

# Heat stress

*Prepared by:*

Workplace Safety Consultation unit

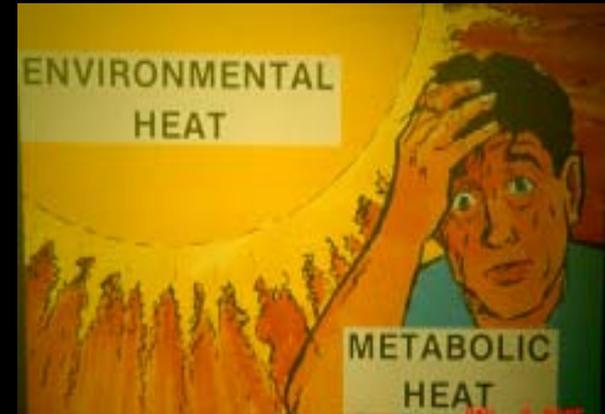
Minnesota Department of Labor and Industry

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# Heat stress

The net heat load to which a worker may be exposed from the combined contributions of:

- environmental factors,
- metabolic cost of work and
- clothing requirements



# Heat strain

The overall physiological response resulting from heat stress aimed at dissipating excess heat from the body

# Heat transfer

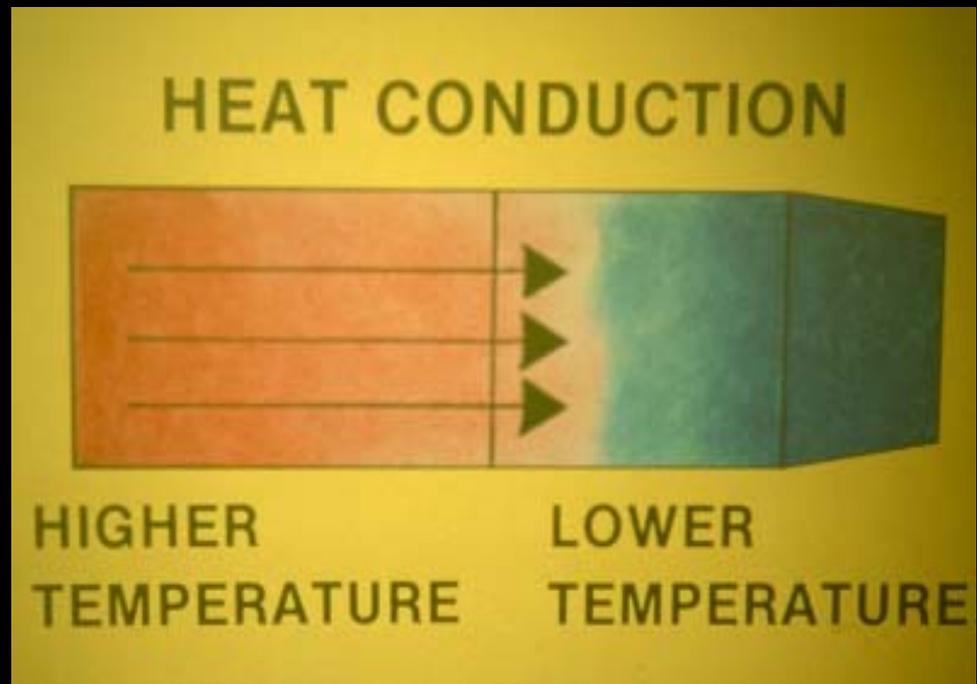
Heat can be transferred whenever two or more objects have differing temperatures.

Heat is always transferred from the object with the higher temperature to that with the lower temperature, and travels by one or more of three mechanisms:

- heat conduction
- heat convection
- heat radiation

# Heat conduction

The transfer of heat by conduction requires physical contact between the two objects or heat transferred from one point to another within a body.



