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Hot Environments

Hot Environments - Control Measures

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How can I measure occupational heat stress exposure?

Feeling hot or cold depends on:

- Air temperature.
- Relative humidity of the air.
- Presence of hot or cold objects in the surrounding area.
- Presence of air movement (breeze, ventilation).
- Physical exertion.
- Clothing.

Various methods of measuring occupational heat exposure combine these environmental factors to obtain a single number as a measure of overall heat load. The most used measure in the workplace is the wet bulb globe temperature (WBGT) index.

Please Note: This OSH Answers document contains information on the prevention of and control of heat-related illnesses. Please see Hot Environments - Health Effects and First Aid and Cold Environments - Health Effects and First Aid for information about the health effects of working in hot and cold environments.

The Wet Bulb Globe Temperature (WBGT)
The wet bulb globe temperature is calculated using a formula that takes into account air temperature, speed of air movement, radiant heat from hot objects, sunshine, and body cooling due to sweat evaporation.

Air temperature is measured using a conventional thermometer.

The contribution due to radiant heat is measured using a black globe thermometer. A conventional thermometer is inserted through a rubber stopper into a hollow, six-inch diameter copper ball which is coated with a flat black paint. The thermometer bulb is positioned at the centre of the copper ball. The black globe thermometer normally requires at least 20 minutes to come to equilibrium reading.

The cooling effect of evaporation and air movement is taken into account using a natural wet bulb thermometer. A natural wet bulb thermometer is a conventional thermometer with its bulb wrapped with an absorbent cotton wick. The wick extends 30 to 35 millimetres above the thermometer bulb, and the lower end of the wick is immersed in distilled water. About 25 mm of moistened wick is exposed between the water and the bulb of the thermometer. The moist wick continuously provides water for evaporation. As with the black globe thermometer, the natural wet bulb thermometer also requires at least 20 minutes to reach equilibrium.

Two different methods are used to calculate WBGT: one for workplaces with direct sunlight, and the other for workplaces without direct sunlight.

When workplace conditions fluctuate widely, time-weighted WBGT is often used. The question below "How do I calculate the WBGT Index?" gives examples of WBGT calculations. WBGT direct reading meters, often called heat stress analyzers, are also available. These meters give direct WBGT readings, and no calculations are necessary.

How do I calculate the WBGT Index?

The wet bulb globe temperature (WBGT) is calculated by using the following equations.

- For conditions in direct sun exposure:

> $WBGT = 0.7 \times Temp_{wet\ bulb} + 0.2 \times Temp_{globe} + 0.1 \times Temp_{dry\ bulb}$

- For shaded or indoor conditions:

> $WBGT = 0.7 \times Temp_{wet\ bulb} + 0.3 \times Temp_{globe}$

where:

$Temp_{wet\ bulb}$ = natural wet bulb temperature measured by using a thermometer whose bulb is covered with wet cotton cloth and is cooled by the natural air movement

$Temp_{globe}$ = temperature measured using a black globe thermometer

$Temp_{dry\ bulb}$ = temperature measured using a conventional thermometer

All temperatures are to be expressed in °C.

Example

Workers employed in an outdoor workplace with direct exposure to the sun. Measurement of workplace conditions produced the following results.

$Temp_{wet\ bulb}$ = 24°C

$Temp_{globe}$ = 42°C

$Temp_{dry\ bulb}$ = 40°C

WBGT = 0.7 x 24 + 0.2 x 42 + 0.1 x 40 = 29.2°C

Time-Weighted Average (TWA)

When thermal conditions of the workplace fluctuate widely, time-weighted average (TWA) WBGT is used to assess heat exposure.

$$\text{TWA WBGT} = \frac{WBGT_1 \times t_1 + WBGT_2 \times t_2 + \ldots + WBGT_n \times t_n}{t_1 + t_2 + \ldots + t_n}$$

$WBGT_1$,$WBGT_2$, etc. = the wet bulb globe temperatures measured or calculated

t_1, t_2, etc. = the elapsed time spent in the corresponding conditions described by $WBGT_1$, $WBGT_2$, etc., respectively.

Example

Measurement and/or calculation of WBGT during a two-hour job produced the following results.

