COMPLIANCE TRAINING ONLINE.com

Cal/OSHA, DOT HAZMAT, EEOC, EPA, HIPAA, IATA, IMDG, TDG, MSHA, OSHA, Australia WHS, and Canada OHS Regulations and Safety Online Training

This document is provided as a training aid and may not reflect current laws and regulations.

Be sure and consult with the appropriate governing agencies or publication providers listed in the "Resources" section of our website.

www.ComplianceTrainingOnline.com

Heat stress

August 2012
Minnesota Department of Labor and Industry
Occupational Safety and Health Division

This material can be provided to you in a different format (Braille, large print or audio) if you call the MNOSHA Training/Outreach Office at (651) 284-5050; at 1-877-470- 6742; or via TTY (651) 297-4198.

For more information, contact:

Minnesota Department of Labor and Industry
Occupational Safety and Health Division
443 Lafayette Road N.
St. Paul, MN 55155-4307
Phone: (651) 284-5050
Toll-free: 1-877-470-6742
Email: osha.compliance@state.mn.us
Website: www.dli.mn.gov

Table of contents

MNOSHA 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.

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 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 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.

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 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 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 in the mother above 102°F 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 five to seven 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.

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 a 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:

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

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 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 scale to the psychrometric wet-bulb temperature on the right 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:

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

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 workload. Examples of light workload are typing or standing at a machine or bench with light arm work. Examples of moderate workload 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 workload, the WBGT limit is 86ºF WBGT. For moderate workload, the WBGT limit is 80ºF. For heavy workload, 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	8:00 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 10:00	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:

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

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

$$WBGT_{2hr} = 83°F$$

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. 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, subparts 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 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 available at www.osha.gov/SLTC/heatillness
- Federal OSHA's Safety and Health Topics: Heat Stress available at www.osha.gov/SLTC/heatstress
- CDC NIOSH Workplace Safety and Health Topics: Heat Stress available at http://www.cdc.gov/niosh/topics/heatstress (includes *Criteria for a recommended standard ... occupational exposure to hot environments* [Rev. Ed.] and *Working in hot environments*)
- OSHA-NIOSH InfoSheet: *Protecting Workers from Heat Illness* available at www.cdc.gov/niosh/docs/2011-174/pdfs/2011-174.pdf
- American Conference of Governmental Industrial Hygienists (ACGIH®). *2011 TLVs® and BEIs®* Book. Copyright 2011. (See Appendix D).

Other materials used in the preparation of this document

ACGIH®. (1982). *Industrial ventilation: A manual of recommended practice* (17th Ed.). Lansing, MI: Author.

ACGIH®. (1998). *Industrial ventilation: A manual of recommended practice* (23th Ed.). Cincinnati, OH: Author.

Ciriello, V. M. & Snook, S. H. (1977). The prediction of WBGT from the Botsball. *American Industrial Hygiene Association journal, 38*, 264-271.

International Organization for Standardization. (1989). ISO 7243 *Hot environments – Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature* (2nd Ed.). Geneva, Switzerland: Author.

Minard, D. (1973). Physiology of heat stress. In NIOSH, *The industrial environment: Its evaluation and control* (pp. 399-429). Cincinnati, OH: Author.

Mutchler, J. E., & Vecchio, J. R. (1977). Empirical relationships among heat stress indices in 14 hot industries. *American Industrial Hygiene Association journal, 38*, 253-263.

OSHA. (1995). Heat stress. In OSHA , *OSHA technical manual* (section III: chapter 4). Washington, DC: Author.

Ramsey, J. D. & Bernard, T. E. (2000). Heat stress. In R. L. Harris (Ed.), *Patty's Industrial Hygiene: Vol 2.* (5th ed., pp. 925-984). New York: Wiley.

Walters, J. D. (1968). A field assessment of a prototype meter for measuring the wet-bulb globe-thermometer index. *British Journal of Industrial Medicine, 25,* 235-240.

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.

Appendix C: 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 (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:

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

Appendix D: American Conference of Governmental Industrial Hygienists threshold limit values for heat stress and heat strain

Note: This section is included for those readers interested in a more detailed discussion about heat stress. The following is adapted from the American Conference of Governmental Industrial Hygienists (ACGIH®), *2011 TLVs® and BEIs®* Book, pages 211-220. Copyright 2011. Reprinted with permission.

