Heat stress

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Minnesota Department of Labor and Industry
Occupational Safety and Health Division

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Minnesota OSHA heat stress guide

I. Introduction

Heat stress may occur year-round in foundries, kitchens or laundries, or for only a few days during the summer in almost any work setting. Emergency response operations may also be impacted.

Heat stress can be as much of a problem in Minnesota as in other regions of the country where high temperatures are common during the summer. This is because people usually do not have the opportunity to become acclimatized and stay acclimatized in climates such as Minnesota's, where daily high temperatures can vary up to 30 degrees from one day to the next during the summer.

Heat stress can result in several illnesses, as well as decreased productivity and increased likelihood of injuries. Minnesota's heat stress standard is designed to protect employees against the risk of heat-induced illnesses and unsafe acts.

Heat stress results from a combination of internal (body) heat production from doing work and external heat exposure from the environment. Both aspects need to be addressed to properly control heat stress.

Minnesota Rules 5205.0110, subp. 2a, which was revised in September 2014 and can be found in Appendix A, is the Minnesota OSHA (MNOSHA) standard for heat exposure. The standard is based on the wet bulb globe temperature (WBGT) and level of work activity. Typically, one will determine the WBGT by using a heat stress monitor or a sling psychrometer and the chart in Appendix B to obtain effective temperature, then converting effective temperature to WBGT. Appendix B contains some examples of conditions that approximate the limits under the standard. If the heat stress limit is approached or exceeded, Employee Right-to-Know requirements specified in Minnesota Rules 5206.0700, subps. 1 and 3, Training Program for Harmful Physical Agents, and Minnesota Rules 5206.1100, Labeling Harmful Physical Agents; Label Content, also apply.

The following pages contain a discussion of heat disorders, prevention of disorders, methods for evaluating heat stress and methods of control.

II. Heat disorders

Heat stroke

Symptoms:	Usually hot, dry skin; red, mottled or bluish. Sweating may still be present. Confusion, loss of consciousness, convulsions. Rapid pulse. Rectal temperature greater than 104ºF. When in doubt, treat as heat stroke. Can be fatal.
Treatment:	**Medical emergency**. Call paramedics and start cooling the victim immediately. Remove the victim to a cool area. Soak clothing and skin with cool water and use a fan to create air movement. Shock may occur. Medical treatment is imperative.
Cause:	Partial or complete failure of the sweating mechanism. The body cannot get rid of excess heat.
Prevention:	Acclimatization, close monitoring for signs of heat illness, medical screening and drinking plenty of water.

Rhabdomyolysis

Symptoms:	Muscle cramps, pain, abnormally dark urine, weakness, exercise intolerance, loss of range of motion of joints. May be asymptomatic.
Treatment:	Stop all activity and increase water intake. Seek immediate medical care and ask to be checked for rhabdomyolysis.
Cause:	Heat stress combined with prolonged, intense, physical exertion causes muscle breakdown, rupture and death. Can lead to seizures, irregular heartbeat, kidney failure and death.
Prevention:	Decrease the amount of physical exertion in hot conditions and drink plenty of fluids.

Heat exhaustion

Symptoms:	Fatigue, weakness, dizziness, faintness. Nausea, headache. Moist, clammy skin; pale or flushed. Rapid pulse. Normal or slightly elevated temperature.
Treatment:	Have the victim rest in a cool area and drink fluids.
Cause:	Dehydration causes blood volume to decrease.
Prevention:	Acclimatization and drinking plenty of water.

Heat syncope

Symptoms:	Fainting while standing erect and immobile. A variant of heat exhaustion. Symptoms of heat exhaustion may precede fainting.
Treatment:	Move the victim to a cool area; have the victim rest and drink fluids.
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.
Prevention:	Acclimatization, drinking plenty of water, avoiding standing in one place and intermittent activity to avoid blood pooling.

Heat cramps

Symptoms:	Painful muscle spasms in the arms, legs or abdomen during or after hard physical work.
Treatment:	Resting, drinking water and eating more salty foods.
Cause:	Not well understood. May be due to a loss of salt from sweating. Dehydration is a factor.
Prevention:	Adequate water intake and adequate salt intake at meals; do not use salt tablets.

