THERMAL WORK LIMIT

Improving Worker Safety in Extreme Heat

*The **TWL Monitoring System** measures real-time data with the common met sensors — temperature, pressure, humidity, and wind speed — with the addition of a black globe temperature sensor.*

Heat stress poses a significant health and safety risk for workers in industries such as construction, public safety, military, and mining. Traditional heat indices, such as the Heat Index (HI) and Wet Bulb Globe Temperature (WBGT), offer guidance but fall short in accounting for critical environmental factors, potentially leading to overly conservative and/or insufficient mitigation.

This paper discusses the Thermal Work Limit (TWL) as an alternative metric, providing actionable guidelines to balance safety and productivity. We explore TWL's scientific basis, advantages, and implementation in workplace safety programs.

Introduction

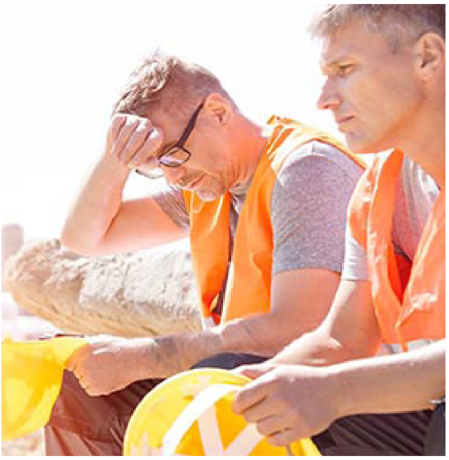
Extreme heat conditions threaten the health and productivity of workers across various industries. Inadequate management of heat stress can result in heat-related illnesses, reduced productivity, and even fatalities.

Indices such as the Heat Index (HI) and Wet Bulb Globe Temperature (WBGT) have been used to measure heat stress, guiding work-rest cycles and additional interventions.

Protocols to protect workers in environments where heat-related illness is a threat include acclimatization, proper hydration, shorter shifts, increasing the number of workers per task, and education around heat-related illness (1).

Many of these interventions are essential; however, some such as increased staffing and shorter shifts can decrease productivity.

Columbia Weather Systems



Heat stress is a leading cause of weather-related deaths in the United States - more than lightning, flooding, or tornadoes. It is a serious health condition that affects workers, athletes, and anyone active in high temperature environments.

This paper evaluates limitations of HI and WBGT, introduces the Thermal Work Limit (TWL) as a comprehensive alternative, and discusses its application to improve worker safety without compromising productivity.

Limitations of HI and WBGT

Heat Index (HI)

The Heat Index combines dry bulb temperature and relative humidity to estimate perceived temperature. While HI is simple to calculate, its accuracy is limited by key assumptions:

– Measurements are taken in shaded environments, ignoring the effects of solar radiation
– Air movement and cloud cover are not considered

These limitations make HI less suitable for outdoor workers exposed to direct sunlight and varying environmental conditions.

Wet Bulb Globe Temperature (WBGT)

WBGT improves upon HI by incorporating dry bulb, wet bulb, and globe thermometer temperatures, accounting for solar radiation. WBGT is widely used and standardized under ISO 7243 for assessing heat stress. However, WBGT also has drawbacks:

– It excludes wind speed, which can significantly enhance cooling
– It does not factor in atmospheric pressure, which can be an important variable for assessing heat stress in specific environments

The conservative nature of WBGT can lead to overly restrictive guidelines, unnecessarily reducing productivity (3).

Thermal Work Limit (TWL)

TWL, developed by Dr. Graham Bates and Dr. Derrick Brake, addresses the shortcomings of traditional indices. TWL calculates the maximum safe metabolic rate (energy expenditure) for workers while maintaining a safe core body temperature and sweat rate.
It incorporates:

– Dry bulb temperature
– Wet bulb temperature
– Globe thermometer temperature
– Wind speed
– Atmospheric pressure

Like WBGT, TWL uses dry and wet bulb temperatures and globe thermometer temperatures (Table 1). It also uses wind speed and atmospheric pressure, which account for the cooling effects of air movement that WBGT omits. By accounting for the additional parameters, TWL provides more tailored guidelines.