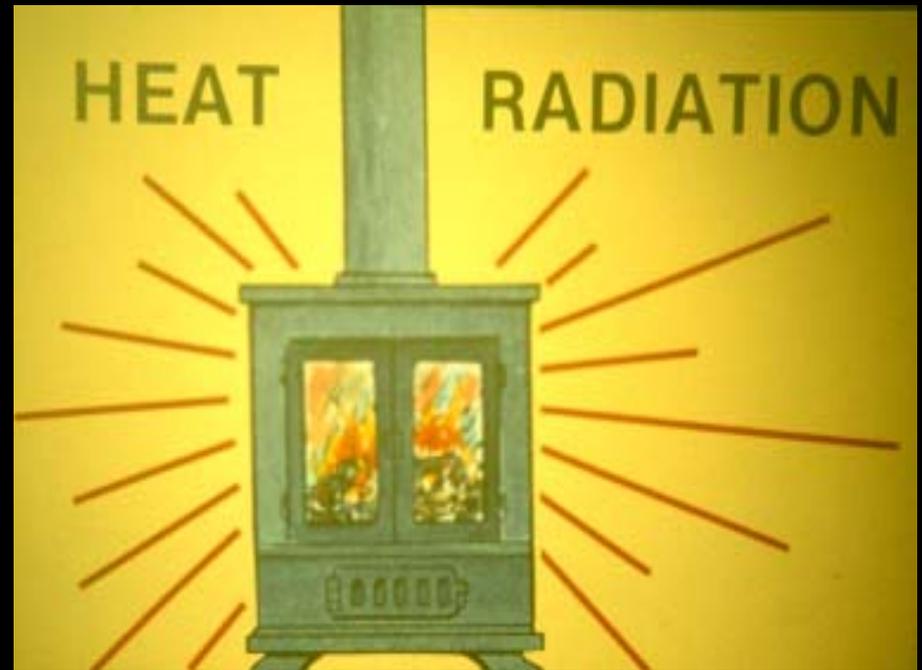
# Heat convection

In convection, heat must be transferred through a circulating medium, such as a gas or a liquid.



# Heat radiation

In radiation, heat passes through space without any intervening matter or movement.



# Heat-stress factors

**Environmental factors** (externally imposed factors):

**Temperature** -- the higher the ambient temperature, the greater the heat load placed on the body.

**Humidity** -- the higher the humidity, the more sweat evaporation is impeded.

**Air movement** -- air movement promotes the evaporation of sweat and convection of heat to the ambient air.

**Radiant heat** -- radiant sources, including the sun, can place additional heat load on the body.

**Metabolic heat factor** (internally generated factor):

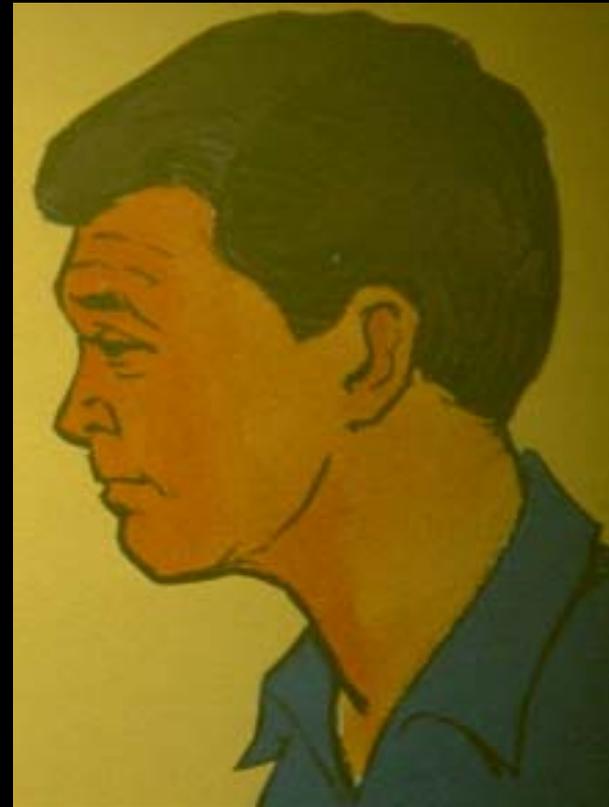
Proportionate to the intensity of the work performed.

**Clothing factor:**

Different types of clothing can impede to varying degrees the movement of air over the skin's surface, which helps in heat removal through convection and evaporation.

# How does the body respond to heat stress?

1. Internally generated metabolic heat is carried to the surface of the body via the blood stream. If the ambient temperature is below body temperature, any excess heat is dissipated from the skin to the air through convection.



# How does the body respond to heat stress?

2. Blood brought to the skin cannot be cooled through convection to the surrounding air if the ambient temperature is as warm as or warmer than the skin.

In this case, blood continues to be pumped to the skin and evaporation of perspiration becomes the primary means of maintaining the body core temperature at an acceptable level.



# How does the body respond to heat stress?

3. This situation is complicated if the humidity is high. Perspiration is only effective when it can evaporate and high humidity retards evaporation.

