QUEST TECHNOLOGIES
A 3M COMPANY

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WBGT

Without the Wet Bulb

The latest heat stress product offerings from Quest Technologies, the QUESTempº 44/46, offer traditional heat stress monitoring without the hassles of maintaining a wet bulb. Through collaboration with Dr. Thomas Bernard at the University of South Florida, mathematical models have been implemented to create a virtual waterless wet bulb through a combination of dry bulb temperature, globe temperature, airflow rate and humidity measurements. This waterless wet bulb is then used to calculate a reasonable estimate of WBGT.

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INTRODUCTION

Over the years, the Wet Bulb Globe Temperature Index (WBGT) has become the most prevalent method for measuring environmental factors related to heat stress [1]. Quest first offered devices to monitor heat stress via WBGT in 1991. While devices to measure WBGT have become prolific, those required to operate the instruments have begrudged the need to maintain the water level and fight wick contamination in the wet bulb. With the advent of the QUESTempº 44 and 46, users no longer need to be inconvenienced with these issues.

DESCRIPTION OF MODELS

Calculating WBGT

WBGT can easily be calculated through the following formula. Once calculated, these values are comparable to indices of work-rest regimens (stay times) based upon work loads.

WBGT (indoor) = 0.7WB + 0.3G

WBGT (outdoor) = 0.7WB + 0.2G + 0.1DB

In the case of the QUESTempº 44/46, the globe and dry bulb temperatures are measured as before, however the wet bulb temperature is estimated using a mathematical model. The model used is a wind-adjusted version of the psychrometric wet bulb [2]. For a description of the model and how the wind adjustments are performed, see Dr. Bernard's website [3]. For the case where an airprobe is not attached to the QTº 44/46, the wind speed is computed by setting the airflow to the current environments wind speed. The instrument's recommended airflow setting for indoor is 0.3 m/s and 2.0 m/s for outdoor.

METHODS

Three Data Collections

Data was collected under three different sets of conditions.

The ***first data collection*** was taken in the laboratory. For this set, the instruments were placed within an environmental chamber and the temperature was varied from 5 degrees Celsius to 60 degrees Celsius and humidity was varied from 19 percent to 97 percent relative humidity. With the first data collection, there was minimal radiant heat and the chamber circulation fan provided varying air movement over time.

The ***second data collection*** was taken under outdoor conditions. For this set, data was taken during both daytime and nighttime hours over differing thermal loads (stone, grass, and asphalt) and weather conditions.

The ***third data collection*** was taken in an enclosed environment with high radiant heat and no air flow to evaluate the efficacy of the calculated wet bulb under a worst-case scenario.

For the three data collections, a waterless sensor bar was installed as the primary sensor bar in a QUESTempº46 and a sensor bar with wet bulb was installed as the secondary sensor bar for direct comparison. The Air-Probe 9 was also connected to the instrument to allow airflow rate corrections. Data was collected at one minute intervals in both daytime and nighttime scenarios.

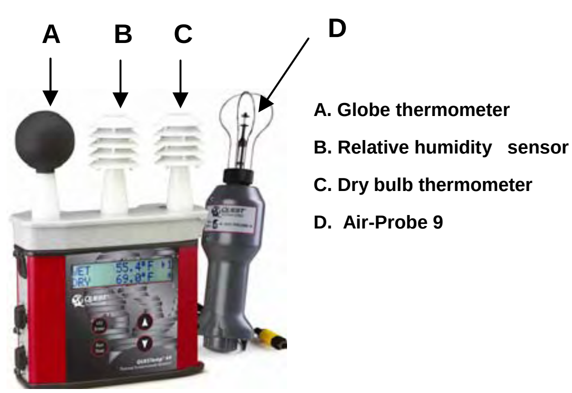

Figure 1: QUESTempº 46 with Air-Probe 9

RESULTS

Wet Bulb vs. Waterless Wet Bulb

The results showed that under normal conditions, the calculated wet bulb led to WBGT values which were within acceptable tolerances. Table 1 and Figure 2 show the differences between the WBGT temperatures with a measured and calculated wet bulb across all data sets.

Data Set	Std.Dev.	RMSE
Laboratory	0.25 ºC	0.39 ºC
Outdoor	0.33 ºC	0.42 ºC
No Airflow	0.58 ºC	0.96 ºC
Combined	0.52 ºC	0.53 ºC

Table 1: Comparison of difference between WBGT temperatures using a measured wet bulb and a waterless wet bulb.

