POLICY STATEMENT ON THE USES OF TLVs® AND BEIs®

The Threshold Limit Values (TLVs®) and Biological Exposure Indices (BEIs®) are developed as guidelines to assist in the control of health hazards. These recommendations or guidelines are intended for use in the practice of industrial hygiene, to be interpreted and applied only by a person trained in this discipline. They are not developed for use as legal standards and ACGIH® does not advocate their use as such. However, it is recognized that in certain circumstances individuals or organizations may wish to make use of these recommendations or guidelines as a supplement to their occupational safety and health program. ACGIH will not oppose their use in this manner, if the use of TLVs and BEIs in these instances will contribute to the overall improvement in worker protection. However, the user must recognize the constraints and limitations subject to their proper use and bear the responsibility for such use.

The Introductions to the TLV/BEI Book and the TLV/BEI *Documentation* provide the philosophical and practical bases for the uses and limitations of the TLVs and BEIs. To extend those uses of the TLVs and BEIs to include other applications, such as use without the judgment of an industrial hygienist, application to a different population, development of new exposure/recovery time models, or new effect endpoints, stretches the reliability and even viability of the database for the TLV or BEI as evidenced by the individual documentations.

It is not appropriate for individuals or organizations to impose on the TLVs or the BEIs their concepts of what the TLVs or BEIs should be or how they should be applied or to transfer regulatory standards requirements to the TLVs or BEIs.

Approved by the ACGIH Board of Directors on March 1, 1988.

Special Note to User

The values listed in this book are intended for use in the practice of industrial hygiene as guidelines or recommendations to assist in the control of potential workplace health hazards and for no other use. These values are *not* fine lines between safe and dangerous concentrations and *should not* be used by anyone untrained in the discipline of industrial hygiene. **It is imperative that the user of this book read the Introduction to each section and be familiar with the *Documentation* of the TLVs and BEIs before applying the recommendations contained herein.** ACGIH disclaims liability with respect to the use of the TLVs and BEIs.

Jaan Natarajan

2000

TLVs® and BEIs®

Based on the Documentations of the

Threshold Limit Values
for Chemical Substances and Physical Agents

and

Biological Exposure Indices

*HEAT STRESS AND HEAT STRAIN

Assessment of both heat stress and heat strain can be used for evaluating the risk to worker safety and health. A decision-making process such as that shown in Figure 1 is required. The guidance provided in Figure 1 and in the associated documentation of the TLV represents conditions under which it is believed that nearly all adequately hydrated, unmedicated, healthy workers may be repeatedly exposed without adverse health effects. The guidance is not a fine line between safe and dangerous levels. Professional judgment and a program of heat stress management are required to ensure adequate protection for each situation.

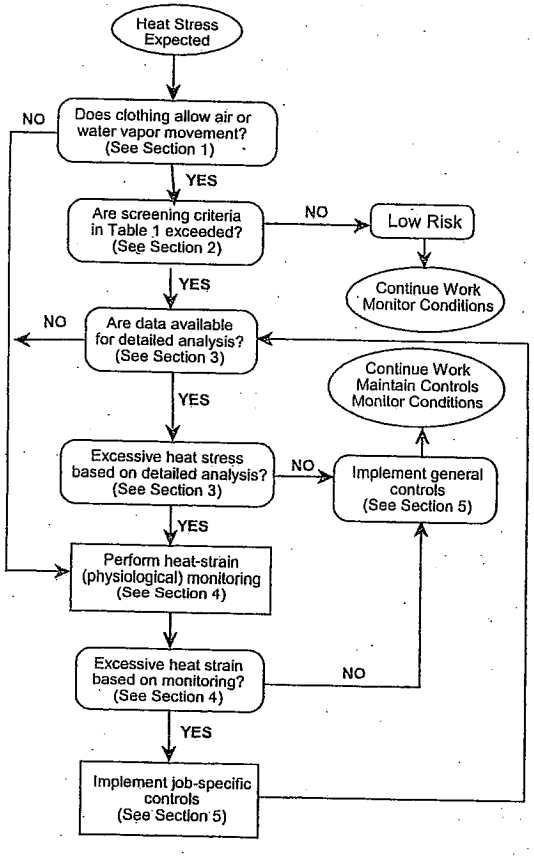

FIGURE 1. Evaluation Scheme for Heat Stress.