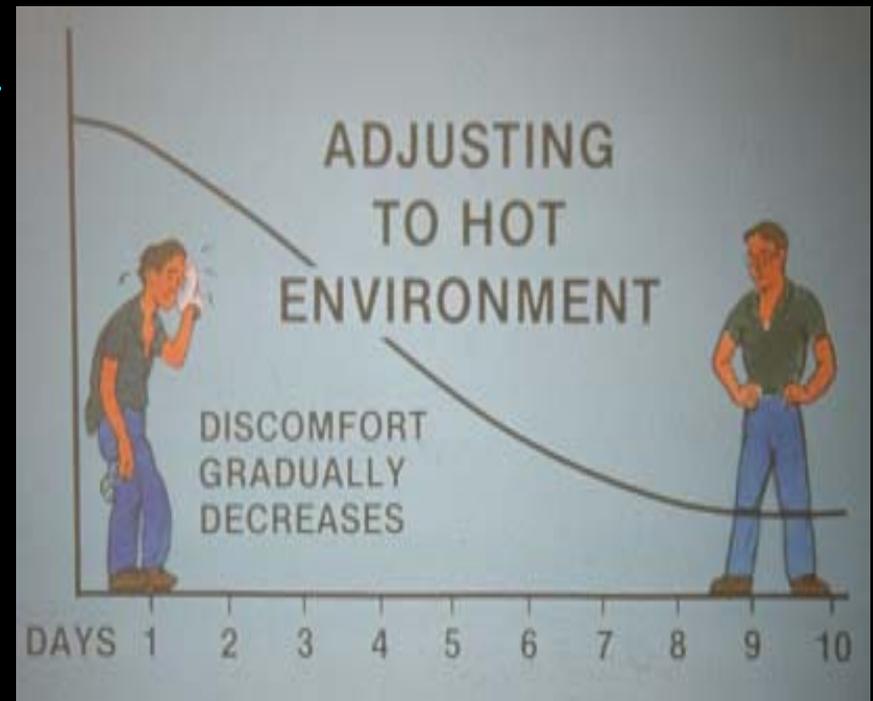
When the environmental heat load is high, the body's cooling mechanism can fail.

# Heat acclimatization

The process of adjusting to a hot environment takes about 10 days. On the first day of working in the hot environment, the body temperature, pulse rate and general discomfort are very noticeable.

With each succeeding daily exposure, the symptoms will gradually decrease. The worker should then be able to perform the work required with minimal strain.

In general, a person who has become acclimatized to heat shows little significant variation in the amount of work that can be performed in a hot or temperate environment.



# Heat disorders

- **Heat stroke**
- **Heat exhaustion**
- **Heat syncope**
- **Heat cramps**
- **Heat rash**
- **Transient heat fatigue**

# Heat stroke

**Cause:** Partial or complete failure of sweating mechanism. The body cannot get rid of excess heat, so the body core temperature is rising.

**Symptoms:** Hot dry skin; red, mottled or bluish skin; confusion; loss of consciousness; convulsions; rapid pulse and elevated temperature. Can be fatal!

**Treatment:** Medical emergency! Call paramedics. Start cooling victim immediately. Remove victim to a cool area. Soak clothing and skin with cool water; use a fan to create air movement. Shock may occur. Medical treatment is imperative.

**Prevention:** Acclimatization, close monitoring of workers, medical screening, drinking plenty of water.



# Heat exhaustion

**Cause:** Dehydration causes blood volume to decrease.

**Symptoms:** Fatigue; weakness; dizziness; faintness; nausea and headache; moist, clammy skin; pale or flushed skin; rapid pulse; normal or slightly elevated temperature.

**Treatment:** Move victim to cool area. Have victim rest and drink fluids.

**Prevention:** Acclimatization, drinking plenty of water to prevent dehydration.



# Heat syncopy

**Cause:** Dehydration causes blood volume to decrease. Blood pools in dilated blood vessels of the skin and lower body, making less blood available to the brain.

**Symptoms:** Fainting while standing erect and immobile. A variant of heat exhaustion. Symptoms of heat exhaustion may precede fainting.

**Treatment:** Move victim to cool area. Have victim rest and drink fluids.

**Prevention:** Acclimatization, drinking plenty of fluids, avoiding standing in one place, intermittent activity will help avoid blood pooling.



