FEATURE ARTICLE

Predicting and preventing heat stress related excessive exposures and injuries: A field-friendly tool for the safety professional

Abstract. While safety professionals are always mindful of heat stress when working in hot environments or while wearing chemical protective clothing, predicting working limits in those environments can be elusive. The authors have developed an Excel tool to help safety professionals stay within the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) or Action Level for heat stress. The tool is most helpful in daily work planning where heat stress may be an issue.

By Harry J. Elston, Michael J. Schmoldt

INTRODUCTION

While most chemical hygiene officers will have little concern with heat stress issues in the comfort of a climate-controlled laboratory, some chemical safety professionals are faced with performing their duties in a variety of environmental conditions. For example, petrochemical refinery workers will be subjected to thermally stressful environments and many small-scale batch production, while conducted indoors are performed in large warehouse-like facilities where temperature and humidity control is difficult. Even indoor, air-conditioned environments can create excessive thermal conditions if full-body chemical protective clothing is required for work such as bulk materials handling.

The US Bureau of Labor Statistics reported there were 2,830 non-fatal and 37 fatal heat-related injuries in 2015.[1] In addition to actual heat-related injuries, worker production suffers, sometimes greatly, when heat-stress concerns are not well managed.[2–4] While there is no specific OHSA standard regulating work in thermally stressful environments, heat-stress is a "recognized health hazard" citable under the OSHA's General Duty Clause.[5] ACGIH states that the goal of their heat stress TLV is " . . . to maintain body core temperature within + 1 °C of normal (37 °C)[6,7]" There is no doubt that heat-stress may be a concern for the chemical safety professional.

Predicting exposure, can appear to be a convoluted process requiring:

- Numerous objective and subjective decisions (i.e., personal protective equipment (objective), acclimatization of the worker and how strenuous the work may be (both subjective decisions));
- Data, which may or may not be highly accurate for measuring the thermal environment (e.g., Wet Bulb Globe Temperature (WBGT) during the preparation, work and rest phases of a project), and;
- Computations for metabolic rate (which include adjustments for weight).

The tool, implemented as an Excel spreadsheet, is downloadable in the Supplemental Data section of ScienceDirect. The tool allows the user to adjust input "on the fly" or in real time plots anticipated exposure on the Action Level/TLV graph. The "on the fly" adjustment to assists the user in preventing exceeding heat stress exposure limits by providing a visual indication of the anticipated exposure. An example of the output is shown in Figure 1. The tool has been provided as an *unprotected Excel Sheet*. The end-user is strongly encouraged to protect the yellow-colored cells with their own password. Those cells are highlighted for protection. Additionally, the spreadsheet has been verified using both MathCad and by hand calculations.

TOOL DEVELOPMENT, LIMITATIONS AND USE

Development

The tool was developed by the authors out of the necessity to provide IH

***Harry J. Elston**, Ph.D., CIH, is affiliated with the Midwest Chemical Safety, LLC (email: helston@midwestchemsafety.com).*

***Michael J. Schmoldt**, PE, CIH, is affiliated with the Argonne National Laboratory.*

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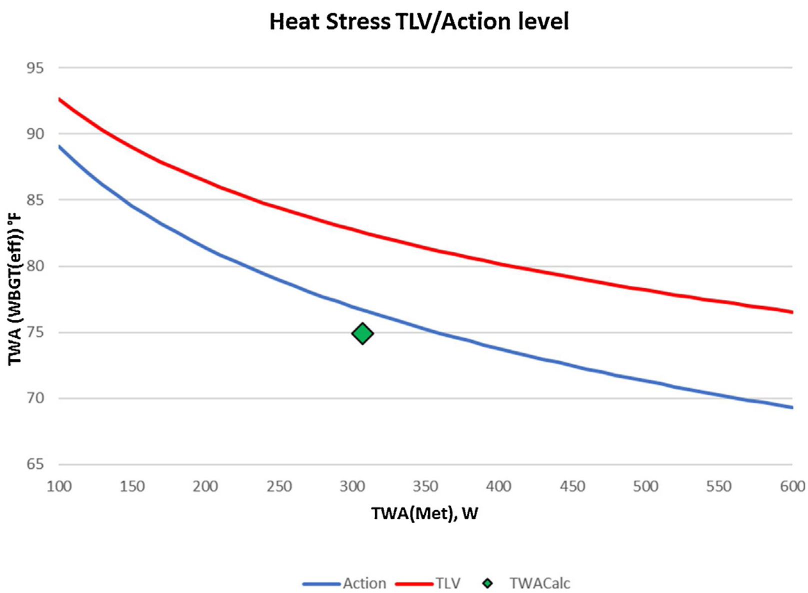

Figure 1. Example output from the Heat Stress tool.