Heat rash

Symptoms:	"Prickly heat"; tiny, raised, blister-like rash.
Treatment:	Keeping skin clean and dry.
Cause:	Skin is constantly wet from sweat. Sweat gland ducts become plugged, leading to inflammation.
Prevention:	Showering after working in a hot environment. Keeping skin dry.

Transient heat fatigue

Symptoms:	Decline in performance, particularly in skilled physical work, mental tasks and those requiring concentration.
Treatment:	No treatment necessary unless other signs of heat illness are present.
Cause:	Discomfort. Stress from the heat is less than what would result in other heat illnesses.
Prevention:	Acclimatization and training.

Notes

1. Alcohol, prescription drugs and other drugs can increase the possibility of heat disorders occurring, even if used the previous day.

2. Heat-related reproductive effects, including reduced fertility and increased risk of miscarriage, can also occur. A core temperature above 102°F in the mother can endanger the fetus.

III. Prevention

The two most important methods of preventing heat disorders are hydration and acclimatization because they increase the ability of the body to tolerate heat stress. Engineering and administrative controls are important in reducing heat exposure and are discussed in Section V.

Hydration

The most important factor in preventing heat illnesses is adequate water intake.

1. Thirst is not an adequate indicator. Relying on thirst will result in dehydration.

2. When the body becomes dehydrated, it is more difficult to rehydrate because the gut does not absorb water as well. Adequate water intake throughout the day is necessary.

3. Workers should drink at least eight ounces of cool water every 15 to 20 minutes.

4. Under conditions of profuse sweating, a commercial electrolyte replacement drink may be appropriate. Some drinks are too concentrated and need to be diluted or consumed along with water.

5. Salt tablets are to be avoided. Salt tablets irritate the stomach and can lead to vomiting, which results in further dehydration. Misuse can result in excessive water retention and high blood pressure.

Acclimatization

A physiological adaptation will occur with repeated exposure to hot environments. The heart rate will decrease, sweating will increase, sweat will become more dilute and body temperature will be lower. The ability to acclimatize varies among workers. Generally, individuals in good physical condition acclimatize more rapidly than those in poor condition.

Approximately one to two weeks of gradually increasing the workload and time spent in the hot environment will usually lead to full acclimatization. The exposure time should be at least two hours a day for acclimatization to occur. On the first day, the individual performs as much as 20 percent of the normal workload and spends 20 percent of the time in the hot environment. Each day an additional 20 percent of the normal workload and time is added, so that by day six, the worker is performing the full workload for an entire day. After daily heat exposure for seven to 14 days, most individuals perform the work with a much lower core temperature, a much lower heart rate and a higher sweat rate.

Acclimatization is lost when exposure to hot environments does not occur for several days. After a one week absence, a worker needs to reacclimatize by following a schedule similar to that for initial acclimatization. The acclimatization will occur more rapidly, so the employee can begin with 50 percent of the workday exposure the first day, 60 percent on the second, 80 percent on the third and 100 percent on day four.

IV. Evaluation

Two commonly used instruments to obtain heat stress measurements are the heat stress monitor and the sling psychrometer. The heat stress monitor measures several temperatures simultaneously and accounts for radiant heat and air movement. The sling psychrometer is a less expensive and simpler device, but does not take into account radiant heat and requires that air movement must be determined separately.

The measurements obtained from either of these instruments are converted to one value, the wet bulb globe temperature (WBGT), for determining compliance with Minnesota Rules. WBGT is an index of heat stress indicating relative comfort. It considers temperature, humidity, radiant heat and air movement. The calculated value can then be compared to those found in Minnesota Rules 5205.0110, subp. 2a (Appendix A).

Heat stress monitor

This monitor measures dry-bulb temperature, natural wet-bulb temperature and radiant heat, and is the preferred method for determining heat stress. The air temperature is measured by the dry-bulb thermometer (T_{db}). The wet-bulb temperature (T_{nwb}) accounts for humidity and air movement. The globe thermometer (T_g) measures heat from radiant energy sources, such as the sun or a furnace, and also accounts for air temperature and movement. The monitor determines a WBGT from these measurements using the following equations.

