HOW TO MEASURE WBGT TO MITIGATE HEAT STRESS

by John Crosby, Meteorologist

Heat Stress: What is it and how is it measured?

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.

Climate change exacerbates the problem, with increased air temperatures and humidity. Colin Raymond of NASA's Jet Propulsion Laboratory reports that extreme levels of heat stress have more than doubled over the past 40 years and the trend is expected to continue.

In simple terms, heat stress is caused by the body being overheated. Whether called heat exhaustion, heat stroke, or heat cramps, typical symptoms include confusion, inability to concentrate, excess sweating, lack of sweating, dizziness, and collapse.

The body of an indoor office worker generates the equivalent of ~120W while an outdoor construction worker generates the equivalent of 500W. If the heat stress is not compensated for, the core body temperature rises and heat illness develops.

Today we have a much better understanding of who is affected, ways to measure heat stress, and best practices to minimize the adverse effects. The Occupational Safety and Health Administration (OSHA), among many others, has practical guidelines to recognize heat hazards for both indoor and outdoor workers.

One final thought, heat stress affects not only construction and agricultural workers, or those participating in sports, but also the elderly, children, and people with medical conditions.

In other words, heat stress can impact all of us.

Being exposed to high heat, high humidity, direct sunlight, and low winds greatly increases the chance you will feel the effects of heat stress, especially if you are being active. Recognizing heat stress

Extreme heat and humidity led Eglin Air Force Base to monitor environmental conditions at a remote radar site with a Wet Bulb Globe Temperature System from Columbia Weather Systems.

> *"We needed a weather station to measure the local conditions . . . we generate our own heat stress indications for when it is safe to work outdoors or not."*
>
> Radar Engineer for Eglin Air Force Base

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allows supervisors and coaches to make real-time changes to outdoor activities including work:rest ratios, hydration breaks, equipment worn, and duration of activities.

Challenge: How can we measure heat stress and take measures to avoid it?

We know that humidity has a major effect on cooling the body. If the humidity is high, sweat on the surface of the skin does not evaporate as quickly, slowing the cooling of the body. Wind speed impacts the body's ability to evaporate sweat - the higher the wind, the more effective the evaporation and cooling.

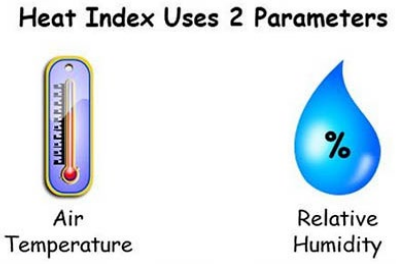
The four main contributing factors to heat stress: high temperatures, high humidity, low winds, and direct sunlight can make for a deadly combination. But also at play are the type of clothing being worn, the metabolic rate (exertion level), and the acclimation level of the individual.

	HEAT INDEX	WBGT
Measured in Sun		X
Measured in Shade	X	
Uses Air Temperature	X	X
Uses Humidity	X	X
Uses Effects of Wind, cloud cover & sun angle		X

Currently there are two measurement techniques available, Heat Index (HI) and Wet Bulb Globe Temperature (WBGT). While the two measures are often confused, they are significantly different as the table to the left shows.

Measurement Techniques

Heat Index (HI) is the most commonly used measure of heat stress, but it is not the most accurate method. HI measures how hot the air feels to the human body. It uses two commonly measured meteorological parameters: ambient temperature and relative humidity. Temperature and humidity sensors are typically installed in a ventilated enclosure shielded from the sun, i.e. in the shade. One of the major deficiencies with the Heat Index is that the air temperature is measured in the shade, but will likely be greater in the sun, where many outdoor activities take place.



It should be noted that the HI is always higher than the ambient temperature. For instance, on a day with the temperature = 32C (90F) and RH = 60%, the HI is 38C (100F). On a more humid day but with the same temperature = 32C (90F) and RH = 80%, the HI is 45C (113F). Remember that the temperatures for HI are taken in the shade, not in the full sunlight where people are working and playing. Therefore, the actual HI can increase as much as 15°F. In this example the actual HI would be 53C (128F) suggesting that HI may not be the best measure of heat stress!

The formula for Heat Index is rather long and complicated but several online calculators are available. The National Weather Service (NWS) regularly reports the HI when the temperature is > 27C (80F) and many weather stations (including those from Columbia Weather Systems) report HI as a standard feature.

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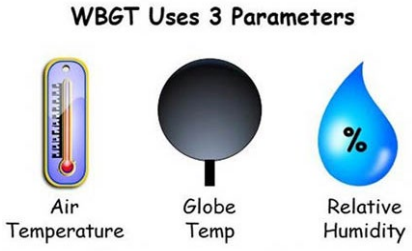
While the Heat Index is a readily available tool, it doesn't give us the most information to address heat stress. Fortunately, there is a better measurement available, that factors in a more useful parameter, called Wet Bulb Globe Temperature.

Wet Bulb Globe Temperature (WBGT) is a greatly improved measurement of heat stress as it accounts for real world conditions and utilizes additional measured parameters. WBGT is a measure of heat stress in direct sunlight.

It was developed in the early 1950s after the US military noticed a high number of heat casualties during boot camp and training exercises. The WBGT index has become the gold standard for measuring heat stress and is now a standard with the military, OSHA, and many states who oversee K-12 athletic programs.

