Georgia Tech Enterprise Innovation Institute: Safety, Health and Environmental Services Group

Head Protection Temperature Study

Partners: Brasfield & Gorrie, LLC; Swinerton Construction; Gilbane Construction
Funded By: Department of Labor: OSHA
Conducted by: 21(d) Consultation Program (Georgia)

Introduction

Heat-related illness (HRI) is an acknowledged occupational risk factor – and one that is entirely preventable. For individuals working in construction, heat illness typically results when the body's total heat load (resulting from physical activity or personal physiological factors) is combined with insufficient heat dissipation (resulting from environmental conditions or personal protective equipment use). In the absence of specific federal regulations for the prevention of heat-related illness in the workplace, employers are encouraged to develop management plans that include hydration, training, acclimatization periods for new employees, and modified work patterns.

Recently, the use of head protection styled as a helmet with an outer shell of acrylonitrile butadiene styrene (ABS), an inner shell of expanded polystyrene (EPS) foam, and equipped with a chin-strap has been on the rise. These helmet-type head protectors have become more popular – and in some instances required PPE – on construction sites due to evidence that risk for traumatic brain injury (TBI) may be lessened based on the side impact protection offered by this style. The lower profile, repositioning of the adjustable ratchet system to lessen interference with a fall protection harness, the durability and replacement schedule, and the potential for integrated eye protection are all significant additional features for an industry constantly seeking improvement in design and safety outcomes.

Anecdotal feedback and employee perception includes concern of increased heat stress and discomfort while wearing these models in high-temperature or full-sun environmental conditions. Those tasked with selecting or recommending head protection at the corporate safety or field level safety management level are seeking empirical information regarding employee perception versus environmental condition. Although limited evaluation of darker color PPE (hardhats and coveralls) has been previously been undertaken for this purpose (*Davis, M., et al 2009; Smith, J. 2006*), there has not been an evaluation (to date) published exploring the temperature conditions possible while using this new helmet model type. The purpose of this study was to explore potential heat stress concerns resulting from wearing different models head protection to better inform the PPE selection process.

Location and Partners

The informal test protocol was administered over 4 days in August 2019 at a current OSHA Partnership jobsite (*The Piedmont Atlanta Hospital Master Facility Project; Atlanta, GA*), at the invitation of the General Contractor Brasfield and Gorrie, LLC. In addition, representatives from the General Contractor firms of Swinterton and Gilbane Construction also provided support with materials, including the helmets/hard hats to be used for the testing.

Methods

1. Six Quest Temp 34 Heat Stress monitors (WBGT) were placed on a fabricated rack located at the construction site in full sun. A 7th WBGT was utilized to record ambient conditions as a control.
2. Six different head protection models were selected for testing. These included:
    a. 3 - Kask helmets (0, 8, 10 air vents),
       1 - 3M helmet (6 air vents),
       1 - MSA Skullgard (unvented)
       1 - MSA Vgard (unvented)
    b. All selected hardhats/helmets were white in color in order to standardize the testing to evaluate the model variable only.
3. A sponge saturated with 50 mL of water (for a total average wet weight of 56 grams) was added to the suspension inside each hardhat to simulate perspiration and water loss was measured at the end of each testing cycle.

4. The hardhats/helmets suspended over the WBGT probes and set to record environmental conditions every ten minutes *(see Photos 1-2)*
5. An infrared thermometer was used to measure surface temperature on the hard hat shell surface every 20 minutes during the testing cycles.
6. The testing protocol was replicated over three consecutive days with each testing cycle lasting four hours during the middle of the work day.
    a. The WBGTs recorded the following parameters:
        i. Globe: measures radiant heat
        ii. Dry: measures air temperature
        iii. WBGTo: accounts for temperature, humidity/evaporation, in an outdoor environment with a solar load via calculation
7. ANOVA analysis was completed using SAS v9 to look for significant statistical differences between the hardhat models.

Photo 1:

Photo 2:

Outcomes

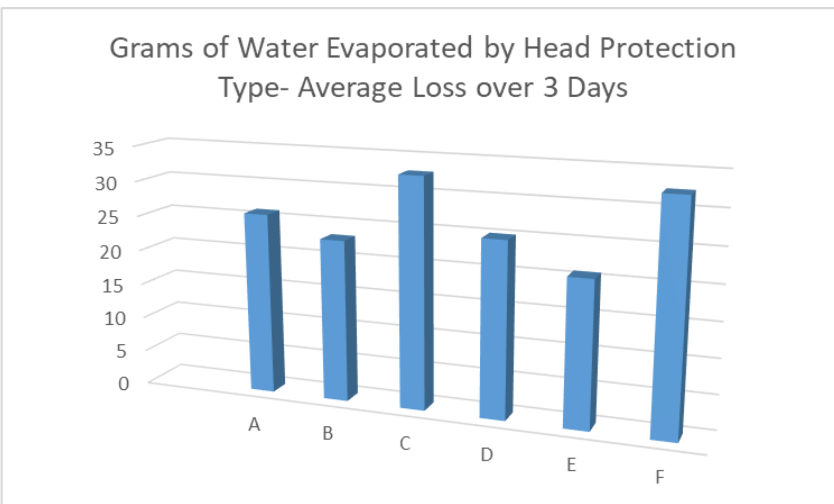
Over the 3-day evaluation, conditions were hot, full sun, and light breeze. Table 1 shows the range of average recorded parameters over the testing. Between the 6 different styles, recorded temperature parameters under the headgear varied approximately 1-3 °F, under the conditions noted. Using an ANOVA t-test, no significant statistical differences were noted between the selected (white color) models.

Table 1

Average Ambient WBGTo - Control	Average External Surface of HH/Helmets	Average Globe – Under HH/Helmets	Average Dry - Under HH/Helmets	Average WBGTo - Under HH/Helmets	Average Grams Water Loss
86.3 °F – 87 °F	89.9 °F – 94.7 °F	89.2 °F – 93.4 °F	87.6 °F – 89.4 °F	79.8 °F – 81.6 °F	20.8 g - 32.8 g

The hardhat/helmet external shells were warmer than the ambient temperatures, indicating higher radiant heat potential that could be transferred to the wearer; however, the average WBGTo values measured under the head protection were lower than the ambient average WBGTo control values. This means the radiant heat was reflected away, rather than absorbed and radiated towards the head, and thereby prevents direct heating of the head by the suns radiant energy. The external shell surface data collected for this study found comparable results to the white HDPE traditional hardhat evaluated by Davis et al (2009), which measured a peak surface temperature in full sun of 100 °F, versus 149 °F for a dark blue hard hat of the sample HDPE material.

The water source added to the interior suspension cradle of each head protection device was added to roughly simulate human perspiration, mimicking the study protocol of Davis, et al (2009). The difference in water loss was not determined to be statistically significant; the average evaporation ranged from 37-56% of the total sponge weight over the 4-hour test periods. The standard, white HDPE hardhat tested by Davis et al (2009), measured an average of 16 grams of water lost; during this field testing, the average loss for the (white colored) head protection models was 20.8 – 32.8 grams. There are two possible interpretations regarding water loss during this testing: (1) that more venting outlets within head protection result in improved evaporation, or (2) that increased water evaporation indicates a higher heat stress load.



A: 3M X5500V (vents)
B: Kask Zenith BA Air (8 vents)
C: Kask Superplasma HD (10 vents)
D: MSA Skullgard (no vents)
E: Kask Zenith (no vents)
F: MSA Vgard (no vents)

Additional data is provided in Appendix A to this report.

Recommendations

Providing decision makers with tangible, evidence-based information on temperature differences between personal protective equipment choices is an additional tool for implementing a robust heat illness prevention program. The outcome of this study was intended to provide management guidance on how to include assessment of certain personal protective equipment in their pre-planning strategies for heat related illness prevention with the goal of reducing risk and increasing productivity. By having specific data regarding temperatures inside and outside the hard hats, this will assist job-site safety management in communicating with employees regarding risk perception and comfort.

Although this informal field study was limited in size and scope, it illustrates the need for additional exploration into how changing safety equipment technologies should include this type of specification data to better educate decision makers on all relevant selection aspects. As data emerges regarding the improvement in head protection with respect to preventing traumatic brain injuries through the use of high density foams (such as EPS), and more employers consider use for their jobsites, further physiological study should be completed during active use by employees. Thermal stress – and even perceived thermal stress – can interfere with work performance, affect safety, or result in heat-related illnesses. Additionally, perceived comfort by staff is essential with regard to compliance with PPE requirements, and while head protection in the construction industry is the most commonly required gear for admittance onto a jobsite, it is also one of the more personalized PPE items (in terms of color, style, adornment) available to employees, provided it meets the mandated ANSI specifications. Indeed, color selection is used to designate supervisors, laborers, safety personnel, training level, or specific trades/activities on many jobsites. Although the results from this limited field trial indicate no statistical significance difference between the white colored head protection models tested, previous evaluations comparing various head protection colors have found significant heat loading possible with darker colors. Further physiological evaluation of these newer models that fit closely against the wearer's head due to the EPS foam should be conducted to account for both color and personal wearer characteristics, such as quantity/style of hair.