The TWL equation integrates weather conditions, metabolic rate, and cooling efficiency. While a detailed explanation of the formula is beyond this summary, Table 1 (see next page) shows the inclusion of parameters in TWL to better assess heat stress potential in a given environment.

Table 1: Parameters used to calculate Heat Index, Wet Bulb Globe Temperature, and Thermal Work Limit

	HEAT INDEX	WET BULB GLOBE TEMPERATURE	THERMAL WORK LIMIT
Dry Bulb Temperature	X	X	X
Wet Bulb Temperature		X	X
Globe Thermometer Temperature		X	X
Relative Humidity	X		*
Wind Speed			X
Atmospheric Pressure			X

**Relative Humidity is incorporated in the calculated Wet Bulb Temperature*

Practical Application of Thermal Work Limit

Guidelines for Worker Safety

TWL and its accompanying guidelines are used to provide safe working parameters for outdoor workers. It is intended for "workers who are well educated about working in heat, have control over their work rate, are healthy, and are well hydrated" (2).

TWL calculates the maximum metabolic rate that is safe for workers to exert while maintaining a safe deep body temperature and sweat rate. The resultant number is in units of watts of metabolic heat per square meter of body surface area.

This makes it relatively simple to use TWL to calculate cooling requirements for indoor environments, as well as changes in scheduling.

Case Studies

TWL was initially adopted in Australia's underground mining industry. Despite intense underground heat, engineering solutions improved airflow and cooling in addition to other mitigations to improve worker conditions (5).

The Health Authority of Abu Dhabi integrated TWL into its "Safety in the Heat" program for outdoor workers, demonstrating its versatility across industries (6).

Table 2 below illustrates the guidelines established by the Abu Dhabi EHSMS Safety in the Heat program, categorizing TWL into three risk zones. The lower TWL numbers correspond to higher heat stress, thus restricting work more. (4)

– **Low-risk zone (TWL 140–220):** No restrictions for self-paced work

– **Moderate-risk zone (TWL 115–140):** Only acclimatized workers should perform tasks, with additional precautions such as avoiding solo work

– **High-risk zone (TWL <115):** Work is restricted to essential functions, with strict rehydration and rest schedules

Thermal Work Limit - Working Zones

Control Interventions, Rest-Work and Rehydration Schedules

Working Zones	Interventions	Rehydration Schedule (per hr)	Work-rest Schedule (minutes)
Low Risk Unrestricted Zone TWL: 140 - 220 <	**No limits on self-paced work**[a] for educated, hydrated workers.	Light Work 600 ml - 1 Litre / hr	Safe for **all** continuous **self-paced work**[a]
Medium Risk Cautionary Zone TWL: 115 – 140	**Cautionary zone indicates situations in which environmental conditions require additional precautions.** • Practicable Engineering control measures to reduce heat stress should be implemented e.g. provide shade, improve ventilation etc. • Working alone to be avoided • No unacclimatised person to work[b] • Ensure adequate fluid intakes appropriate for type of work	Light Work 1 -1.2 Litres / hr	Safe for continuous **self-paced light work**[a]
		Heavy Work > 1.2 Litres / hr *	**Continuous paced work** 45 work - 15 rest
High Risk Zone TWL: < 115	• **Strict Work/Rest cycling required** • No person to work alone • No unacclimatised person to work[b] • High Risk induction required emphasising hydration and identifying signs of heat strain • Provide personal water bottle (2 litre capacity) on-site at all times	All Work >1.2 Litres / hr *	Light work[c] 45 work – 15 rest
			Heavy work[d] 20 work - 40 rest

a) Self-paced work - workers must be allowed to adjust their work rate according to environmental conditions. Paced work is when the work rate is not under the worker's control