Exposure duration (hours)	WBGT (°C)
0.5	25
1.0	27
0.5	28

These data would yield the following time-weighted average.

$$\text{TWA WBGT} = \frac{25 \times 0.5 + 27 \times 1.0 + 28 \times 0.5}{0.5 + 1.0 + 0.5} = 26.75°C$$

What are the exposure limits for heat stress?

Exposure limits intended to minimize the risk of heat-related illnesses are represented by a range of acceptable temperatures for specific circumstances. The Threshold Limit Values® (TLVs®) for heat stress as published by the American Conference of Governmental Industrial Hygienists (ACGIH) have been formally adopted as occupational exposure limits in some jurisdictions, while other jurisdictions use the TLVs® as guidelines. See the OSH Answers Temperature Conditions - Legislation for a list of legislation from each jurisdiction.

ACGIH defines heat stress as the net heat load to which a worker may be exposed from the combined contributions of metabolic heat, air temperature, air movement, humidity, radiant energy, and clothing.

Heat strain is defined by ACGIH as the overall physiological response resulting from heat stress.

The ACGIH gives these limits in units of WBGT degrees Celsius (°C). The WBGT value considers environmental factors, such as air temperature, humidity, and air movement, which contribute to the perceived temperature. In some workplace situations, solar load (heat from radiant sources) is also considered in determining the WBGT.

WBGT values are not the same as humidex values. Please see the OSH Answers document Humidex Rating and Work for relevant information.

The ACGIH publication " 2024 TLVs® and BEIs®" (or the most current booklet) provides recommended screening criteria for heat stress exposure for workers (Table 1).
The ACGIH exposure limits are intended to protect most workers from heat-related illnesses. The limits are higher than they would have been if they had been developed to prevent discomfort. This publication and the "Documentation of TLVs® and BEIs®" should be consulted for more detailed information on these screening criteria, categories of work demands, guidelines for limiting heat strain and heat strain management.

Table 1 ACGIH Screening Criteria for Heat Stress Exposure (WBGT values in °C) for 8 hour work day five days per week with conventional breaks								
Allocation of Work in a Work/Rest Cycle	Acclimatized Workers				Unacclimatized Workers (Action Limit)			
	Light	Moderate	Heavy	Very Heavy	Light	Moderate	Heavy	Very Heavy
75-100%	31.0	28.0	--	--	28.0	25.0	--	--
50-75%	31.0	29.0	27.5	--	28.5	26.0	24.0	--
25-50%	32.0	30.0	29.0	28.0	29.5	27.0	25.5	24.5
0-25%	32.5	31.5	30.5	30.0	30.0	29.0	28.0	27.0

Notes:

Table 1 is intended as a screening tool to evaluate if a heat stress situation may exist. ACGIH states that this table is more protective than the TLV® or Action Limit. Because the values are more protective, they are not intended to prescribe work and recovery periods.

Assumes 8-hour workdays in a 5-day workweek with conventional breaks.

TLVs assume that workers exposed to these conditions are adequately hydrated, are not taking medication, are wearing lightweight clothing (long-sleeve shirts and pants) and are in generally good health.

See the TLV® booklet for additional guidance.

Examples of workloads:

Rest - sitting (quietly or with moderate arm movements)

Light work - sitting or standing to control machines; performing light hand or arm work (e.g. using a table saw); occasional walking; driving

Moderate work - walking about with moderate lifting and pushing or pulling; walking at a moderate pace; e.g. scrubbing in a standing position

Heavy work - pick and shovel work, digging, carrying, pushing/pulling heavy loads; walking at fast pace; e.g. carpenter sawing by hand

Very Heavy - very intense activity at fast to maximum pace; e.g. shovelling wet sand

Adapted from: 2024 TLVs® and BEIs® - Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati: American Conference of Governmental Industrial Hygienists (ACGIH), 2024, p.236 and 237.

How do I use the heat stress exposure table (Table 1)?

As an example, the wet bulb globe air temperature was measured with a WBGT direct reading meter at 27.0ºC for an 8-hour work period. The worker is not used to hot conditions (i.e., unacclimatized) and is performing moderate cleaning duties (e.g., scrubbing floors and walls). Considering these factors, ACGIH guidelines suggest that an unacclimatized worker can perform this work for approximately 25 to 50% of an 8-hour workday. A "rest break" can include other job duties. Duties involving high activity or exertion levels may not allow a person's body to cool effectively and should be avoided during the rest period. When it is very hot, breaks should be distributed appropriately (e.g., shorter breaks every hour) rather than working for a longer time and taking longer breaks.
See below for more information about controls and acclimatization.