The goal of this TLV® is to maintain body core temperature within + 1°C of normal (37°C). This core body temperature range can be exceeded under certain circumstances with selected populations, environmental and physiologic monitoring, and other controls.

More than any other physical agent, the potential health hazards from work in hot environments depends strongly on physiological factors that lead to a range of susceptibilities depending on the level of acclimatization. Therefore, professional judgment is of particular importance in assessing the level of heat stress and physiological heat strain to adequately provide guidance for protecting nearly all healthy workers with due consideration of individual factors and the type of work. Assessment of both heat stress and heat strain can be used for evaluating the risk to worker safety and health. A decisionmaking process is suggested in Figure 1. The exposure guidance provided in Figures 1 and 2 and in the associated documentation of the TLV® represents conditions under which it is believed that nearly all heat acclimatized, adequately hydrated, unmedicated, healthy workers may be repeatedly exposed without adverse health effects. The action limit (AL) is similarly protective of unacclimatized workers and represents conditions for which a heat stress management program should be considered. While not part of the TLV®, elements of a heat stress management program are offered. The exposure guidance is not a fine line between safe and dangerous levels.

Heat stress is the net heat load to which a worker may be exposed from the combined contributions of metabolic heat, environmental factors, (i.e., air temperature, humidity, air movement and radiant heat) and clothing requirements. A mild or moderate heat stress may cause discomfort and may adversely affect performance and safety, but it is not harmful to health. As the heat stress approaches human tolerance limits, the risk of heat-related disorders increases.

Heat strain is the overall physiological response resulting from heat stress. The physiological responses are dedicated to dissipating excess heat from the body.

Acclimatization is a gradual physiological adaptation that improves an individual’s ability to tolerate heat stress. Acclimatization requires physical activity under heat-stress conditions similar to those anticipated for the work. With a recent history of heat-stress exposures of at least two continuous hours (e.g., five of the past seven days to 10 of 14 days), a worker can be considered acclimatized for the purposes of the TLV®. Its loss begins when the activity under those heat stress conditions is discontinued, and a noticeable loss occurs after four days and may be completely lost in three to four weeks. Because acclimatization is to the level of the heat stress exposure, a person will not be fully acclimatized to a sudden higher level; such as during a heat wave.

The decision process illustrated in Figure 1, should be started if:
(1) a qualitative exposure assessment indicates the possibility of heat stress;
(2) there are reports of discomfort due to heat stress; or
(3) professional judgment indicates heat stress conditions.