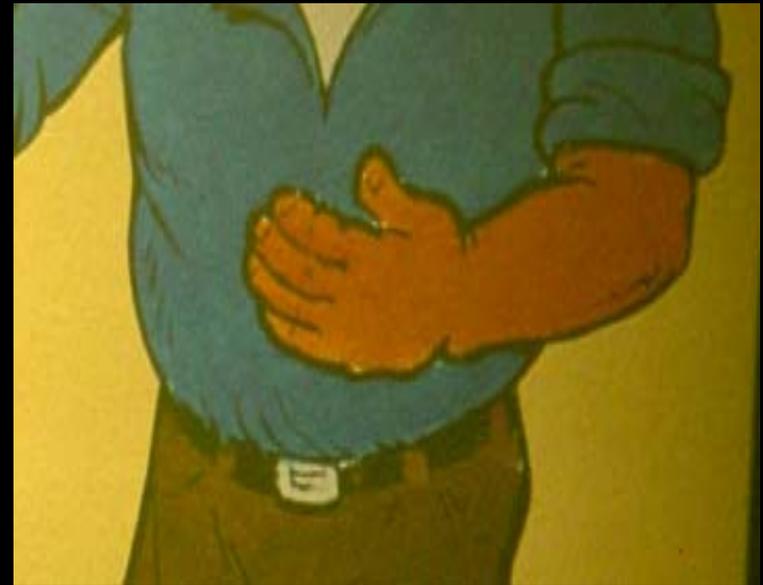
# Heat cramps

**Cause:** Not well-understood. May be due to a loss of salt from sweating. Dehydration is a factor.

**Symptoms:** Painful muscle spasms in the arms, legs or abdomen during or after hard physical work.

**Treatment:** Rest, drink water and eat more salty foods.

**Prevention:** Adequate water intake and adequate salt intake at meals. *Do not* use salt tablets.



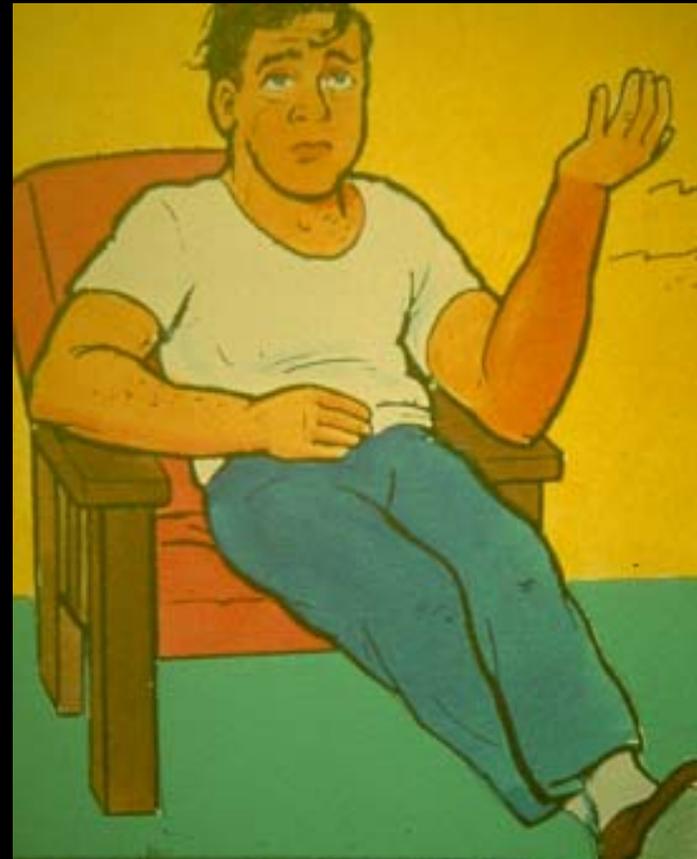
# Heat rash

**Cause:** Skin is constantly wet from sweat. Sweat glands become plugged, leading to inflammation.

**Symptoms:** “Prickly heat”; tiny, raised, blister-like rash.

**Treatment:** Keep skin clean and dry.

**Prevention:** Shower after working in hot environments; keep skin dry.



# Transient heat fatigue

**Cause:** Discomfort and stress from the heat, less than what would result in other heat illnesses.

**Symptoms:** Decline in performance, particularly in skilled physical work, mental tasks and those requiring concentration.

**Treatment:** No treatment is necessary, unless other signs of heat illness are present.

**Prevention:** Acclimatization and training.



# Heat disorders – risk factors

The following can increase the possibility of heat disorder occurrences in workers:

- use of alcohol;
- use of certain drugs (prescription and over-the counter);
- older age;
- certain medical conditions, including heart disease and emphysema.

*If any of the above apply, worker consultation with their personal physician is recommended.*

# Heat-stress standards

## Federal OSHA standards

**General industry** – none

**Construction** – 29 CFR 1926.21(b)(2)

*The employer shall instruct each employee in the recognition and avoidance of unsafe conditions and the regulations applicable to his work environment to control or eliminate any hazards or other exposure to illness or injury.*

# Heat-stress standards

## Minnesota OSHA standards

### General industry

- Minnesota Rules Chapter 5206 Employee Right-To-Know
  - 5206.0500 Subpart 3 Harmful physical agents list
  - 5206.0700 Subparts 1 and 3 Training program for harmful physical agents
  - 5206.1100 Labeling Harmful Physical Agents; Label Contents
- Minnesota Rules 5205.0110 Indoor Workroom Ventilation and Temperature Subpart 2a Heat stress

