# HEAT STRESS

DEPARTMENT OF LABOR AND INDUSTRY

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Occupational Safety and Health Division

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# MNOSHA HEAT STRESS GUIDE

## I. INTRODUCTION

Heat stress may occur year-round in foundries, kitchens, or laundries, or only a few days during the summer in almost any work setting.

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, subpart 2a, which was revised in July, 1997 and can be found in Appendix A, is the Minnesota OSHA 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 by using a sling psychrometer and the nomogram in Appendix B to obtain effective temperature, then converting effective temperature to WBGT. Appendix C 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, subparts 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, lose 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 victim immediately. Remove 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 sweating mechanism. The body cannot get rid of excess heat. |
| Prevention: | Acclimatization. Close monitoring of workers for signs of heat illness. Medical screening. Drink plenty of water. |

**HEAT EXHAUSTION**

| | |
|---|---|
| Symptoms: | Fatigue, weakness, dizziness, faintness. Nausea, headache. Moist, clammy skin; pale or flushed. Rapid pulse. Normal or slightly elevated temperature. |
| Treatment: | Have victim rest in a cool area and drink fluids. |
| Cause: | Dehydration causes blood volume to decrease. |
| Prevention: | Acclimatization. Drink 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 victim to a cool area. Have 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. Drink plenty of water. Avoid standing in one place. 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: | Rest. Drink water and eat more salty foods. |
| Cause: | Not well understood. May be due to a lose 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: | Keep skin clean and dry. |
| Cause: | Skin is constantly wet from sweat. Sweat gland ducts become plugged, leading to inflammation. |
| Prevention: | Shower after working in hot environment. Keep 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 less than what would result in other heat illnesses. |
| Prevention: | Acclimatization and training. |

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

# 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. Once 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 five to seven ounces of cool water every 15-20 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.

## 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 week of gradually increasing the workload and time spent in the hot environment will usually lead to full acclimatization. On the first day the individual performs 50 percent of the normal workload and spends 50 percent of the time in the hot environment. Each day an additional 10 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. The exposure time should be at least two hours per day for acclimatization to occur.

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 increases in workload and time can increase by approximately 20 percent each day after the first day, reaching normal work conditions by 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 these found in Minnesota Rules 5205.0110, subpart 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 dry-bulb thermometer measures air temperature ($T_{db}$). 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 wet-bulb globe temperature (WBGT) from these measurements using the following equations.

For outdoor use in sunshine:

$$WBGT_{out}=0.7(T_{nwb})+0.2(T_g)+0.1(T_{db})$$

For indoor measurements or outdoor measurements in the shade:

$$WBGT=0.7(T_{nwb})+0.3(T_g)$$

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 thermodynamic wet-bulb temperature ($T_{wb}$). The thermodynamic 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 (i.e., 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 determined from the nomogram in Appendix B. Draw a line from the dry-bulb temperature on the left-hand scale to the psychrometric wet-bulb temperature on the right-hand scale. The effective temperature is read at the point where this line intersects the appropriate curved line representing the estimated air velocity.

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

$$WBGT = 1.102ET - 9.1$$

## 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 workload 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 workload are shoveling, heavy lifting, pushing, or pulling.

The two-hour time-weighted average WBGT along with the workload (light, moderate or heavy) is used to determine if an overexposure has occurred. Minnesota Rules 5205.0110, General Ventilation and Temperature Requirements, 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 plan. 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 | 08:00-08:30 | 30 | Cooker | Product rotation — moderate work | 98 | 95 | 80 | 85 |
| 2 | 08:30-08:50 | 20 | Cooker | Unloading — moderate work | 97 | 90 | 78 | 83 |
| 3 | 08:50-09:15 | 25 | Cooker | Finishing — moderate work | 95 | 90 | 78 | 83 |
| 4 | 09:15-09:30 | 15 | Break Room | Break | 80 | 78 | 73 | 75 |
| 5 | 09:30-10:00 | 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:

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

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

$$WBGT_{2hr} = 83°F$$

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.

# 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, and/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, and providing heat shields if radiant heat is a problem.

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.

The most important measure in reducing heat stress is ensuring adequate hydration. Cool water should be readily available in the work area so that 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 on heat stress, symptoms of heat illnesses, and treatment. Under Minnesota's Employee Right-to-Know Rules (Minnesota Rules 5206.0700, subparts 1 and 3) employers are required to provide training on 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 manufacturing of 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, and 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.

# APPENDICES

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# Appendix A: Minnesota Rules 5205.0110 — Workroom Ventilation and Temperature

Subpart 1. **Air.** Air shall be provided and distributed in all workrooms as required in this code unless prohibited by process requirements.

Outside air shall be provided to all workrooms at the rate of 15 cubic feet per minute per person.

Air circulated in any workroom 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 code or where approved by the Department of Labor and Industry.

Subp. 2. Repealed (6/30/97)

Subp. 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. $WBGT = 0.7T_{nwb} + 0.3T_g$

(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 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.

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 Minnesota Rules 5206.0700, subparts 1 and 3.