TABLE 1. Additions to Measured WBGT Values (°C) for Some Clothing Ensembles

Clothing Type	WBGT Addition*
Summer work uniform	0
Cloth (woven material) overalls	+3.5
Double-cloth overalls	+5

*These values must not be used for encapsulating suits or garments that are impermeable or highly resistant to water vapor or air movement through fabrics.

Heat Stress is the net heat load to which a worker may be exposed from the combined contributions of metabolic cost of work, environmental factors (i.e., air temperature, humidity, air movement, and radiant heat exchange) 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 adjustments 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.

The decision process should be started if there are reports of discomfort due to heat stress or when professional judgment indicates it.

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 usually 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 life-threatening 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, then the YES branch can be taken.

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) barriers to water vapor or air movement, 2) encapsulating suits, or 3) multiple layers. 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. Physiological and behavioral monitoring described in Section 4 and Table 3 should be followed to assess the exposure, unless a detailed analysis method appropriate to the clothing requirements is available.

170

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, 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.

WBGT values are calculated using one of the following equations:

- With direct exposure to sunlight:

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

- Without direct exposure to the sun:

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

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 as well as state of acclimatization. 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.

Acclimatization is a set of physiological adaptations, the development and loss of which are described in the Documentation. Full-heat acclimatization requires up to 3 weeks of continued physical activity under heat-stress conditions similar to those anticipated for the work. Its loss begins when the activity under those heat-stress conditions is discontinued, and a noticeable loss occurs after 4 days. With a recent history of heat-stress exposures (e.g., 5 of the last 7 days), a worker can be considered acclimatized for the purpose of using Table 2.

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 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 experience a core body temperature above 38°C. Correct assessment of work rate is of equal importance to environmental assessment in evaluating heat stress. Table 4 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 acclimatization state, metabolic rate category for the work, and the approximate proportion of work within an hour, a WBGT criterion can be found in Table 2. If the measured time-weighted WBGT adjusted for clothing is less than the table value, the NO branch in Figure 1 is taken, and there is little risk of excessive exposures to heat stress. Nevertheless, if there are reports of the symptoms of heat-related disorders such as fatigue, nausea, dizziness, and lightheadedness, then the analysis should be reconsidered.

If the work conditions are above the 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 criteria provided in Table 2 and still not represent an unacceptable exposure. 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.

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

	Acclimatized				Unacclimatized			
Work Demands	Light	Moderate	Heavy	Very Heavy	Light	Moderate	Heavy	Very Heavy
100% Work	29.5	27.5	26		27.5	25	22.5	
75% Work; 25% Rest	30.5	28.5	27.5		29	26.5	24.5	
50% Work; 50% Rest	31.5	29.5	28.5	27.5	30	28	26.5	25
25% Work; 75% Rest	32.5	31	30	29.5	31	29	28	26.5

Notes:

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

TABLE 3. Examples of Activities within Metabolic Rate Categories

Categories	Example Activities
Resting	Sitting quietly
	Sitting with moderate air movements
Light	Sitting with moderate arm and leg movements
	Standing with light work at machine or bench while using mostly arms
	Using a table saw
	Standing with light or moderate work at machine or bench and some walking about
Moderate	Scrubbing in a standing position
	Walking about with moderate lifting or pushing
	Walking on level at 6 Km/hr while carying 3 Kg weight load
Heavy	Carpenter sawing by hand
	Shoveling dry sand
	Heavy assembly work on a noncontinuous basis
	Intermittent heavy lifting with pushing or pulling (e.g., pick-and-shovel work)
Very Heavy	Shoveling wet sand

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 WBGT 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 TLVs for acclimatized and unacclimatized workers are provided in the Documentation, and they are the same as the 1986 NIOSH REL and RAL, respectively.

