times, alarm options, data out-put, printing options, etc.

### **Cold stress**

Cold Stress limits are intended to prevent workers from the most severe effects of hypothermia and cold injury. The objective of these limits is to keep the body core temperature from falling below 36° C. It is important to also protect extremities from frost bite. The wind chill factor is a combination of air temperature and wind speed that affects the freezing rate of exposed skin. Wind chill should be considered when assessing the work environment. See table 4 for the ACGIH cooling power of wind chart.

Frostbite is a medical condition that can happen to anyone. In the most basic terms frostbite is when the skin and/or the tissue under the skin freezes and causes cell damage. This is caused by exposure to cold, either through the air or through a chemical exposure, like to dry ice or highly compressed gas. Under extreme conditions frostbite can occur in one second. The elderly, young children, people with circulatory disorders, and people from warmer climates have a higher risk factor of getting frostbite. People who have had previous cold injuries are also more at risk of getting frostbite again in the same places.

Frostbite is a preventable outdoor-related injury. Preparation and understanding is all it takes to prevent serious injury while working outdoors. Below is a list of some steps that can be taken to prevent cold stress.

- Use a work/warm regiment.
- Use a buddy system to watch for symptoms.
- Avoid sweating that can result in wet clothing.
- Understand the prevailing weather conditions and wind chill.
- Wear layers of clothing and protect exposed skin from the elements.
- Wear a hat that will cover your ears. In extreme conditions use a facemask and or goggles.
- Allow workers to acclimate to cold conditions.

Table 4. Cooling power of wind on exposed flesh.													
Estimated wind speed in MPH	Actual Temperature Reading (°F)												
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	
	Equivalent Chill Temperatures												
Calm	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68	
10	40	28	16	4	-9	-24	-33	-46	-58	-70	-83	-95	
15	36	22	9	-5	-18	-32	-45	-58	-72	-85	-99	-112	
20	32	18	4	-10	-25	-39	-53	-67	-82	-96	-110	-121	
25	30	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133	
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140	
35	27	11	-4	-20	-35	-51	-67	-82	-98	-113	-129	-145	
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116	-132	-148	
(wind speeds greater than 40 mph have little additional effect)	LITTLE DANGER In < hr with dry skin. Maximum danger of false sense of security.				INCREASED DANGER Danger from freezing of exposed skin within one minute.					GREAT DANGER Flesh may freeze in 30 seconds.			
	Trench foot and emersion foot may occur at any point on this chart												

The ACGIH TLV book is an excellent source to learn more about thermal stress and the prevention of related injury and illness. With a comprehensive industrial hygiene program that includes IH monitoring, observation, engineering and administrative controls, and appropriate PPE adverse effects from thermal stress can be prevented.