Achieving a balance between the anticipated gains and the unintended side-effects will be up to each individual contractor, but this initial data hopefully demonstrates that there wasn't a striking difference between the models included in study. Together with the appropriate attention to providing shade/cooling areas, rest breaks, and adequate hydration and training, head protection selection should be considered as a component of proper heat illness prevention management.

Benefit to All On-site Consultation Programs, OSHA, and Others

In 1986, NIOSH estimated that 5-10 million American workers were to be considered at risk for a heat related illness for at least part of the year (as cited in Gubernot, 2013). However, the most recent Intergovernmental Panel on Climate Change (IPCC) report concluded that increases in the frequency and magnitude of temperature extremes will occur with almost 100% probability throughout the 21st century, and that heat waves will also increase in frequency and severity (Crider, 2014). The recent years of record-breaking temperatures in the

KEY TAKEAWAYS

This study illustrates a need to explore how changing safety equipment technologies should include heat stress type monitoring to better educate decision makers on all relevant selection aspects.

Thermal stress – and even perceived thermal stress – can interfere with work performance, affect safety, or result in heat-related illnesses.

Previous evaluations comparing various head protection colors have found significant heat loading possible with darker colors of head protection.

Further physiological evaluation of these newer models that fit closely against the wearer's head due to the EPS foam should be conducted to account for both color and personal wearer characteristics, such as quantity/style of hair.

Together with the appropriate attention to providing shade/cooling areas, rest breaks, and adequate hydration and training, head protection selection should be considered as a component of proper heat illness prevention management.

The recent years of record-breaking temperatures in the southern United States has demonstrated that even a slight change in average temperature can result in an increased risk of heat-related morbidity and mortality.

southern United States has demonstrated that even a slight change in average temperature can result in an increased risk of heat-related morbidity and mortality. In 2012, approximately 43% of the heat-related illnesses reported to the Alabama Department of Public Health under its notifiable disease list were reported as work-related (Crider, 2014).

Although heat illness is an acknowledged occupational condition – and one that has received heighted attention in recent years due to the Occupational Safety and Health Administration's (OSHA) national Campaign to Prevent Heat Illness in Workers – research on private-sector occupational heat exposure on construction sites has remained fairly limited. The recent Centers for Disease Control and Prevention review of twenty heat-related enforcement cases (occurring 2012-2013) investigated by OSHA found that in all cases, heat illness prevention programs were found to incomplete or absent, with no provision for addressing the elevated risk for new (non-acclimatized) workers (OSHA 2014). In addition, the review recommended that employers develop prevention programs incorporating basic tenets of an adequate Safety and Health Management Program: oversight, hazard identification, and control strategies including training, physiological monitoring and emergency planning.

Sources:

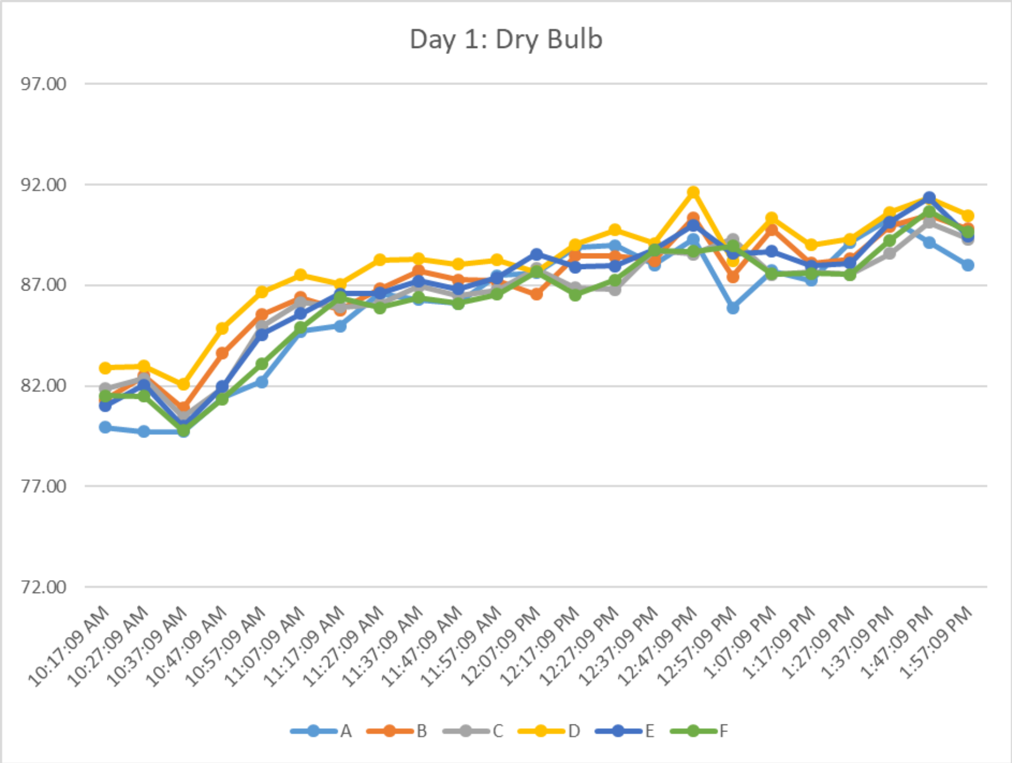
Crider, KG, Maples EH, Gohlke, JM (2014) Incorporating occupational risk in heat stress vulnerability mapping. Journal of Environmental Health 77(1):16-22