### Construction

- Minnesota Statutes §182.653 Rights and duties of employers Subdivision 2

# Minnesota OSHA standards

Minnesota Rules Chapter 5206 Employee Right-To-Know

5206.0500 Subpart 3 Harmful physical agents list

- A. Heat**
- B. Noise
- C. Ionizing radiation
- D. Nonionizing radiation

# Minnesota OSHA standards

## Minnesota Rules Chapter 5206 Employee Right-To-Know 5206.0700 Training Subpart 1, in general

The requirements in items A to J apply to training programs provided to employees concerning hazardous substances, **harmful physical agents** and infectious agents.

- A. Training availability and cost
- B. Written program requirements
- C. Multi-employer worksite requirements
- D. Records of training
- E. Approaches to training and effectiveness
- F. Display device access and hard copy printout requirements
- G. Frequency of training
- H. Certification of training programs
- I. Maintaining current information
- J. Technically qualified individuals

*(See the actual items A to J in this standard for the specifics regarding the above.)*

# Minnesota OSHA standards

Minnesota Rules Chapter 5206 Employee Right-To-Know

5206.0700 Training

Subpart 3 Training program for harmful physical agents

The training program for employees who may be routinely exposed to harmful physical agents at a level which may be expected to approximate or exceed the permissible exposure limit or applicable action levels shall be provided in a manner which can be reasonably understood by the employee and shall include the information required by the standard for that physical agent as determined by the commissioner including the following:

- A. the names or names of the physical agent including any commonly used synonym;
- B. the level, if any and if known, at which exposure to the physical agent has been restricted according to standards adopted by the commissioner, or, if no standard has been adopted, according to guidelines established by competent professional groups which have conducted research to determine the hazardous properties of potentially harmful physical agents;
- C. the known acute and chronic effects of exposure at hazardous levels;
- D. the known symptoms of the effects;
- E. appropriate emergency treatment;
- F. the known proper conditions for use of and/or exposure to the physical agent;
- G. the name, phone number and address, if appropriate, of a manufacturer of the equipment which generates the harmful physical agent; and
- H. a written copy of all of the above information.

# Minnesota OSHA standards

## Minnesota Rules Chapter 5206 Employee Right-To-Know

### 5206.1100 Labeling Harmful Physical Agents; Label Content

Equipment or a work area that specifically generates harmful physical agents at a level which may be expected to approximate or exceed the permissible exposure limit or applicable action level shall be labeled. The label shall include:

- A. the name of the physical agent; and
- B. the appropriate hazard warning.

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*An example of an acceptable label for a heat stress area would be:*

*“Potential heat-stress area – training required.”*

# Minnesota OSHA standards

Minnesota Rules 5205.0110

## Indoor Workroom Ventilation and Temperature

Subpart 2a Heat stress – The requirements of this subpart cover employee exposure to environmental heat conditions indoors.

A. The following definitions apply when assessing and controlling health hazards associated with extremes in temperature and humidity indoors.

(1) "Wet bulb globe temperature index" or WBGT means a measure of the combined effect of air temperature, air speed, humidity and radiation.  $WBGT = 0.7 T_{nwb} + 0.3 T_g$ .

(2) "Natural wet-bulb temperature" or " $T_{nwb}$ " means temperature measured by a thermometer which has its sensor covered by a wetted cotton wick, exposed to natural air movement.

(3) "Globe temperature" or " $T_g$ " means temperature measured by a thermometer with its sensor inside a matte black globe, exposed to radiant heat, Vernon Globe or equivalent.

(4) "Heavy work" means 350 to 500 kcal/hr (kilocalories per hour), for example: heavy lifting and pushing, shovel work.

(5) "Moderate work" means 200 to 350 kcal/hr, for example: walking about with moderate lifting and pushing.

(6) "Light work" means up to 200 kcal/hr, for example: sitting or standing, performing light hand or arm work.

Minnesota Rules 5205.0110  
Indoor Workroom Ventilation and Temperature

Subpart 2a Heat stress (continued) ...

B. Employees shall not be exposed to indoor environmental heat conditions in excess of the values listed in Table 1. The values in Table 1 apply to fully clothed, acclimatized workers.

Table 1. Two-hour time-weighted average permissible heat exposure limits.