Subp. 3. **Minimum air temperature.** Workroom temperatures shall be maintained as follows:

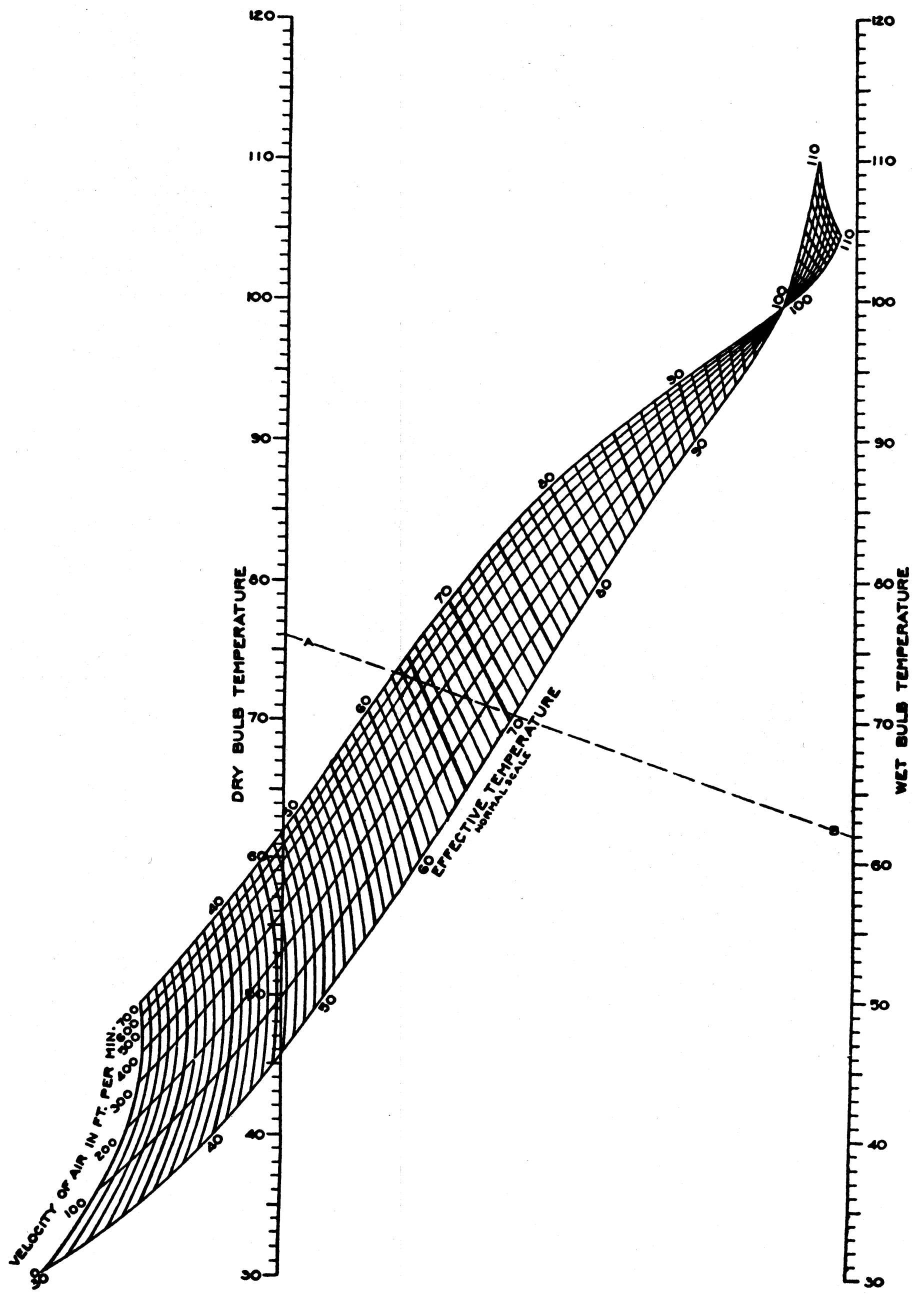
A. The minimum air temperature of 60 degrees Fahrenheit shall be maintained in all rooms where work of a strenuous nature is performed, unless prohibited by process requirements.

B. The minimum air temperature of 65 degrees Fahrenheit shall be maintained in all other workrooms 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.

**SA:** MS s 182.655; 182.657
**HIST:** 12 SR 634, 21 SR 1897

## APPENDIX B: EFFECTIVE TEMPERATURE CHART




**Note:** From *Industrial Ventilation: A Manual of Recommended Practice* (17th ed.) (p. 3-5) by the American Conference of Governmental Industrial Hygienists, 1982, Lansing, MI: ACGIH. Copyright 1982 by the American Conference of Governmental Industrial Hygienists. Reprinted by permission.

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

| 2-hour TWA Permissible Heat Exposure Limit<br><br>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<br><br>Light work<br><br>(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<br><br>Moderate work<br><br>(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<br><br>Heavy work<br><br>(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:

$$WBGT = 1.102\ ET - 9.10$$