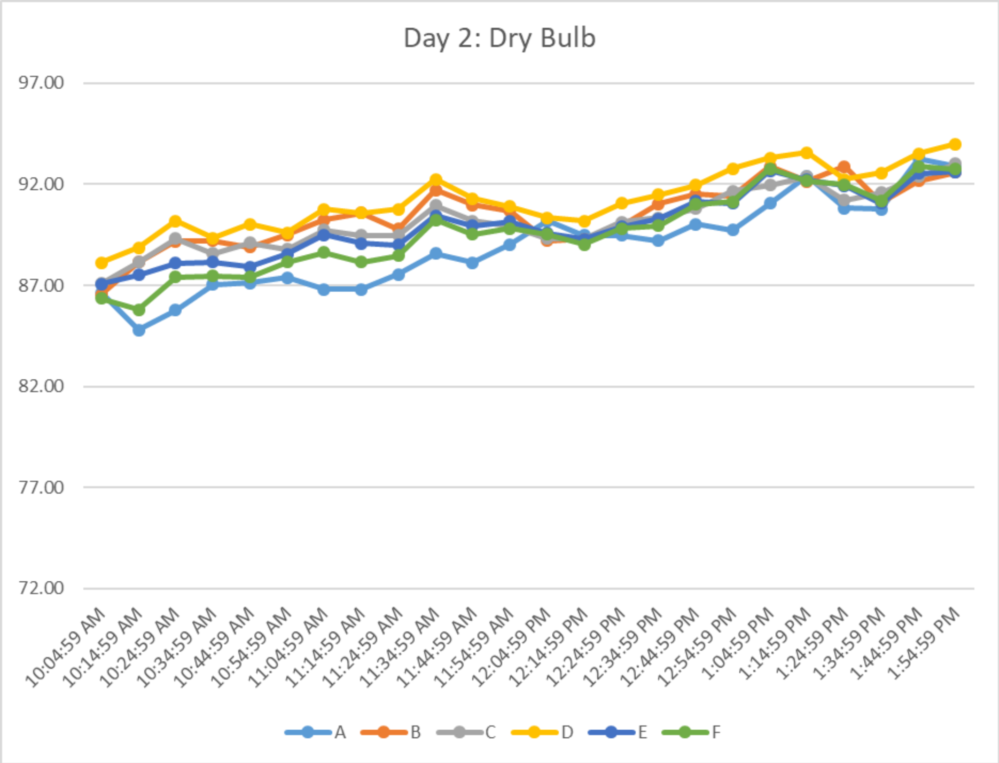
Davis, M., Kaminski, D. R., Oliver, M. C., Graf, J., & Pilling, L. (2009, January). A Study of Heat-Related Factors Caused by Color Selection of Hard Hats and FR Garments in Outdoor Work Environments. In *SPE Annual Technical Conference and Exhibition*. Society of Petroleum Engineers