<u>Work activity</u>	<u>WBGT, °F</u>
Heavy work	77
Moderate work	80
Light work	86

## Calculating a two-hour, time-weighted average

$$\text{WBGT}_{2 \text{ hr}} = \frac{\text{WBGT}_1 \times T_1 + \text{WBGT}_2 \times T_2 + \text{WBGT}_3 \times T_3 + \dots + \text{WBGT}_n \times T_n}{T_1 + T_2 + T_3 + \dots + T_n}$$

where:

$\text{WBGT}_x$  = wet bulb globe temperature during interval X,

$T_x$  = time of interval of X,

two hours =  $T_1 + T_2 + T_3 + \dots + T_n$ , and

$n$  = number of time intervals in two-hour evaluation period

# Sample problem

An employee at a food processing plant was monitored for heat-stress exposure. The worker operated one machine in the production area and took a break in a separate room. The following exposures during a two-hour period are observed:

Sample #	Sampling period	Time (min)	Area sampled	Activity	T <sub>g</sub> °F	T <sub>db</sub> °F	T <sub>nwb</sub> °F	WBGT °F
1	8-8:30	30	Cooker	Product rotation – moderate work	98	95	80	85
2	8:30-8:50	20	Cooker	Unloading – moderate work	97	90	78	83
3	8:50-9:15	25	Cooker	Finishing – moderate work	95	90	78	83
4	9:15-9:30	15	Break room	Break	80	78	73	75
5	9:30-10	30	Cooker	Unloading – moderate work	98	94	80	85

## Sample problem, continued ...

$$\text{WBGT}_{2\text{-hour}} = \frac{\text{WBGT}_1 \times T_1 + \text{WBGT}_2 \times T_2 + \text{WBGT}_3 \times T_3 + \dots + \text{WBGT}_n \times T_n}{T_1 + T_2 + T_3 + \dots + T_n}$$

$$\text{WBGT}_{2\text{-hour}} = \frac{(85)(30) + (83)(20) + (83)(25) + (75)(15) + (85)(30)}{30 + 20 + 25 + 15 + 30}$$

$$\text{WBGT}_{2\text{-hour}} = \frac{2550 + 1660 + 2075 + 1125 + 2550}{120} = \frac{9960}{120}$$

$$\text{WBGT}_{2\text{-hour}} = 83 \text{ }^\circ\text{F}$$

The Minnesota OSHA two-hour, time-weight average WBGT limit for moderate work is 80 degrees F; therefore, an employee overexposure has occurred and steps must be taken to reduce the heat stress.

## EXAMPLES OF CONDITIONS THAT CORRESPOND TO THE HEAT STRESS LIMITS (APPROXIMATE).

2-hour TWA Permissible Heat Exposure Limit  Work load	Relative Humidity (%)	No air movement		300 fpm	
		Dry Bulb $T_{db}$ (°F)	Psychrometric Wet Bulb $T_{wb}$ (°F)	Dry Bulb $T_{db}$ (°F)	Psychrometric Wet Bulb $T_{wb}$ (°F)
WBGT = 86°F  Light work  (Sitting/standing with light hand/arm work)	80	90	85	93	87
	70	92	83	95	85
	60	94	82	97	84
	50	97	80	99	83
	40	100	79	101	82
	30	104	77	105	79
WBGT = 80°F  Moderate work  (walking about with moderate lifting and pushing)	80	84	79	87	82
	70	86	77	89	80
	60	87	76	90	79
	50	89	74	92	77
	40	92	72	95	75
	30	94	71	97	73
WBGT = 77°F  Heavy work  (e.g., shoveling)	80	80	76	84	80
	70	82	74	86	78
	60	84	72	87	76
	50	85	71	89	74
	40	87	70	91	71
	30	90	67	93	69

**Notes:**

- < This method can only be used where no significant radiant heat sources are present.
- < Limits apply only to general industry indoor work performed by acclimatized workers wearing normal work clothing.
- < When using a sling psychrometer to determine compliance, first measure the wet bulb and dry bulb temperatures and estimate the air speed. Using these figures, determine Effective Temperature (ET) from the nomogram in Appendix B. The following equation can be used to approximate WBGT from ET:

$$WBGT = 1.102 ET - 9.10$$

The above information was taken from Minnesota OSHA Compliance's heat-stress guideline, accessible at [www.doli.state.mn.us/mnosh.html](http://www.doli.state.mn.us/mnosh.html).

# Minnesota OSHA standards

## Minnesota Statutes §182.653 **Rights and duties of employers**

Subdivision 2. Each employer shall furnish to each of its employees conditions of employment and a place of employment free from recognized hazards that are causing or are likely to cause death or serious injury or harm to its employees.