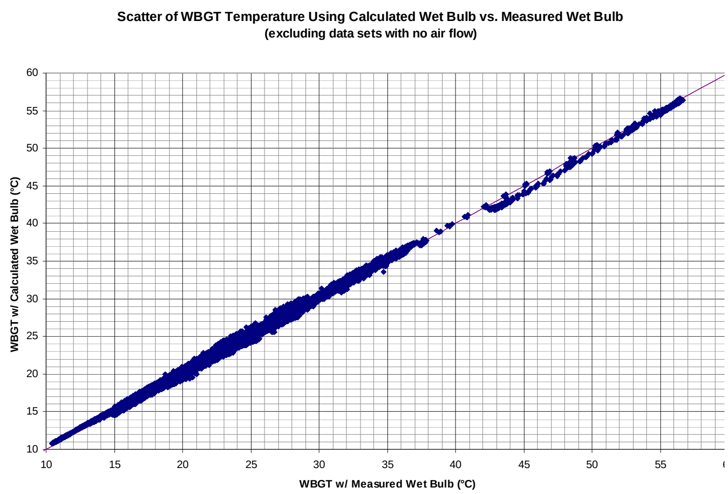

Figure 2: Scatter plot for all collected data sets of WBGT temperature calculated from the waterless wet bulb temperature versus measured natural wet bulb temperature.

Across all data sets there was a mean deviation of 0.11ºC, which is well within the margin of error for the instrument.

The measurement uncertainty for the combined data set was calculated as u_c = 0.54ºC. Using a coverage factor of k = 2, the expanded measurement uncertainty was calculated as U = 1.1ºC. This uncertainty was determined from a combination of supplied sensor specifications and statistical analysis of the wet bulb differences.

It has been argued that the enclosed windless condition is unrealistic due to the complete lack of airflow. Worker movement alone should create some air movement. If we accept this premise and remove the windless data set, our differences are even smaller, as seen in Table 2 and Figure 3.

Data Set	Std.Dev.	RMSE
Laboratory	0.25 ºC	0.39 ºC
Outdoor	0.33 ºC	0.42 ºC
Combined	0.33 ºC	0.42 ºC

Table 2: Comparison of difference between WBGT temperatures using a naturally aspirated wet bulb and a waterless wet bulb.

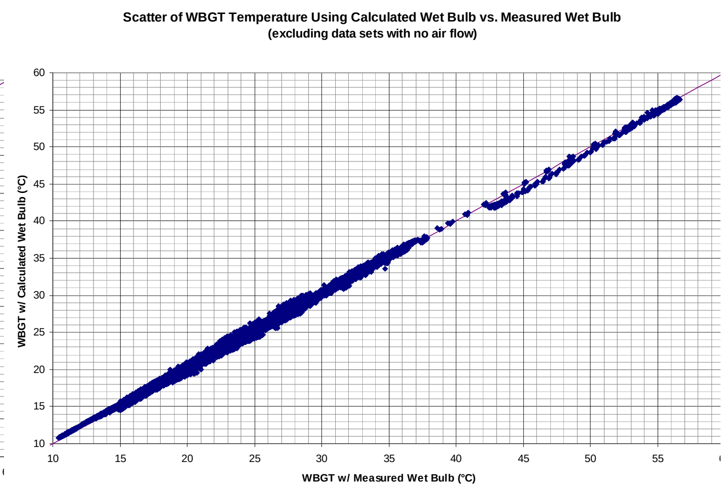

Figure 3: Scatter plot of WBGT temperature calculated with waterless wet bulb temperature versus measured natural wet bulb temperature excluding data from the enclosed environment with no air flow.

While the waterless wet bulb worked well, there are a few conditions which should be avoided if possible to minimize measurement bias.

Areas with no air movement

As seen in the third data set, measurements in areas with no air movement will tend to be underreported by approximately one degree Celsius. This condition can rarely be found in a real-world environment, as worker movement itself will create some flow of air. For this reason, the QUESTempº 44/46 without the AirProbe 9 attachment defaults at a minimum airflow rate of 0.3 m/s (indoor) and 2.0 m/s (outdoor).

Dynamic changes in the environment

The wet bulb model performs best in steady-state conditions. Sudden changes in conditions can momentarily increase the bias of the estimator while the system adjusts.

Condensing Environments

If water condenses on the humidity sensor, a recoverable bias will be introduced to the estimator.

SUMMARY

The data presented demonstrates the efficacy of WBGT measurements using a calculated wet bulb in place of a measured wet bulb. While using a measured wet bulb is the gold standard and should always be considered, this change is desirable for many situations where wet bulb maintenance is impractical. Under normal conditions, values were well within an acceptable margin of the measured WBGT temperature, however the expanded measurement uncertainty was calculated as 1.1ºC. Care should be taken however to note situations where there is no airflow or rapidly changing conditions, as these conditions lead to the greatest discrepancies with the waterless wet bulb heat stress units.

References

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