If workers are wearing heavier clothing or personal protective equipment, the WBGT value must be adjusted to reflect a higher heat load. ACGIH recommendations for such situations are suggested in Table 2.

Table 2 **Clothing Adjustment Values (CAV) added to WBGT to estimate $WBGT_{eff}$**	
Clothing Type	CAV (°C)
Short sleeves and pants of woven material	-1
Work clothes (long sleeve shirt and pants)	0
Cloth (woven material) coveralls	0
SMS (Spunbonded - Meltdown - Spunbonded) polypropylene coveralls	+0.5
Polyolefin coveralls	+1
Double-layer woven clothing	+3
Limited-use vapour-barrier coveralls	+ 11
Adding a hood (full head and neck covering; not face)	+1
Notes: 1. These values are not to be used for completely encapsulating suits, often called Level A as defined by OSHA. 2. CAVs are not additive for multiple layers. 3. Coveralls assume that only undergarments are worn underneath, not a second layer of clothing. 4. There is no evidence to suggest that respirators or face coverings add to the heat stress burden.	
Adopted from: 202 4 TLVs® and BEIs®: Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati, Ohio: American Conference of Governmental Industrial Hygienists, 202 4 p. 23 5	

For example, an acclimatized worker wearing double-layer woven clothing doing moderate work at a WBGT of 28°C would have a corrected exposure level of 28.0 + 3 = 31°C, which would lower their allowable exposure to 0-25% work (from 75 -100% work). If the measured WBGT is 30°C, then the adjusted WBGT value would be 33°C, which is higher than all the screening values in Table 1. When working in this type of condition, the employer should monitor the workers for heat strain and implement controls as needed.

What control measures can be used to reduce the effects of heat?

The risk of heat-related illnesses can be reduced by:

- Engineering controls to provide a cooler work environment.
- Safe work practices to reduce worker exposure.
- Training employees to recognize and prevent heat illnesses.

Table 3 (below) provides a summary of these controls.

Engineering Controls

Engineering controls are the most effective means of reducing excessive heat exposure. The following examples illustrate some engineering approaches to reducing heat exposure.

- **Reducing Metabolic Heat Production (heat produced by the body)**: Automation and mechanization of tasks minimize the need for heavy physical work and the resulting buildup of body heat.
- **Reducing Radiant Heat Emission from Hot Surfaces**: Covering hot surfaces with sheets of low-emissivity material such as aluminum or paint reduces the amount of heat radiated into the workplace.
- **Insulating Hot Surfaces**: Insulation reduces the heat exchange between the source of heat and the work environment.
- **Shielding**: Shields stop radiated heat from reaching work areas. Two types of shields can be used. Stainless steel, aluminum or other bright metal surfaces reflect heat back towards the source. Absorbent shields, such as water-cooled jackets made of black-surfaced aluminum, can effectively absorb and carry away heat.
- **Ventilation and Air Conditioning:** Ventilation, localized air conditioning, and cooled observation booths are commonly used. Cooled observation booths allow workers to cool down after brief periods of intense heat exposure while still allowing them to monitor equipment.
- **Reducing Humidity**: Air conditioning, dehumidification, and elimination of open hot water baths, drains, and leaky steam valves help reduce humidity.

Personal Protection

Ordinary clothing provides some protection from heat radiated by surrounding hot surfaces. Specially designed heat-protective clothing is available for working in extremely hot conditions. In hot and humid workplaces, light clothing allows maximum skin exposure and efficient body cooling by sweat evaporation.

Workers who move back and forth between very hot, dry indoor environments and cold winter outdoor environments find that long underwear moderates the extremes in temperatures.

Eye protection that absorbs radiation is needed when the work involves very hot objects, such as molten metals and hot ovens.

Work that requires the wearing of impermeable clothing presents an add itional heat burden as the clothing reduces the body's ability to dissipate heat. Under such circumstances, it is often necessary to adjust the WBGT value to account for the additional heat burden.