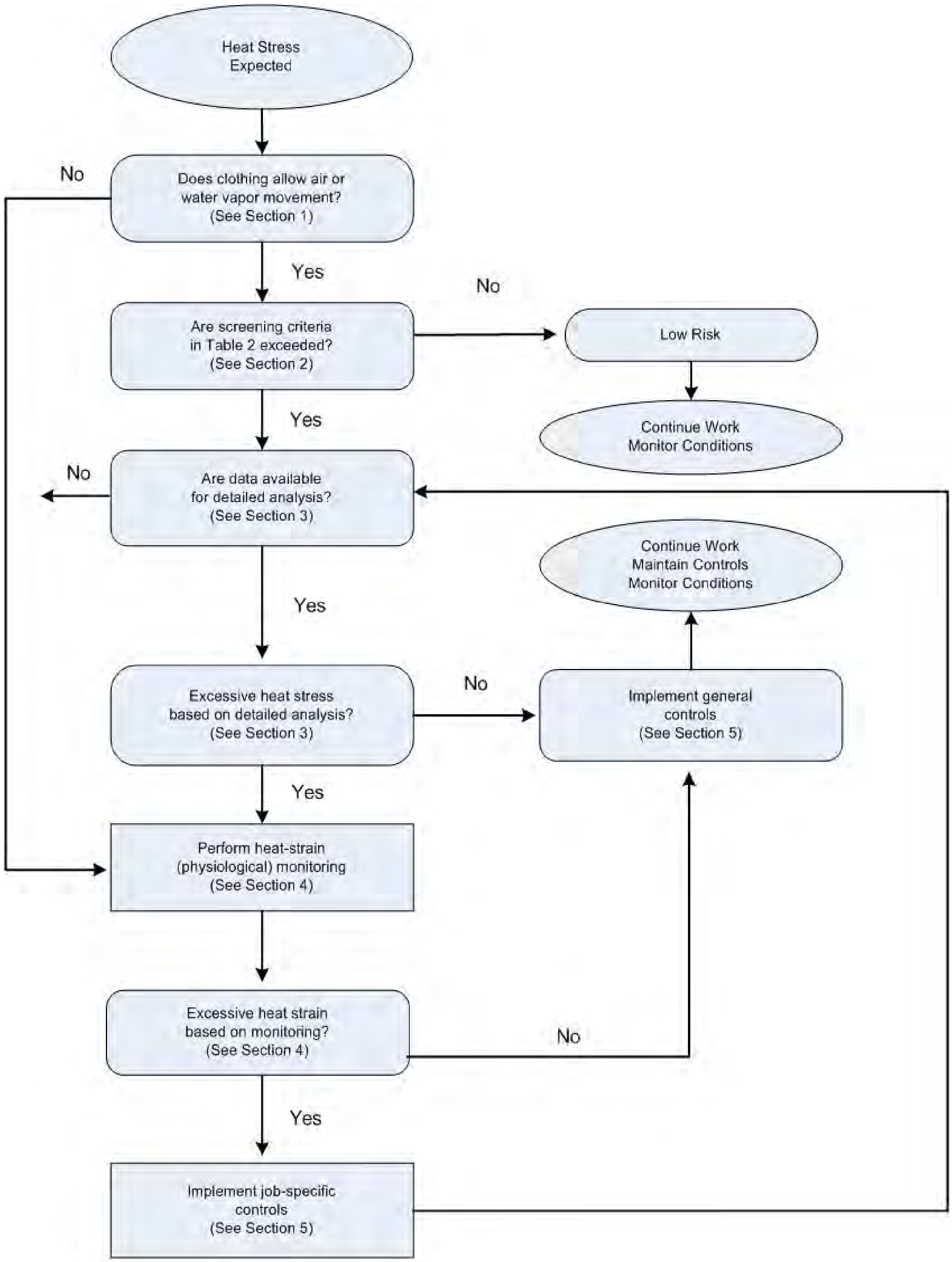

Figure 1. Evaluating heat stress and strain.

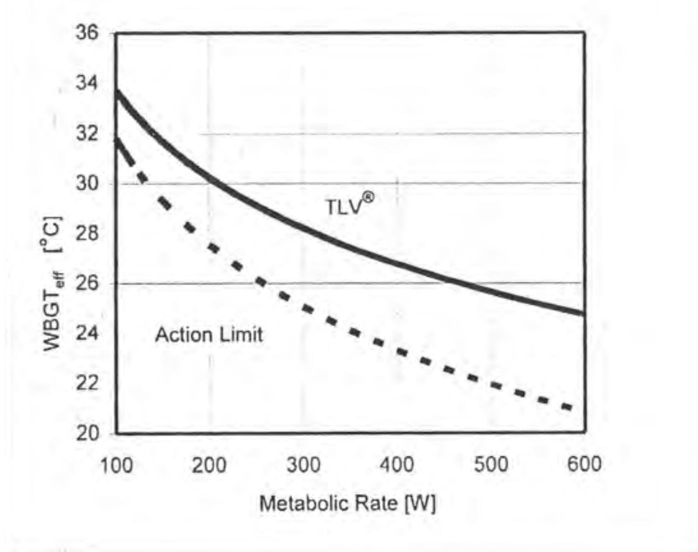

Figure 2. TLV® (solid line) and action limit (broken line) for heat stress. $WBGT_{eff}$ is the measured WBGT plus the clothing-adjustment factor.

Section 1: *Clothing.* Ideally, free movement of cool, dry air over the skin's surface maximizes heat removal by both evaporation and convection.