b) Unacclimatised workers are defined as new workers or those who have been off work for more than 14 days due to illness or on vacation leave (in a cool climate area)

c) Light work - sitting or standing, light arm work

d) Heavy work - carrying, climbing, lifting, pushing, whole-body work

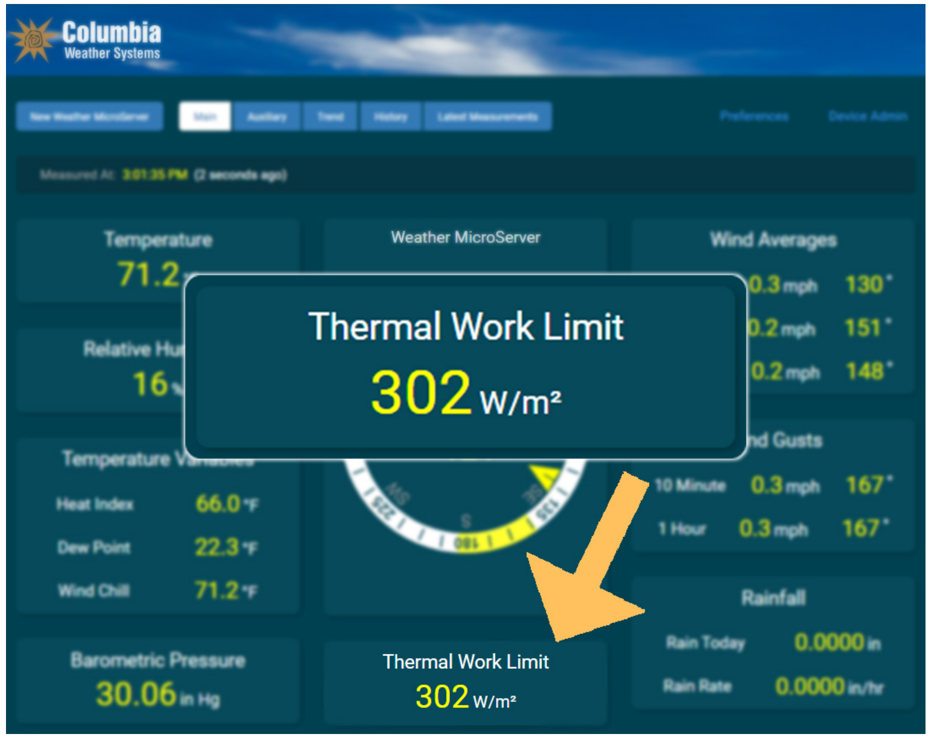
** At high workloads and or thermal stress, sweat rates exceed 1.2 Litres / hr. Increasing fluid intake much above this level is not practical due to gastric discomfort as the upper limit for gastric emptying and fluid absorption is ~ 1.5 Litres / hr so control solutions to improve thermal conditions should be implemented in addition to providing adequate hydration to replace sweat lost.*

Monitoring TWL with Available Technology

Professional weather stations can monitor TWL in real time with the common met sensors -- temperature, pressure, humidity, and wind speed -- with the addition of a black globe temperature sensor.

For Columbia Weather Systems, TWL is provided as a calculated parameter via the Weather MicroServer, Weather Display Console and in the upcoming new version of WeatherMaster Software. Wet Bulb Temperature is calculated from ambient temperature and humidity.

Data is collected systematically, and alarms can be set to notify personnel. This automation ensures accurate and timely interventions.



TWL reading shown on the Weather MicroServer home screen.

Benefits of TWL

TWL's advantages include:

– **Improved Accuracy:** Accounts for all critical environmental factors affecting heat stress

– **Enhanced Productivity:** Balances safety with realistic work-rest schedules, minimizing unnecessary downtime

– **Scalability:** Applicable across diverse environments

– **Ease of Implementation:** Compatible with existing weather station technologies

Contact us to learn how professional grade weather systems can help you mitigate the effects of heat stress in your organization.

Call or email for a quote | 503-629-0887 | info@columbiaweather.com

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