Technicians was near-real time exposure predictions based onsite conditions in order to prevent over-exposure conditions to workers. Inputs are purposefully in US Customary Units (e.g., degrees Fahrenheit, pounds) because that is the system within the site technicians worked. The spreadsheet is provided in the Supplemental Data as an editable spreadsheet: If users desire SI units, they may rewrite the calculations; however, ***if done so, users must ensure that the output is correct. This may be accomplished by hand calculations or using a program such as MathCad.***

Equations for the TLV and Action Limit were taken from Reference 7. Users are strongly encouraged to read and understand References 6 and 7 before using this tool.

The tool assumes that the user can measure WBGT using a direct-reading instrument. WBGT instruments provide the most accurate measurement of the environmental factors in thermal stress and can be readily obtained from rental instrument providers. If a WBGT instrument is not available, an estimate of WBGT from temperature and relative humidity can be estimated from tables,[8] or can be calculated based on meterological station data from the National Weather Service (https://forecast.weather.gov). But these may not take into account wind speed and radiant heat contributions which are difficult to determine.

Clothing adjustment factors are directly from Reference 6, although "Work Clothes" and "Cloth (woven material) coveralls" have been combined. Both have clothing adjustment factors of zero.

Worker acclimatization is important factor and is the basis for selecting either the TLV or AL value as the applicable exposure limit. Acclimatization is a gradual adaption that requires a recent history of exposure in similar conditions for 5–7 days. Workers who do not engage in similar levels of activity using the same level of protective equipment and thermal strain should be considered not acclimatized.

Limitations

Unlike most TLVs which are 8-hour time-weighted averages of exposure, heat stress TLVs are evaluated hourly[6]; under no circumstances should the tool be used for activity periods (e.g., preparation, work, rest) exceeding 90 min.

Note carefully that fully encapsulated, vapor barrier clothing ("Level A" chemical protective clothing) is not supported in this tool.

The current presentation of the tool is limited to wet bulb globe temperatures between 65 °F and 95 °F and calculated metabolism rates between 100–600 W. As written, this tool will calculate exposures outside of these ranges, but it will not graphically display them and has been done to avoid a false sense of precision in the results.

The tool assumes that normal work clothing (Clothing Adjustment Factor = 0) will be worn during the preparation and rest phases of the job.

Selected WBGT values should be closely representative of the local work environment.

The Action Limit should be considered the occupational exposure limit for workers who are not acclimatized to hot environments.

This tool estimates exposure to thermal stress. When individual or more accurate evaluation is needed, additional tools such as worker physiological monitoring[7,9,10] of heart rate and temperature are recommended.

Tool Use

In order to use the tool, the following information is needed:

- Wet Bulb Globe Temperatures for the work preparation areas, work area and rest area. It is the best obtain actual location measurements but WBGT may be estimated using the equations above. Data input is in degrees Fahrenheit.
- The estimated time for the work preparation time, working time and resting time (in minutes). Total time should be 60 min, but must not exceed 90 min.
- Worker's weight (in pounds): This information is necessary to adjust the metabolic calculations in comparison with the "standard person" (154 lbs).
- Protective clothing: Choose the closest set of protective clothing from the dropdown menu.
- Job Prep, Job and Recovery Description: Choose the activity level from the drop-down menu.
- Worker's age: The maximum heart rate is calculated (180-age). This information is used in the event physiological monitoring is used to manage heat stress.

The worksheet is especially useful for worker training and job planning.

Exposure is plotted as working conditions change so that management can adjust exertion levels, work/rest times or plan work for lower WBGT conditions. Likewise, the tool can be used to alert workers to be aware of conditions which they may encounter heat stress concerns.

CONCLUSIONS

The tool is useful for calculating expected exposure during work planning and for rapidly evaluating changing field conditions encountered. The tool helps organize the collection of essential input information and eliminates the potential for errors in multiple-step chain calculations and provides clear documentation of the basis for assessing risk from excessive heat strain.

The graphical output provides a useful method of visualizing the results which is easily communicated to workers and management. By illustrating the estimated exposure relative to the TLV/AL values, the tool allows meaningful discussion of what factors can be affected by changes in work practices or controls used to reduce heat stress to within acceptable limits.

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