Evaporation of sweat from the skin is the predominant heat removal mechanism. Water-vapor-impermeable, air-impermeable and thermally insulating clothing, as well as encapsulating suits and multiple layers of clothing, severely restrict heat removal. With heat removal hampered by clothing, metabolic heat may produce excessive heat strain even when ambient conditions are considered cool.

Figure 1 requires a decision about clothing and how it might affect heat loss. The WBGT-based heat exposure assessment was developed for a traditional work uniform of a long-sleeved shirt and pants. If the required clothing is adequately described by one of the ensembles in Table 1 or by other available data, then the "Yes" branch is selected.

If workers are required to wear clothing not represented by an ensemble in Table 1, then the "No" branch should be taken. This decision is especially applicable for clothing ensembles that are:
1) totally encapsulating suits; or 2) multiple layers where no data are available for adjustments. For these kinds of ensembles, Table 2 is not a useful screening method to determine a threshold for heat-stress management actions and some risk must be assumed. Unless a detailed analysis method appropriate to the clothing requirements is available, physiological and signs/symptoms monitoring described in Section 4 and Table 4 should be followed to assess the exposure.

Section 2: *Screening threshold based on wet-bulb globe temperature (WBGT).* The WBGT offers a useful first order index of the environmental contribution to heat stress. It is influenced by air temperature, radiant heat, air movement and humidity. As an approximation, it does not fully account for all the interactions between a person and the environment and cannot account for special conditions such as heating from a radiofrequency/microwave source.

Table 1. Clothing – Adjustment factors for some clothing ensembles*	
Clothing type	***Addition to WBGT [°C]***
Work clothes (long-sleeved shirt and pants)	0
Cloth (woven material) coveralls	0
Double layer woven clothing	3
SMS polypropylene coveralls	0.5
Polyolefin coveralls	1
Limited-use vapor-barrier coveralls	11

*These values must not be used for completely encapsulating suits, often called Level A. Clothing adjustment factors cannot be added for multiple layers. The coveralls assume that only modesty clothing is worn underneath, not a second layer of clothing.

WBGT values are calculated using one of the following equations:

With direct exposure to sunlight:

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

Without direct exposure to the sun:

$$WBGT_{in} = 0.7\ T_{nwb} + 0.3T_g$$

Where

T_{nwb}= natural wet-bulb temperature (sometimes called NWB)
T_g= globe temperature (sometimes called GT)
T_{db}= dry-bulb (air) temperature (sometimes called DB)

Because WBGT is only an index of the environment, the screening criteria are adjusted for the contributions of work demands and clothing. Table 2 provides WBGT criteria suitable for screening purposes. For clothing ensembles listed in Table 1, Table 2 can be used when the clothing adjustment factors are added to the environmental WBGT.

To determine the degree of heat stress exposure, the work pattern and demands must be considered. If the work (and rest) is distributed over more than one location, then a time-weighted average WBGT should be used for comparison to Table 2 limits.

As metabolic rate increases (i.e., work demands increase) the criteria values in the table decrease to ensure that most workers will not have a core body temperature above 38°C. Correct assessment of work rate is of equal importance to environmental assessment in evaluating heat stress. Table 3 provides broad guidance for selecting the work rate category to be used in Table 2. Often there are natural or prescribed rest breaks within an hour of work, and Table 2 provides the screening criteria for three allocations of work and rest.

Based on metabolic rate category for the work and the approximate proportion of work within an hour, a WBGT criterion can be found in Table 2 for the TLV® and for the action limit. If the measured time-weighted average WBGT adjusted for clothing is less than the table value for the action limit, the "No" branch in Figure 1 is taken and there is little risk of excessive exposures to heat stress. If the conditions are above the action limit, but below the TLV®, then consider general controls described in Table 5. If there are reports of the symptoms of heat-related disorders such as fatigue, nausea, dizziness and lightheadedness, then the analysis should be reconsidered.