For outdoor use in sunshine:

$$WBGT_{out} = 0.7(T_{nwb}) + 0.2(T_g) + 0.1(T_{db}) \text{ in °F or °C}$$

For indoor measurements or outdoor measurements in the shade:

$$WBGT = 0.7(T_{nwb}) + 0.3(T_g) \text{ in °F or °C}$$

For comparison to the Minnesota heat stress limits, the indoor WBGT must be used.

The monitor should be placed on a flat surface at about the chest height of workers in the area. Care should be taken that the surface chosen has approximately the same temperature as the air.

When using a heat stress monitor, sufficient time must be allowed for the readings to stabilize. This can take up to 20 minutes if the change in temperature is great.

Sling psychrometer

The sling psychrometer measures dry-bulb temperature (T_{db}) and psychometric wet-bulb temperature (T_{wb}). The psychometric wet-bulb temperature is not the same as the natural wet-bulb temperature obtained with a heat stress monitor, because the swinging of the psychrometer creates a very high rate of air movement. A sling psychrometer should not be used if there is heat from a radiant heat source (such as hot surfaces) in the area. Use of the sling psychrometer under such circumstances would result in an underestimate of total heat exposure.

The wick covering the wet-bulb thermometer must be clean and thoroughly wetted. The psychrometer must be swung for one minute, read, then swung for an additional half minute to be sure the readings do not change.

The humidity can be read from the sliding scale on the psychrometer using wet- and dry-bulb readings.

Air movement needs to be estimated using the following guide:

still air – no sensation of air movement	< 40 fpm
light breeze – slight perception of air movement	40-200 fpm
moderate breeze – papers move, hair disturbed	200-240 fpm
strong breeze – clothing moves	> 240 fpm

Effective temperature (ET) can be approximated using the table in Appendix B.

WBGT can be approximated from effective temperature by using the following relationship:

$$WBGT = 1.102ET - 9.1 \text{ in °F}$$

Time-weighted average

A two-hour time-weighted average effective temperature ($WBGT_{2hr}$) is used by MNOSHA to measure a short-term exposure to heat stress. The short-term exposure is important for identifying exposures of only a few hours, since even short exposures can be hazardous. On the other hand, an exposure of only a few minutes is not likely to be hazardous unless the temperature is extreme.

Representative measurements must be made during the time period chosen. This period should include the hottest working conditions during the day. If the worker is exposed to differing levels of heat stress during the two hours, the $WBGT_{2hr}$ in each area and time spent in each area must be determined. This would include time spent on breaks in cooler areas.

$$WBGT_{2hr} = \frac{WBGT_1 \times t_1 + WGBT_2 \times t_2 + WGBT_3 \times t_3 + ... + WBGT_n \times t_n}{t_1 + t_2 + t_3 + ... + t_n}$$

$$2\ hr = t_1 + t_2 + t_3 + ... + t$$

The work activity needs to be categorized as light, moderate or heavy work. Examples of light work are typing or standing at a machine or bench with light arm work. Examples of moderate work are use of arms and hands while walking about. Examples of heavy work are shoveling, heavy lifting, pushing or pulling.

The two-hour time-weighted average WBGT, with the work category (light, moderate or heavy) is used to determine if an overexposure has occurred. Minnesota Rules 5205.0110, Indoor Ventilation and Temperature in Places of Employment, contains the heat stress standard for indoor settings. For light work, the WBGT limit is 86ºF WBGT. For moderate work, the WBGT limit is 80ºF. For heavy work, the WBGT limit is 77ºF.

Example

Measurements were taken in a food processing plant. One employee was monitored. The worker operated one machine in the production area and took a break in a separate room.

No.	Sampling period	Time (min.)	Area sampled	Activity	Readings from heat stress monitor (ºF)			
					T_g	T_{db}	T_{nwb}	WBGT
1	8 to 8:30	30	Cooker	Product rotation – moderate work	98	95	80	85
2	8:30 to 8:50	20	Cooker	Unloading – moderate work	97	90	78	83
3	8:50 to 9:15	25	Cooker	Finishing – moderate work	95	90	78	83
4	9:15 to 9:30	15	Break room	Break	80	78	73	75
5	9:30 to 10	30	Cooker	Unloading – moderate work	98	94	80	85

T_g = globe temperature
T_{db} = dry-bulb temperature (regular thermometer reading)
T_{nwb} = natural wet-bulb temperature