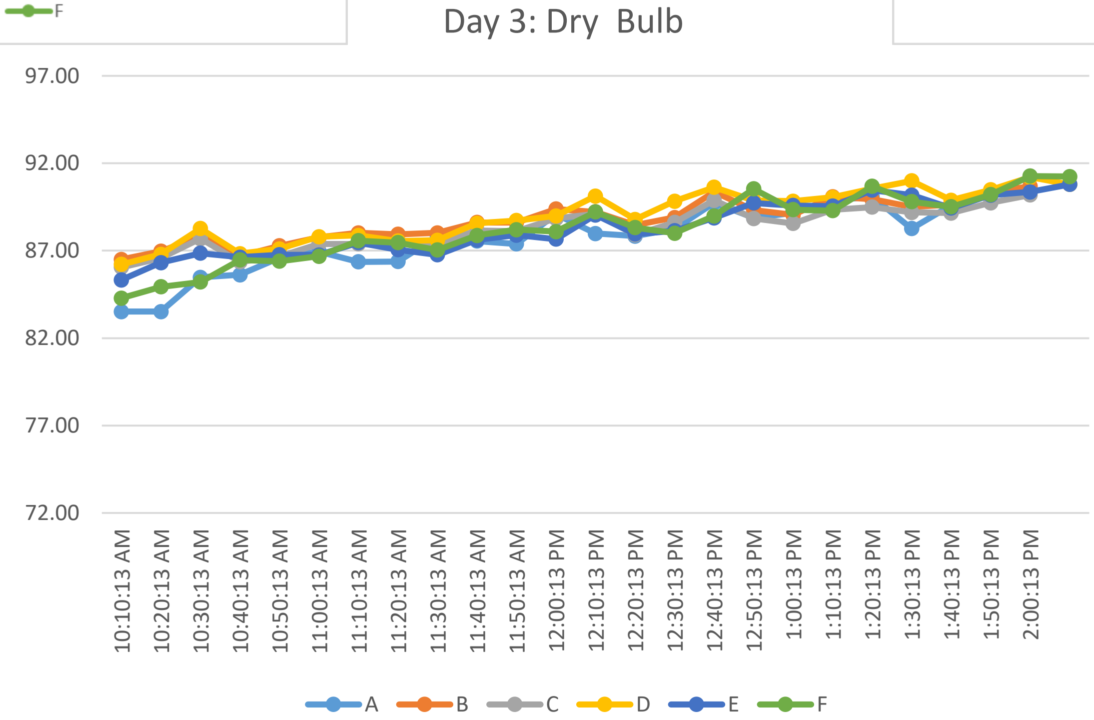
Gubernot, D, Anderson GB, Hunting, KL (2013) The epidemiology of occupational heat exposure in the United States: a review of the literature and assessment of research needs in a changing climate. International Journal of Biometeorology.

Smith, J. (2006) The Effect of Color on Temperatures Inside Hardhats. Tech Tip 0651-2312-MTDC. Missoula, MT: US Department of Agriculture, Forest Service, Missoula Technology and Development Center. 4 p. (http://www.fs.fed.us/t-d)