Table 2. Screening criteria for TLV® and action limit for heat stress exposure

	TLV® (WBGT values in °C)				*Action limit (WBGT values in °C)*			
Allocation of work in a cycle of work and recovery	**Light**	**Moderate**	**Heavy**	**Very heavy**	**Light**	**Moderate**	**Heavy**	**Very heavy**
75 to 100%	31.0	28.0	-	-	28.0	25.0	-	-
50 to 75%	31.0	29.0	27.5	-	28.5	26.0	24.0	-
25 to 50%	32.0	30.0	29.0	28.0	29.5	27.0	25.5	24.5
0 to 25%	32.5	31.5	30.5	30.0	30.0	29.0	28.0	27.0

Notes:

- See Table 3 and *Documentation* for work demand categories.
- WBGT values are expressed to the nearest 0.5 °C
- The thresholds are computed as a TWA-metabolic rate where the metabolic rate for the rest is taken as 115 W and work is the representative (mid-range) value of Table 3. The time base is taken as the proportion of work at the upper limit of the percent work range (e.g., 50 percent for the range of 25 to 50 percent).
- If work and rest environments are different, hourly time-weighted averages (TWA) WBGT should be calculated and used. TWAs for work rates should also be used when the work demands vary within the hour, but note that the metabolic rate for rest is already factored into the screening limit.
- Values in the table are applied by reference to the “work-rest regimen” section of the documentation and assume eight-hour workdays in a five-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 heavy and very heavy work among less fit workers regardless of WBGT, criteria values are not provided for continuous work and for up to 25 percent rest in an hour for very heavy. The screening criteria are not recommended and a detailed analysis and/or physiological monitoring should be used.
- Table 2 is intended as an initial screening tool to evaluate whether a heat stress situation may exist (according to Figure 1) and, thus, the table is more protective than the TLV® or action limit (Figure 2). Because the values are more protective, they are not intended to prescribe work and recovery periods.

If the work conditions are above the TLV® screening criteria in Table 2, then a further analysis is required following the YES branch.

Section 3: *Detailed analysis.* Table 2 is intended to be used as a screening step. It is possible that a condition may be above the TLV® or action limit criteria provided in Table 2 and still not represent an exposure above the TLV® or the action limit. To make this determination, a detailed analysis is required. Methods are fully described in the documentation, in industrial hygiene and safety books, and in other sources.

Provided that there is adequate information on the heat stress effects of the required clothing, the first level of detailed analysis is a task analysis that includes a time-weighted average of the effective WBGT (environmental WBGT plus clothing adjustment factor) and the metabolic rate. Some clothing adjustment factors have been suggested in Table 1. Factors for other clothing ensembles appearing in the literature can be used in similar fashion following good professional judgment. The TLV® and action limit are shown in Figure 2.

Table 3. Metabolic rate categories and the representative metabolic rate with example activities		
Category	**Metabolic rate [W]***	**Examples**
Rest	115	Sitting
Light	180	Sitting with light manual work with hands or hands and arms and driving. Standing with some light arm work and occasional walking.
Moderate	300	Sustained moderate hand and arm work, moderate arm and leg work, moderate arm and trunk work, or light pushing and pulling. Normal walking.
Heavy	415	Intense arm and trunk work, carrying, shoveling, manual sawing; pushing and pulling heavy loads; and walking at a fast pace.
Very heavy	520	Very intense activity at fast to maximum pace.

*The effect of body weight on the estimated metabolic rate can be accounted for by multiplying the estimated rate by the ratio of actual body weight divided by 70 kg (154 lb).

The second level of detailed analysis would follow a rational model of heat stress, such as the International Standards Organization (ISO) Predicted Heat Strain (ISO 7933 2004; Malchaire et al., 2001). While a rational method (versus the empirically derived WBGT thresholds) is computationally more difficult, it permits a better understanding of the sources of the heat stress and is a means to appreciate the benefits of proposed modifications in the exposure. Guidance to the ISO method and other rational methods is described in the literature.

The screening criteria require the minimal set of data to make a determination. Detailed analyses require more data about the exposures. Following Figure 1, the next question asks about the availability of data for a detailed analysis. If these data are not available, the “No” branch takes the evaluation to physiological monitoring to assess the degree of heat strain.