A two-hour time-weighted average is then determined:

$$WBGT_{2hr} = \frac{(85)(30)+(83)(20)+(83)(25)+(75)(15)+(85)(30)°F \text{ min}}{30+20+25+15+30 \text{ min}}$$

$$WBGT_{2hr} = \frac{2550+1660+2075+1125+2550}{120} = \frac{9960}{120}$$

$$WBGT_{2hr} = 83ºF$$

The two-hour time-weighted average WBGT limit for moderate work is 80ºF, so an overexposure has occurred and steps must be taken to reduce the heat stress.

Heat index

While the MNOSHA heat stress standard for indoor work areas is based on the WBGT method, federal OSHA has promoted the use of the heat index as part of their heat stress campaign for outdoor workers. This tool was created by the National Weather Service and uses a combination of air temperature and relative humidity. The heat index is then determined from the chart in Appendix C.

V. Control

If the heat exposure limit has been exceeded, steps must be taken to reduce the temperature of the work environment, the time spent in the hot area, the type of work performed or the amount of work done.

Engineering controls to reduce the workplace temperature may be needed. This may include improving the general ventilation, installing local exhaust ventilation to remove heat produced by machinery, installing air conditioning, such as in break rooms or in work areas, and providing heat shields if radiant heat is a problem. Outdoor workers should be provided with shade during their rest breaks. Fans should be used with caution. If the air temperature is higher than the skin temperature (which is normally about 95°F), the heat load on the individual actually increases.

Outside temperature and humidity levels should be measured. This information can be useful in determining the feasibility of engineering controls. The information could also be used to predict days on which heat stress will be a problem. If overexposures occur only on unusually hot days, then engineering controls may not be necessary and exposures could be reduced by limiting the time spent in the hot areas.

If no breaks in cooler areas occurred during the measuring period, the WBGT should be determined for the break area so that a work/rest pattern could be developed to reduce heat exposure to an acceptable level.

Administrative controls can include providing more frequent rest breaks and/or longer breaks in cool areas to reduce the two-hour time-weighted average WBGT. However, rest breaks do not necessarily have to be in a cooler area. Under extreme conditions, the length of the breaks may be longer than the work periods. Worker rotation or assigning more workers to perform the same tasks can reduce the exposure time and decrease the physical workload.

If other controls are not adequate, personal protective equipment (PPE) should be considered. PPE includes reflective clothing, ice vests, wetted clothing, and air- and water-cooled garments. However, PPE used as protection from other hazards, such as respirators and totally encapsulating suits, can add to heat stress and heat strain. (This is also true of heavier or multiple layers of clothing, which interferes with the transfer of heat from the body to the air.)

The most important measure in reducing heat stress is ensuring adequate hydration. Cool water should be readily available in the work area so workers do not need to leave the area to get a drink of water. The employer must stress the importance of drinking water frequently and more than thirst indicates.

VI. Training

Supervisors and workers who may be exposed to hot environments must receive training about heat stress, symptoms of heat illnesses and treatment. Under Minnesota's Employee Right-to-Know rules (Minnesota Rules 5206.0700, subps. 1 and 3), employers are required to provide training about the hazards of exposure to heat if exposures are expected to approach the limits in the heat stress standard. This training should include:

- the limits in the heat stress standard;
- the possible adverse health effects of exposure to heat;
- the symptoms of heat-related illnesses;
- appropriate medical treatment;
- the known proper conditions for exposure to heat; and
- if appropriate, the name, address and phone number of the manufacturer of the equipment creating or contributing to the risk of heat stress.

This training must be conducted before an employee is exposed to heat approaching the limits in the heat stress standard; refresher training must be conducted at least annually. All training must be conducted at the employer's expense. Other requirements under Employee Right-to-Know include a complete written program, the availability of a data sheet describing the same information as covered in the training program and signs identifying those areas in the facility where exposures approach the limits in the heat stress standard.