*This standard could be cited in construction or in outdoor settings in general industry for employee heat exposures that exceed best available guideline recommendations.*

# Heat-stress guidelines

ACGIH TLV for **Heat Stress and Heat Strain**

Section 2 (screening criteria)

Section 3 (detailed analysis)

# ACGIH TLV for Heat Stress and Heat Strain Sections 2 (screening criteria)

Table 2. Screening Criteria for Heat Stress Exposure (WBGT values in °C)

Work Demands	Acclimatized				Unacclimatized			
	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

*Notes:*

- See Table 3 and the *Documentation* for work demand categories.
- WBGT values are expressed in °C, and represent thresholds near the upper limit of the metabolic rate category.
- If work and rest environments are different, hourly time-weighted averages (TWA) should be calculated and used. TWAs for work rates should also be used when the work demands vary within the hour.
- Values in the table are applied by reference to the "Work-Rest Regimen" section of the *Documentation* and assume 8-hour workdays in a 5-day workweek with conventional breaks, as discussed in the *Documentation*. When workdays are extended, consult the "Application of the TLV" section of the *Documentation*.
- Because of the physiological strain associated with Very Heavy work among less fit workers regardless of WBGT, criteria values are not provided for continuous work and for up to 25% rest in an hour. The screening criteria are not recommended, and a detailed analysis and/or physiological monitoring should be used.

The above information was taken from Minnesota OSHA Compliance's heat-stress guideline, accessible at [www.doli.state.mn.us/mnosha.html](http://www.doli.state.mn.us/mnosha.html).

# ACGIH TLV for Heat Stress and Heat Strain Section 3 (detailed analysis)

Table 3. Examples of Activities within Metabolic Rate Categories

Categories	Example Activities
Resting	Sitting quietly
	Sitting with moderate air movements
Light	Sitting with moderate arm and leg movements
	Standing with light work at machine or bench while using mostly arms
	Using a table saw
	Standing with light or moderate work at machine or bench and some walking about
Moderate	Scrubbing in a 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 sand
	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

The above information was taken from Minnesota OSHA Compliance's heat-stress guideline, accessible at [www.doli.state.mn.us/mnosha.html](http://www.doli.state.mn.us/mnosha.html).

## Heat-stress guidelines, continued ...

NIOSH Criteria Document for Heat Stress – One-hour TWA for continuous exposure or two-hour TWA for intermittent exposure 79 degrees F WBGT.

International Standard **ISO 7243**: 1989-08-01 Hot environments – estimation of the heat stress on working man, based on the *WBGT*-index.

Department of the Army Technical Bulletin, Department of the Navy Publication, Department of the Air Force Publication TB MED 507 NAVMED P-5052-5 AFP 160-1 Prevention, Treatment and Control of Heat Injury.

## Heat-stress guidelines, continued ...

### Hazard Alert: Heat stress in construction

- Heat is a serious hazard in construction. Your body builds up heat when you work and sweats to get rid of extra heat. But sometimes — say, if you are up on a roof, pouring hot asphalt or lifting heavy loads — your body may not cool off fast enough.
- Too much heat can make you tired, hurt your job performance and increase your chance of injury.



# Heat-stress guidelines, continued ...

		Relative Humidity (%)												
		40	45	50	55	60	65	70	75	80	85	90	95	100
Air Temperature	110	136												
	108	130	137											
	106	124	130	137										
	104	119	124	131	137									
	102	114	119	124	130	137								
	100	109	114	118	124	129	136							
	98	105	109	113	117	123	126	134						
	96	101	104	108	112	116	121	126	132					
	94	97	100	102	106	110	114	119	124	129	135			
	92	94	96	99	101	105	108	112	116	121	126	131		
	90	91	93	95	97	100	103	106	109	113	117	122	127	132
	88	88	89	91	93	95	98	100	103	106	110	113	117	121
	86	85	87	88	89	91	93	95	97	100	102	105	108	112
	84	83	84	85	86	88	89	90	92	94	96	98	100	103
82	81	82	83	84	84	85	86	88	89	90	91	93	95	
80	80	80	81	81	82	82	83	84	84	85	85	86	87	

Heat Index  
(Apparent  
Temperature)

With Prolonged Exposure  
and/or Physical Activity

<b>Extreme Danger</b>
Heat stroke or sunstroke highly likely
<b>Danger</b>
Sunstroke, muscle cramps, and/or heat exhaustion likely
<b>Extreme Caution</b>
Sunstroke, muscle cramps, and/or heat exhaustion possible
<b>Caution</b>
Fatigue possible

# Wet bulb globe temperature (WBGT): How is it determined?

**With direct exposure to sunlight:**

$$\text{WBGT}_{\text{out}} = 0.7T_{\text{nwb}} + 0.2T_{\text{g}} + 0.1T_{\text{db}}$$

**Without direct exposure to the sun\*:**

$$\text{WBGT}_{\text{in}} = 0.7T_{\text{nwb}} + 0.3T_{\text{g}}$$

Where:

$T_{\text{nwb}}$  = natural wet bulb temperature (sometimes called NWB)

$T_{\text{g}}$  = globe temperature (sometimes call GT)

$T_{\text{db}}$  = dry bulb (air) temperature (sometimes called DB)

\*Also found in Minnesota Rules 5205.0110 Subpart 2A.