If the data for a detailed analysis are available, the next step in Figure 1 is the detailed analysis. If the exposure does not exceed the criteria for the action limit (or unacclimatized workers) for the appropriate detailed analysis (e.g., WBGT analysis, another empirical method or a rational method), then the “No” branch can be taken. If the action limit criteria are exceeded but the criteria for the TLV® (or acclimatized workers) in the detailed analysis are not exceeded, then implement general controls and continue to monitor the conditions. General controls include training for workers and supervisors, heat stress hygiene practices and medical surveillance. If the exposure exceeds the limits for acclimatized workers in the detailed analysis, the “Yes” branch leads to physiological monitoring as the only alternative to demonstrate that adequate protection is provided.

Section 4: *Heat strain.* The risk and severity of excessive heat strain will vary widely among people, even under identical heat stress conditions. The normal physiological responses to heat stress provide an opportunity to monitor heat strain among workers and to use this information to assess the level of heat strain present in the workforce, to control exposures, and to assess the effectiveness of implemented controls. Table 4 provides guidance for acceptable limits of heat strain.

Table 4. Guidelines for limiting heat strain

Monitoring heat strain and signs and symptoms of heat-related disorders is sound industrial hygiene practice, especially when clothing may significantly reduce heat loss. For surveillance purposes, a pattern of workers exceeding the heat strain limits is indicative of a need to control the exposures. On an individual basis, the limits represent a time to cease an exposure and allow for recovery.

One or more of the following measures may mark excessive heat strain, and an individual's exposure to heat stress should be discontinued when any of the following occur:

- sustained (several minutes) heart rate is in excess of 180 bpm (beats per minute) minus the individual's age in years (e.g., 180 - age), for individuals with assessed normal cardiac performance; or
- body core temperature is greater than 38.5°C (101.3°F) for medically selected and acclimatized personnel or greater than 38°C (100.4°F) in unselected, unacclimatized workers; or
- recovery heart rate at one minute after a peak work effort is greater than 120 bpm; or
- there are symptoms of sudden and severe fatigue, nausea, dizziness or lightheadedness.

An individual may be at greater risk of heat-related disorders if:

- profuse sweating is sustained over hours; or
- weight loss over a shift is greater than 1.5 percent of body weight; or
- 24-hour urinary sodium excretion is less than 50 mmoles.

Emergency response: If a worker appears to be disoriented or confused, suffers inexplicable irritability, malaise or chills, the worker should be removed for rest in a cool location with rapidly circulating air and kept under skilled observation. Absent medical advice to the contrary, treat this as an emergency with immediate transport to a hospital. An emergency response plan is necessary.

– Never ignore anyone's signs or symptoms of heat-related disorders. –

Following good industrial hygiene sampling practice, which considers likely extremes and the less tolerant workers, the absence of any of these limiting observations indicates acceptable management of the heat stress exposures. With acceptable levels of heat strain, the “No” branch in Figure 1 is taken. Nevertheless, if the heat strain among workers is considered acceptable at the time, consideration of the general controls is recommended. In addition, periodic physiological monitoring should be continued to ensure acceptable levels of heat strain.

If limiting heat strain is found during the physiological assessments, then the “Yes” branch is taken. This means that suitable job-specific controls should be implemented to a sufficient extent to control heat strain. The job-specific controls include engineering controls, administrative controls and personal protection.

After implementation of the job-specific controls, it is necessary to assess their effectiveness and to adjust them as needed.

Section 5: *Heat stress management and controls*. The elements of a heat stress management program including general and job-specific controls should be considered in the light of local conditions and the judgment of the industrial hygienist. The recommendation to initiate a heat stress management program is marked by 1) heat stress levels that exceed the action limit or 2) work in clothing ensembles that limit heat loss. In either case, general controls should be considered (Table 5).

Heat stress hygiene practices are particularly important because they reduce the risk that an individual may suffer a heat-related disorder. The key elements are fluid replacement, self-determination of exposures, health status monitoring, maintenance of a healthy lifestyle and adjustment of expectations based on acclimatization state. The hygiene practices require the full cooperation of supervision and workers.

In addition to general controls, appropriate job-specific controls are often required to provide adequate protection. During the consideration of job-specific controls, Table 2 and Figure 2, along with Tables 1 and 3, provide a framework to appreciate the interactions among acclimatization state, metabolic rate, work-rest cycles and clothing. Among administrative controls, Table 4 provides acceptable physiological and signs/symptoms limits. The mix of job-specific controls can be selected and implemented only after a review of the demands and constraints of any particular situation. Once implemented, their effectiveness must be confirmed and the controls maintained.