VII. Additional resources

- Federal OSHA's Campaign to Prevent Heat Illness in Outdoor Workers – www.osha.gov/SLTC/heatillness

- Federal OSHA's Safety and Health Topics: Heat Stress – www.osha.gov/SLTC/heatstress

- CDC NIOSH Workplace Safety and Health Topics: Heat Stress – www.cdc.gov/niosh/topics/heatstress (includes *Criteria for a recommended standard: occupational exposure to hot environments*)

- OSHA-NIOSH InfoSheet: *Protecting Workers from Heat Illness* – www.cdc.gov/niosh/docs/2011-174/pdfs/2011-174.pdf

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Appendix A: Minnesota Rules 5205.0110 — Workroom Ventilation and Temperature in Places of Employment

Subpart 1. **Air flow and circulation.** Air shall be provided and distributed in all indoor places of employment as required in this part, unless prohibited by process requirements.

Outdoor air shall be provided to all indoor places of employment at the rate of 15 cubic feet per minute per person.

Air circulated in any indoor place of employment shall be supplied through air inlets arranged, located, and equipped so that the workers shall not be subjected to air velocities exceeding 200 feet per minute except under special circumstances specified in this part or where approved by the Department of Labor and Industry.

Subp. 2. [Repealed, 21 SR 1897]

Subp. 2. **Heat conditions.** The requirements of this subpart cover employee exposure to indoor environmental heat conditions.

A. The following definitions apply when assessing and controlling health hazards associated with indoor climate.

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

   (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 or higher 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 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.

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.

Work activity	WBGT, ºF
Heavy work	77
Moderate work	80
Light work	86

C. Employees with exposure to heat shall be provided training according to part 5206.0700, subparts 1 and 3.

Subp. 3. **Cold conditions.** The requirements of this subpart cover employee exposure to indoor environmental cold conditions. The definitions in subpart 2 apply to this subpart.

A. Indoor places of employment shall maintain a minimum air temperature of 60 degrees Fahrenheit where heavy work is performed, unless prohibited by process requirements.

B. Indoor places of employment shall maintain a minimum air temperature of 65 degrees Fahrenheit where light to moderate work is performed, unless prohibited by process requirements.

Subp. 4. **Recirculated air.** Air from any exhaust system handling materials listed in Code of Federal Regulations, title 29, subpart Z, shall not be recirculated without written permission from the Department of Labor and Industry.

Subp. 5. **Definitions.** For the purposes of this part, the following definitions apply.

A. "Indoor" means any space between a floor and a ceiling that is bound on all sides by walls. A wall includes any door, window, retractable divider, garage door, or other physical barrier that is temporary or permanent, whether open or closed.

B. "Place of employment" has the meaning given in Minnesota Statutes, section 182.651, subdivision 10.

Statutory Authority: *MS s 182.655; 182.657*
History: *12 SR 634, 21 SR 1897; 39 SR 418*

Appendix B: Examples of conditions that correspond to the heat stress limits (approximate)

Two-hour TWA permissible heat exposure limit Work load	Relative humidity (%)	No air movement		300 fpm	
		Dry bulb T_{db} (ºF)	Psychrometric wet bulb T_{wb} (ºF)	Dry bulb T_{db} (ºF)	Psychrometric wet bulb T_{wb} (ºF)
WBGT = 86ºF 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 = 80ºF 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 = 77ºF Heavy work (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 chart above. The following equation can be used to approximate WBGT from ET:

$$WBGT = 1.102\ ET - 9.1 \text{ in degrees °F}$$

Appendix C: Heat index chart

The National Weather Service developed the heat index to alert the public of the combined effects of heat and humidity. The National Oceanic and Atmospheric Administration (NOAA) values are based on shaded areas with light winds. Full sunshine alone can increase the heat index by 15°F. Strenuous work and the use of heavy or specialized protective clothing can also increase the risk to workers. Additional various protective measures to be taken at each level can be found on the federal OSHA website at www.osha.gov/SLTC/heatillness/heat_index/protective_measures.html.

NOAA's National Weather Service heat index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Modified heat index table to protect workers

The values below are different from those in the NOAA chart above to adjust for working conditions.

Heat index	Risk level	Protective measures
Less than 91°F	Lower (caution)	Basic heat safety and planning
91°F to 103°F	Moderate	Implement precautions and heighten awareness
103°F to 115°F	High	Additional precautions to protect workers
Greater than 115°F	Very high to extreme	Triggers even more aggressive protective measures