Appendix A: Results

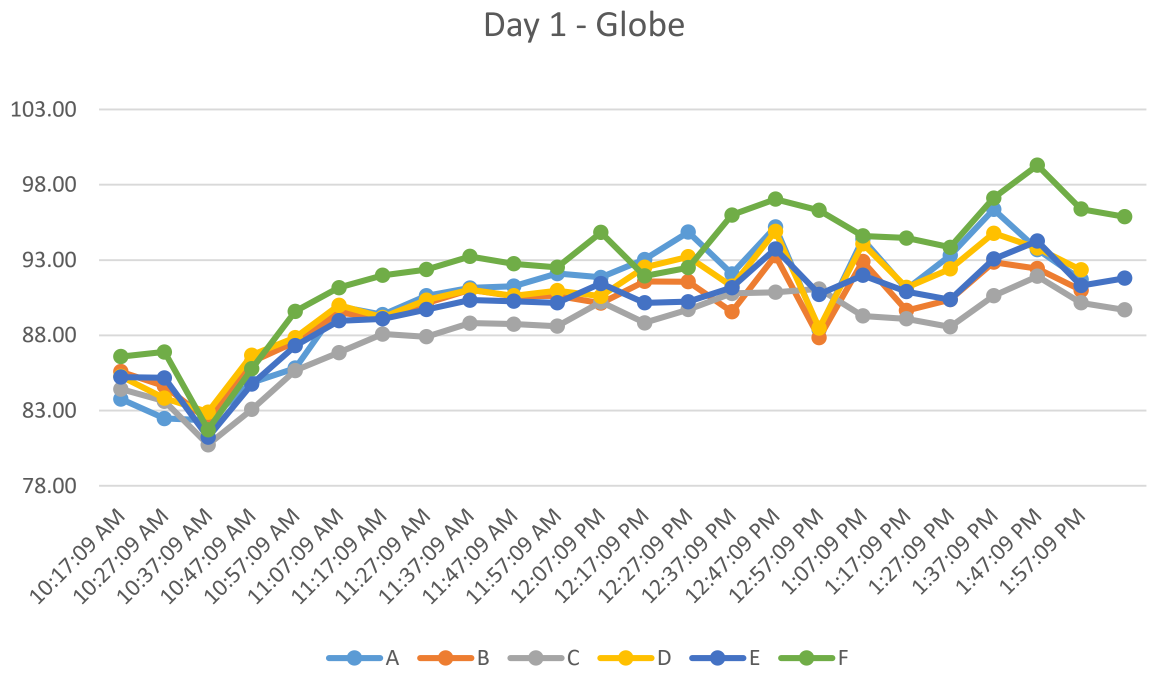


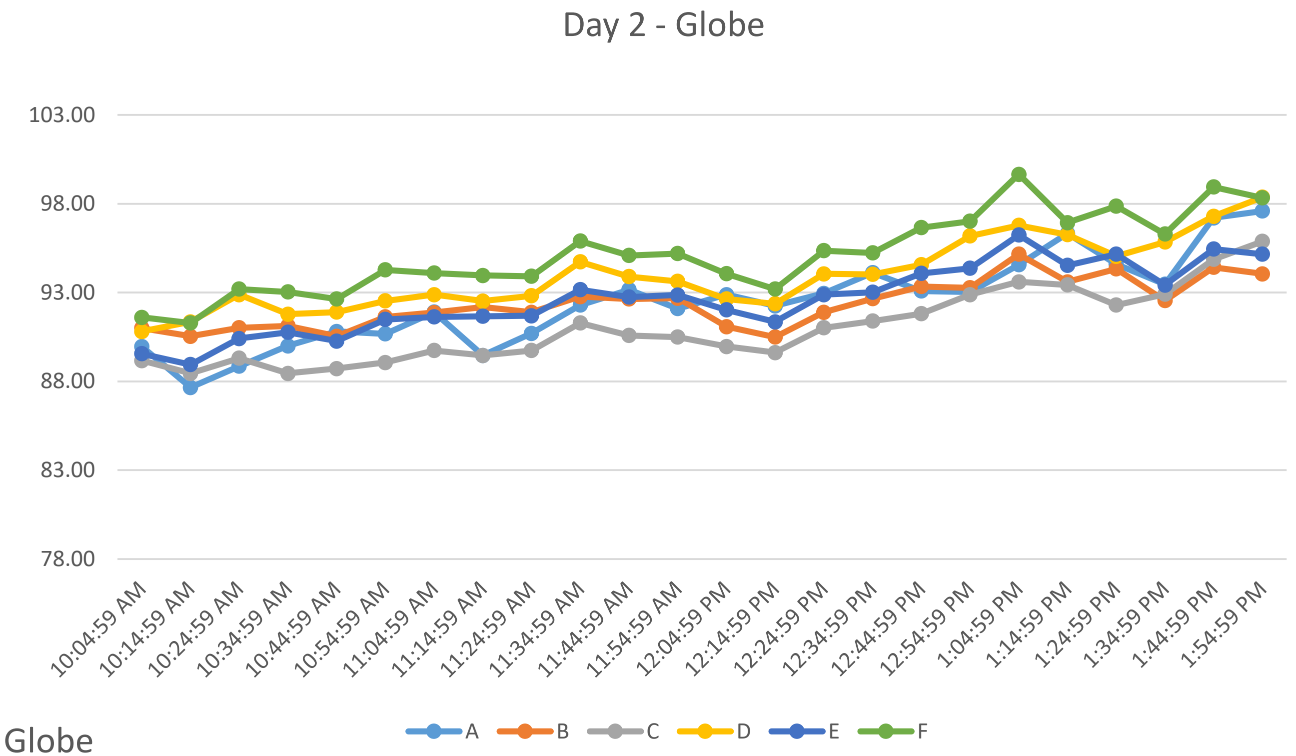


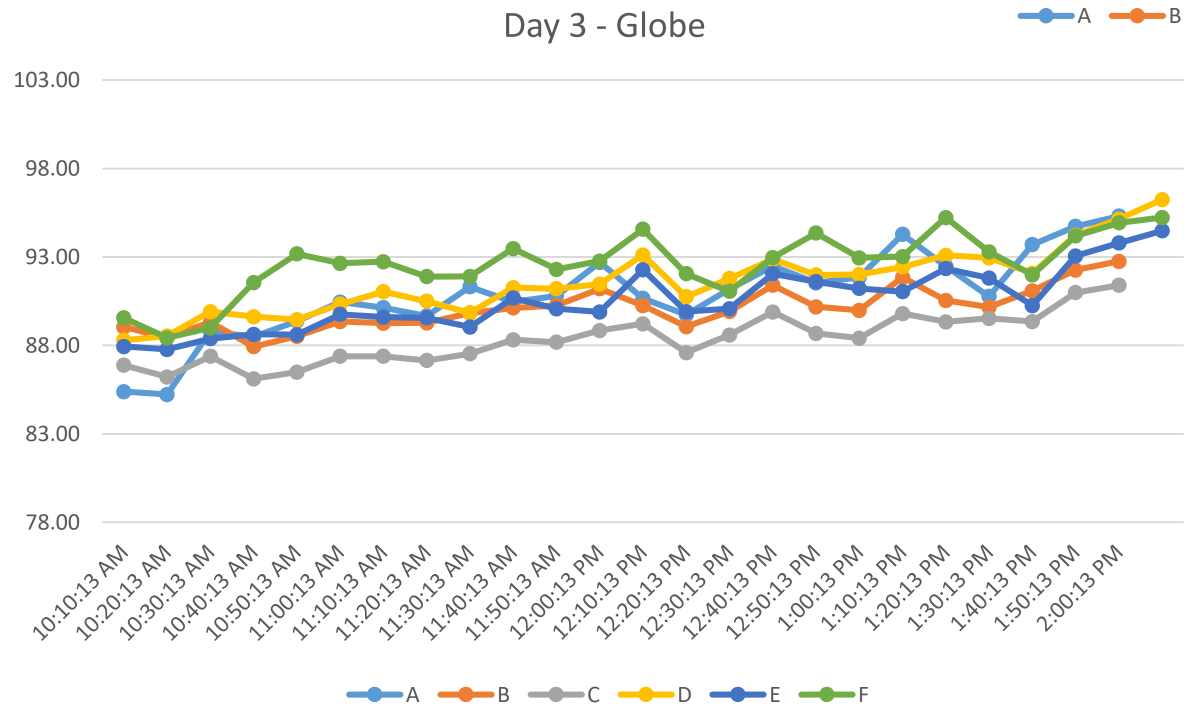


A: 3M X5500V (vents)
B: Kask Zenith BA Air (8 vents)
C: Kask Superplasma HD (10 vents)
D: MSA Skullgard (no vents)
E: Kask Zenith (no vents)
F: MSA Vgard (no vents)