The second level of detailed analysis would follow a rational model of heat stress, such as the International Standards Organization (ISO) required sweat rate (ISO 7933, 1987). While a rationale 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 is provided in the Documentation and elsewhere, and other rational methods are 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.

TABLE 4. Guidelines for Limiting Heat Strain

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

Excessive heat strain may be marked by one or more of the following measures, 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 (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 110 bpm; or
- There are symptoms of sudden and severe fatigue, nausea, dizziness, or lightheadedness.

An individual may be at greater risk if

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

If a worker appears to be disoriented or confused, or suffers inexplicable irritability, malaise, or flu-like symptoms, the worker should be removed for rest in a cool location with rapidly circulating air and kept under skilled observation. Immediate emergency care may be necessary. If sweating stops and the skin becomes hot and dry, immediate emergency care with hospitalization is essential.

If the data are available, the next step in Figure 1 is the detailed analysis. If the exposure does not exceed the criteria for the appropriate detailed analysis (e.g., WBGT analysis, another empirical method, or a rational method), then the NO branch can be taken. Because the criteria in Table 2 have been exceeded, general heat stress controls are appropriate. General controls include training for workers and supervisors, heat stress hygiene practices, and medical surveillance. If the exposure exceeds the limits in the detailed analysis, the YES branch leads to physiological monitoring as the only alternative to demonstrate that adequate protection is provided.

170

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.

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, the general controls are necessary. 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 must be considered and 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. The decision tree in Figure 1 returns to the detailed analysis step, and in the absence of detailed information, then the only method to ensure protection is to return to physiological monitoring.

Section 5: Heat Stress Management and Controls. The requirement to initiate a heat stress management program is marked by 1) heat stress levels that exceed the criteria in Table 2 or 2) work in clothing ensembles that limit heat loss. In either case, workers should be covered by general controls (see 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, along with Tables 1 and 3, provides 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 behavioral limits. The mix of job-specific controls can only be selected and implemented after a review of the demands and constraints of any particular situation. Once implemented, their effectiveness must be confirmed and the controls maintained.

TABLE 5. Guidelines for Heat Stress Management

- Monitor heat stress (e.g., WBGT Screening Criteria in Table 2) and heat strain (Table 5) to confirm adequate control.

General Controls

- Provide accurate verbal and written instructions, frequent training programs, and other information about heat stress and strain.
- Encourage drinking small volumes (approximately 1 cup) of cool, palatable water about every 20 minutes (refer to Documentation for choice of the contents provided in drinks for fluid replacement).
- Permit self-limitation of exposures and 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 life-styles, 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 preplacement medical screening to identify those susceptible to systemic heat injury.

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—

In all cases, 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 skin may be hot and dry, sweating has ceased, and the body core temperature is greater than 40°C (104°F). Immediate, appropriate, emergency care and hospitalization are essential if signs of heat stroke develop. 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.

2000 PHYSICAL AGENTS UNDER STUDY

The Physical Agents TLV Committee solicits information, especially data, which may assist it in its deliberations regarding the following agents and issues. Comments and suggestions, accompanied by substantive supporting data, should be forwarded to The Science Group, ACGIH. In addition, the Committee solicits recommendations for additional agents and issues of concern to the industrial hygiene and occupational health communities.

1. Issues
   - Carcinogenicity of physical agents—known and suspected.
   - Combined effects with chemical substances (e.g., noise and chemical exposure interaction).
   - Reproductive hazards.
2. Acoustic
   - Impulse noise, including blast over-pressure.
3. Ergonomic
   - Hand–Arm Vibration.
   - Musculoskeletal Disorders.
4. Ionizing Radiation
5. Nonionizing Radiation and Fields
   - Extremely low frequency (ELF) magnetic fields.
   - Contact currents.
   - Radiofrequency (RF) radiation and ultra-wide-band communications.
   - Electromagnetic pulses.
   - Lighting levels and safety performance during night work.
6. Thermal Stress
   - Cold stress.
7. Hyperbaric and Hypobaric Environments.

170