# Temperature scale conversion formulas

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To convert Fahrenheit to Celsius, use the following formula:

$$T_C = (5/9)(T_F - 32)$$

To convert Celsius to Fahrenheit, use the following formula:

$$T_F = (9/5)(T_C) + 32$$

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Where:

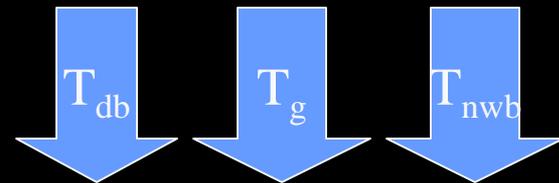
$T_C$  = temperature in degrees Celsius

$T_F$  = temperature in degrees Fahrenheit

# WBGT heat-stress monitor

Digital read-out of:

- dry bulb temperature ( $T_{db}$ )
- globe temperature ( $T_g$ )
- natural wet bulb temperature ( $T_{nwb}$ )
- automatically calculates  $WBGT_{in}$  or  $WBGT_{out}$  based upon dial selection
- Some models have computer programs that track changes in WBGT during a monitored time-interval and allow printouts showing that information.



# Determining relative humidity

## Electronic digital psychrometer

Digital readout for:

- relative Humidity in %
- dry bulb temperature
- wet bulb temperature
- dew point
- can be set to read out in degrees F or C



# Determining relative humidity

## Sling psychrometer

(spin thermometer end in air to be evaluated)

Reads out:

- dry bulb temperature
- thermodynamic wet bulb temperature
- can determine % relative humidity
- based on difference (use sliding scale)



# Measuring air speed

## Hot wire anemometer

- Determines air velocity stated in linear feet per minute (FT/MIN)
- Must know air flow direction so monitor can be positioned correctly for an accurate measurement



# Estimating air speed

Air movement can be estimated using the following guide:

- still air – no sensation of air movement < 40 ft/min
- light breeze – slight perception of air movement 40-200 ft/min
- moderate breeze – paper moves, hair disturbed 200-240 ft/min
- strong breeze – clothing moves > 240 ft/min

The above information was taken from Minnesota OSHA Compliance's heat-stress guideline, accessible at [www.doli.state.mn.us/mnosha.html](http://www.doli.state.mn.us/mnosha.html).

# Engineering controls

## Air conditioning

Overall AC or spot cooling in those areas where high exposure occurs



# Engineering controls

## Fans

Air movement promotes evaporation of sweat and helps dissipate heat from the skin surface through convection.



# Engineering controls

Heat shields

Reduce the amount of radiant heat reaching the worker.



# Engineering controls

## Ventilation considerations

Increase the amount of ventilation supplied into the affected area, preferably with cooler air

Increase the exhaust ventilation from the affected area to remove generated heat

Open windows

# Administrative controls

- Alter employee work/rest schedules, so MNOSHA limits (indoors in general industry) or ACGIH limits (outdoors in general industry or in construction) are not exceeded
- Reduce work activity levels to reduce the amount of metabolic heat internally generated by a worker
- Start work shifts earlier (or later) and end work shifts earlier (or later) in the day to avoid work during the hottest part of day
- Acclimatize workers
- Provide and encourage affected workers to drink fluids to avoid dehydration and encourage them to wear loose-fitting, breathable clothing
- Consider shutdown to avoid exposures

# Personal protective equipment

- heat-reflective clothing



- AC backpacks

- ice vests

- vortex cooling systems



## Heat stress – conclusions

Heat stress may be a source of serious health problems for workers who must work in hot environments, especially if humid conditions prevail.

It is also a stressor that increases strain and fatigue, giving a greater opportunity for accidents.

# Heat stress – conclusions

To minimize potential problems with heat stress, take the following approach:

1. Monitor the work environment to determine where workers are at potential risk to heat stress.
2. Where exposure limits are exceeded, implement engineering and/or administrative controls to minimize the risk to affected workers.
3. Where engineering or administrative controls are not feasible, implement the use of personal protective equipment by affected workers.
4. Monitor the workforce for indications of heat-stress disorders.
5. Train workers at-risk about heat-stress disorders.

# Questions?



Thank you