Traditionally, the WBGT index was calculated using shaded air temperature, black globe temperature, and wet bulb temperature as described below.



The traditional method of measuring Wet Bulb Temperature is not practical for modern unattended weather stations, so several techniques have been developed using the Relative Humidity (RH) sensor normally collocated with the air temperature sensor. The RH % is converted to an equivalent Wet Bulb Temperature.

Knowing the three critical elements, the weighted formula used to obtain the WBGT temperature is:

$$WBGT = 0.7Tw + 0.2Tg + 0.1Td$$

The formula clearly demonstrates that WBGT is much more dependent on the Wet Bulb Temperature (seven times) than the dry bulb air temperature. It should be noted that the Wet Bulb Globe Temperature is always lower than the ambient air temperature.

With the HI value always higher than air temperature and the WBGT value always lower than the air temperature, the two methods are not directly comparable.

The following table shows the differences:

	READING	HI	WBGT
Air Temp (T_d)	33C (92F)	45C (112F)	32.7C (91F)
Relative Humidity	70%		
Equiv Wet Bulb Temp (T_w)	29C (84F)		
Globe Temp (T_g)	46C (115F)		

The development of the WBGT has led to a series of charts that the user must refer to understand the reading. These charts are different for the different climatic regions of the country and the level of

The CWS Heat Stress System shown above includes the following elements:

- Black Globe Temp Sensor
- Ambient Temp and Relative Humidity Sensors in a Self-Aspirating Radiation Shield
- Capricorn FLX Control Module
- Weather Display Console

exertion. For example, the U.S. State of Georgia, one of the early adopters of WBGT, uses the data in the WBGT decision table for student athletes.

Suggested Actions and Impact Prevention		
WBGT(F)	**Effects**	**Precautionary Actions**
80-85	Working or exercising in direct sunlight will stress your body after 45 minutes.	Take at least 15 minutes of breaks each hour if working or exercising in direct sunlight
85-88	Working or exercising in direct sunlight will stress your body after 30 minutes.	Take at least 30 minutes of breaks each hour if working or exercising in direct sunlight
88-90	Working or exercising in direct sunlight will stress your body after 20 minutes.	Take at least 40 minutes of breaks each hour if working or exercising in direct sunlight
>90	Working or exercising in direct sunlight will stress your body after 15 minutes.	Take at least 45 minutes of breaks each hour if working or exercising in direct sunlight

Additional sources of information on implementing WBGT include:

- The International Organization for Standardization ISO 7243:2017 that contains exhaustive details on the WBGT method.
- The Korey Stringer Institute of the University of Connecticut guidelines for each US state, along with other useful information.
- The National Federation of State High School Associations article entitled "Wet Bulb Globe Temperature (WBGT) – Why Should Your School Be Using It?"

Solution: Monitor WBGT to Mitigate Heat Stress

Columbia Weather Systems first developed a monitoring system with WBGT for the U.S. Coast Guard in Florida. The extreme heat and humid environment in Florida make it an important location to monitor heat stress.

Eglin Airforce Base remote radar site is another Florida application where a CWS WBGT system offers data for work/no work decisions for maintenance crews.

At the National Security Campus in Kansas City, government contractor Honeywell oversees a busy campus of 7,000 people where guidelines for outdoor training activities include weather factors to help mitigate risk of Heat Stress. A CWS weather monitoring system configured to accurately measure WBGT is used to accomplish this.

The images to the left show a typical CWS system configured to measure WBGT.

CWS utilizes a Black Globe Temperature Sensor that meets the ISO 7243:2017 standards. A 15 cm black sphere provides the globe temperature (Tg) used in the WBGT formula. Standard CWS air temperature (Td) and relative humidity sensors compute an equivalent wet bulb temperature (Tw).

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The CWS Heat Stress System was developed to help keep workers safe in extreme heat and humid environments.

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These sensors connect with a Capricorn FLX Control Module and Weather Display Console to display the data. The screen displays WBGT, wet bulb temp, ambient temp, globe temp, and barometric pressure. Weather Display features include trend graphs, min/max, and alarms. Additional sensors can be incorporated such as wind and solar radiation.

Conclusion

With climate-induced changes to our atmosphere, ambient temperatures and relative humidity are rising around the world. This phenomenon not only impacts our daily weather, but also the length of the seasons. As weather records show, temperatures are higher in August but October is also seeing higher temperatures making for a longer season of potential heat stress.

There is an increasing need to carefully measure and take action to keep outdoor workers and athletes from being subject to environmental heat stress.

The two methods discussed in this white paper to measure heat stress are summarized below:

Heat Index: Unlike WBGT, heat index is a measurement that only takes into account air temperature and humidity. Think of it as the "feels-like" temperature in a shaded area. Heat Index is measured in the shade rather than the sun, and doesn't factor in cloud cover (solar radiation), wind, or sun angle. While heat index remains the default measurement in some organizations and general public weather forecasts, it's not always the ideal measurement to use.

WBGT: WBGT is more comprehensive than Heat Index because it takes into account many more factors (solar radiation, wind, cloud cover, etc) to give a better idea of heat stress in particular environments. For situations where precision and heat safety are needed, like in outdoor sports practice or outdoor events, WBGT is preferred.

Contact Columbia Weather Systems to learn how their professional-grade weather monitoring systems can help 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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