Dry Bulb: Ambient air temp

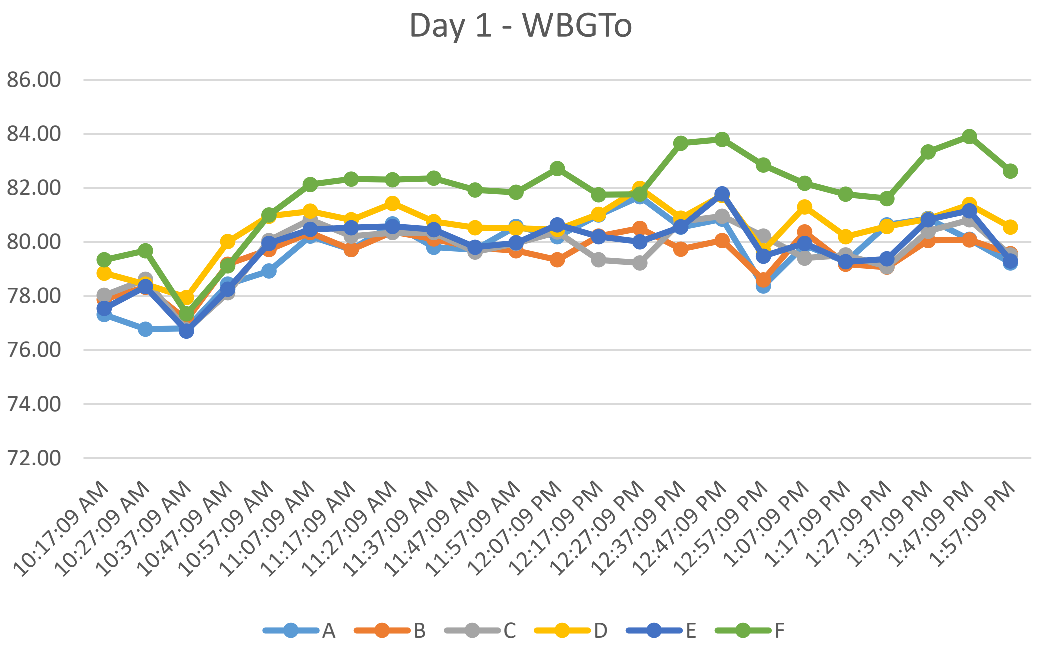


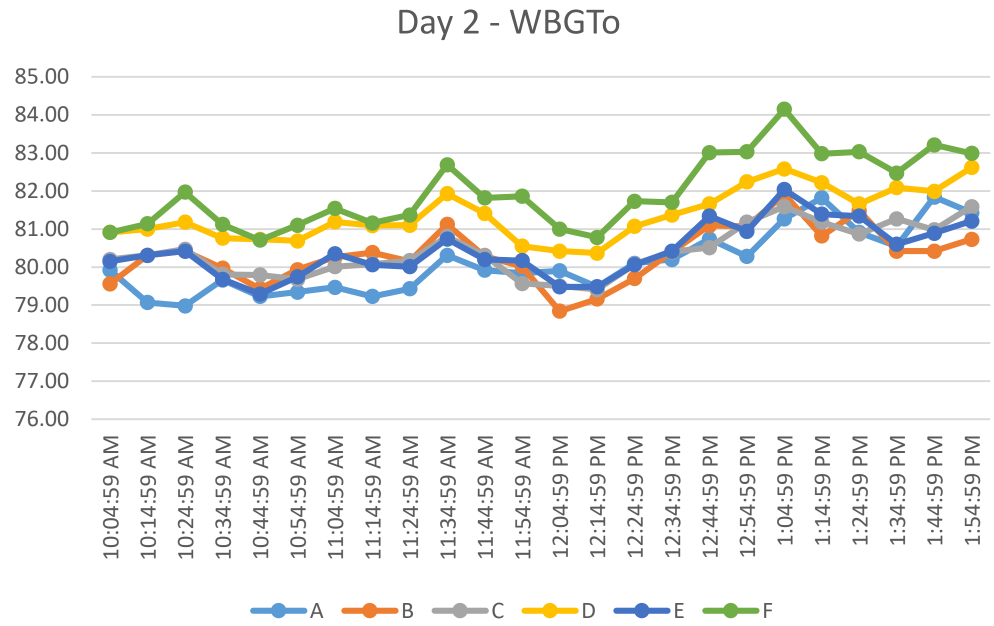


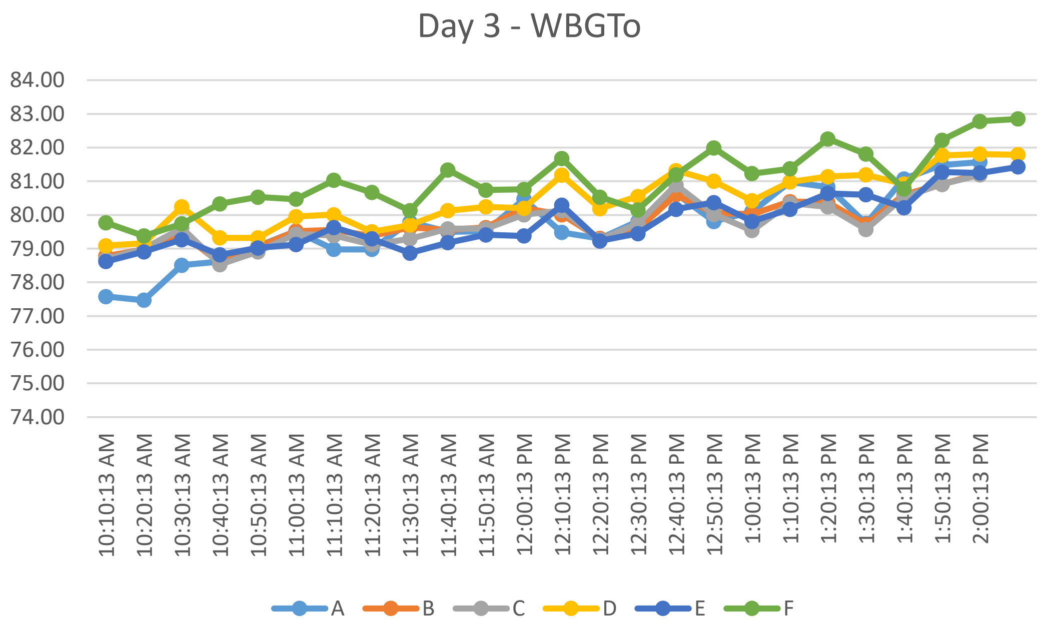


A: 3M X5500V (vents)
B: Kask Zenith BA Air (8 vents)
C: Kask Superplasma HD (10 vents)
D: MSA Skullgard (no vents)
E: Kask Zenith (no vents)
F: MSA Vgard (no vents)

Globe:
Radiant heat







A: 3M X5500V (vents)
B: Kask Zenith BA Air (8 vents)
C: Kask Superplasma HD (10 vents)
D: MSA Skullgard (no vents)
E: Kask Zenith (no vents)
F: MSA Vgard (no vents)

WBGTo: Outdoors, solar load

Averages

	Average external Surface	AverageGlobe internal	Average Dry Internal	Average WBGTo Internal	Average Grams H20 Loss - Sponge
A	94.7	91.3	87.6	79.8	26.0
B	91.4	90.7	88.7	79.9	23.1
C	92.7	89.2	88.3	79.9	32.8
D	92.9	91.9	89.4	80.8	25.1
E	92.7	90.9	88.3	80.0	20.8
F	89.8	93.4	88.0	81.6	32.5