Table 3 Summary of Control Measures	
Methods of Control	Actions
Engineering controls	
Reduce body heat production	Mechanize or automate tasks.
Stop exposure to radiated heat from hot objects	Insulate hot surfaces. Use reflective shields, aprons, and remote controls.
Reduce convective heat gain	Lower the air temperature. If the air temperature is below 35°C, increase the airspeed. Increase ventilation. Provide cool observation booths.
Increase sweat evaporation	Reduce humidity. Use a fan to increase air speed (movement).
Clothing	
	Wear loose clothing that permits sweat evaporation but stops radiant heat. Use cooled protective clothing for extreme conditions.
Administrative controls	
Acclimatization	Allow sufficient acclimatization period before full workload.
Duration of work	Shorten exposure time and use frequent rest breaks.
Rest area	Provide cool (air-conditioned) rest areas.
Water	Provide cool drinking water.
Pace of Work	If practical, allow workers to set their own pace of work.
First aid and medical care	Develop and implement emergency procedures. Assign one person trained in first aid to each work shift. Train workers in how to recognize symptoms of heat exposure in themselves and others.

Can we become acclimatized to hot environments?

The body adapts to a new thermal environment by a process called acclimatization. Complete heat acclimatization generally takes six to seven days, but some individuals may need longer. Loss of acclimatization occurs gradually when a person is moved permanently away from a hot environment. However, a decrease in heat tolerance can occur even after a few days away from work. Therefore, it is not advisable for anyone to assume a full workload under very hot conditions on the first day of their return to work.

New and returning employees should acclimatize before assuming a full workload. It is advisable to assign about half of the normal workload on the first day of work and gradually increase it over the subsequent days.

Although well-trained, physically fit workers tolerate heat better than people in poor physical condition, fitness and training are not substitutes for acclimatization.

Some medications interfere with acclimatization. For example, hypotensives (drugs causing low blood pressure), diuretics, antispasmodics, sedatives, tranquilizers, antidepressants and amphetamines decrease the body's ability to cope with heat. Workers should seek a doctor's advice on the suitability of a medication for them if they work in hot environments. Consumption of alcohol also interferes with acclimatization.

How can I prevent heat-related illnesses?

If practical, workers in hot environments should be encouraged to set their own work and rest schedules based on industry standards such as the ACGIH Screening Criteria in Table 1. Infrequent or irregular tasks , such as emergency repairs of hot process equipment, often result in heat exposure. Experienced workers can often judge heat strain and limit their exposure accordingly. Inexperienced workers may need special attention as they may continue to work beyond the point at which signs of heat strain appear.

People are generally unable to notice their own heat stress-related symptoms. Their survival depends on their coworker's ability to recognize these symptoms and seek timely first aid and medical help.

Salt and Fluid Supplements: A person working in a very hot environment loses water and salt through sweat. This loss should be compensated by water and salt intake. Fluid intake should equal fluid loss. On average, about one litre of water each hour may be required to replace the fluid loss. Plenty of cool (10-15°C) drinking water should be available on the job site, and workers should be encouraged to drink water every 15 to 20 minutes even if they do not feel thirsty.

An acclimatized worker loses relatively little salt in their sweat, and therefore, salt in a normal diet is usually sufficient to maintain the electrolyte balance in the body fluids. For unacclimatized workers who may sweat continuously and repeatedly, additional salt in food may be used. Salt tablets are not recommended because the salt does not enter the body system as fast as water or other fluids. Too much salt can cause higher body temperatures, increased thirst and nausea. Workers on salt-restricted diets should discuss the need for supplementary salt with their doctor.

Sport drinks and fruit juice: Drinks specially designed to replace body fluids and electrolytes may be taken but for most people, they should be used in moderation. They may be of benefit for workers who have very physically active occupations but keep in mind they may add unnecessary sugar or salt to your diet. Fruit juice or sport and electrolyte drinks, diluted to half the strength with water, is an option.

Emergency Action Plan: An emergency plan is needed in extreme environments. The plan should include procedures for providing affected workers with first aid and medical care.

Note: Drinks with alcohol or caffeine should be avoided, as they dehydrate the body. Water is the most efficient fluid for rehydration for most.

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