The prime objective of heat stress management is the prevention of heat stroke, which is life-threatening and the most serious of the heat-related disorders. The heat stroke victim is often manic, disoriented, confused, delirious or unconscious. The victim's body core temperature is greater than 40°C (104°F). If signs of heat stroke appear, aggressive cooling should be started immediately, and emergency care and hospitalization are essential. The prompt treatment of other heat-related disorders generally results in full recovery, but medical advice should be sought for treatment and return-to- work protocols. It is worth noting that the possibility of accidents and injury increases with the level of heat stress.

Prolonged increases in deep body temperatures and chronic exposures to high levels of heat stress are associated with other disorders such as temporary infertility (male and female), elevated heart rate, sleep disturbance, fatigue and irritability. During the first trimester of pregnancy, a sustained core temperature greater than 39°C may endanger the fetus.

References

(1) International Organization for Standardization (ISO): Ergonomics of the thermal environment – Analytical determination and interpretation of heat stress using calculation of the predicted heat strain. ISO 7933:2004. ISO, Geneva (2004).
(2) Malchaire J; Piette A; Kampmann B; et al.: Development and validation of the predicted heat strain model. Ann Occup Hyg. 45(2):123-135 (2001).

Table 5. Elements to consider in establishing a heat stress management program

Monitor heat stress (e.g., WBGT screening criteria in Table 2) and heat strain (Table 4) to confirm adequate control.

General controls

- Provide accurate verbal and written instructions, annual training programs and other information about heat stress and strain
- Encourage drinking small volumes (approximately one cup) of cool, palatable water (or other acceptable fluid replacement drink) about every 20 minutes
- Encourage employees to report symptoms of heat-related disorders to a supervisor
- Encourage self-limitation of exposures when a supervisor is not present
- Encourage co-worker observation to detect signs and symptoms of heat strain in others
- Counsel and monitor those who take medications that may compromise normal cardiovascular, blood pressure, body temperature regulation, renal or sweat gland functions, and those who abuse or are recovering from the abuse of alcohol or other intoxicants
- Encourage healthy lifestyles, ideal body weight and electrolyte balance
- Adjust expectations of those returning to work after absence from hot exposure situations and encourage consumption of salty foods (with approval of physician if on a salt-restricted diet)
- Consider pre-placement medical screening to identify those susceptible to systemic heat injury
- Monitor the heat stress conditions and reports of heat-related disorders

Job-specific controls

- Consider engineering controls that reduce the metabolic rate, provide general air movement, reduce process heat and water vapor release and shield radiant heat sources, among others
- Consider administrative controls that set acceptable exposure times, allow sufficient recovery and limit physiological strain
- Consider personal protection that is demonstrated effective for the specific work practices and conditions at the location

– Never ignore anyone's signs or symptoms of heat-related disorders. –

ACGIH® statement of position regarding the TLVs® and BEIs® (excerpt)

- ACGlH® is a not-for-profit scientific association.
- ACGlH® proposes guidelines known as TLVs® and BEls® for use by industrial hygienists in making decisions regarding safe levels of exposure to various hazards found in the workplace.
- ACGlH® is not a standards-setting body.
- Regulatory bodies should view TLVs® and BEls® as an expression of scientific opinion.
- TLVs® and BEls® are not consensus standards.
- ACGlH® TLVs® and BEls® are based solely on health factors; there is no consideration given to economic or technical feasibility. Regulatory agencies should not assume that it is economically or technically feasible to meet established TLVs® or BEls®.
- ACGlH® believes that TLVs® and BEls® should *not* be adopted as standards without an analysis of other factors necessary to make appropriate risk management decisions.
- TLVs® and BEls® can provide valuable input into the risk characterization process. Regulatory agencies dealing with hazards addressed by a TLV® or BEI® should review the full written documentation for the numerical TLV® or BEI®.

ACGIH® published this statement to assist ACGIH® members, government regulators and industry groups in understanding the basis and limitations of the TLVs® and BEls® when used in a regulatory context. The statement was adopted by the ACGIH® board of directors on March 1, 2002.