CDC Workplace Safety and Health

Evaluation of Heat Stress at a Glass Bottle Manufacturer

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Health Hazard Evaluation Report
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The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

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Abbreviations

ACGIH®	American Conference of Governmental Industrial Hygienists
BPM	beats per minute
BUN	blood urea nitrogen
CBT	core body temperature
CFR	Code of Federal Regulations
ECF	extracellular fluid
ICF	intracellular fluid
ISO	International Standards Organization
kcal/hour	kilocalories per hour
kcal/min	kilocalories per minute
lbs	pounds
mEq/L	milliequivalents per liter
mosm/L	milliosmoles per liter
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
OEL	occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	permissible exposure limit
RAL	recommended action limit
REL	recommended exposure limit
SRreq	required sweat rate
STEL	short term exposure limit
TLV®	threshold limit value
TWA	time-weighted average
WBGT	wet bulb globe temperature
WEEL	workplace environmental exposure limits

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation (HHE) at Owens-Illinois in Lapel, Indiana. A group of employees submitted the HHE request because of a concern with the hot working conditions in the forming department. NIOSH investigators conducted an HHE in September 2006.

What NIOSH Did

- We talked with management and union officials about the hot working conditions.
- We measured employees' exposure to the heat in the forming department.
- We interviewed forming department employees about their work environment.
- We reviewed injury and illness records.

What NIOSH Found

- Employees were not exposed to excessive heat at the time of the NIOSH evaluation.
- There is a chance for greater heat exposure during the hotter summer months.
- Some employees had heat-related symptoms on hot summer days before the NIOSH evaluation.
- Some employees said they were not trained on hot working environment hazards.
- No formal heat stress management program was in place.

What Managers Can Do

- Set up a preventive maintenance schedule for the man coolers and swamp coolers.
- Let employees take unscheduled breaks if they feel weak, nauseated, excessively tired, confused, and/or irritable due to the heat.
- Develop a continuing education program about the hot working environment.
- Develop a heat-related illness surveillance program.
- Check heat exposures.
- Start a heat alert program.

What Employees Can Do

- Tell your supervisor if you feel weak, nauseated, excessively fatigued, confused, and/or irritable due to the heat.
- Drink plenty of fluids.
- Work with a buddy, and watch for signs and symptoms of excessive heat exposure in one another.

Summary

Environmental temperature measurements and work load assessments during this evaluation showed that workers in the forming department were not exposed to heat stress in excess of the occupational screening criteria. However, some employees reported developing heat strain symptoms during their shifts on hot summer days. We recommend the company create a formal heat stress management program.

In August 2003, NIOSH received a confidential employee request for an HHE at Owens-Illinois in Lapel, Indiana. The requestors were concerned about heat-related illnesses among employees exposed to the hot conditions in the forming department. In response to this request, NIOSH investigators visited the facility in September 2006. We conducted an opening conference with management and union representatives, a walk-through survey of the forming department, confidential medical interviews, a review of the Logs of Work-Related Injuries and Illnesses (OSHA's Form 300), and heat stress measurements in the forming department.

At the time of this NIOSH evaluation we found that workers in the forming department were not exposed to heat stress in excess of the NIOSH and ACGIH screening criteria. However, environmental temperatures may be warmer than those on the days of our evaluation, making it more likely that NIOSH and ACGIH heat stress screening criteria would be exceeded and that employees would be at increased risk for heat stress.

Interviews with forming department employees and a review of the Logs of Work-Related Injuries and Illnesses (OSHA's Form 300) found that some workers reported that they had developed heat strain symptoms during their shifts on hot summer days.

This report includes recommendations to help identify potential heat stress and strain risks and how to limit heat-related illnesses in hot end workers. These recommendations include creating a formal heat stress management program regarding heat acclimatization, continuing education for heat stress prevention, heat-related illness surveillance, environmental heat exposure monitoring, criteria for heat alerts, and preventive maintenance of man coolers and swamp coolers.

Keywords: NAICS 327213 (Beverage containers, glass, manufacturing), heat stress, heat strain, hot work environment, glass, glass bottles

Introduction

In August 2003, NIOSH received a confidential employee request to perform an HHE at Owens-Illinois in Lapel, Indiana. The request concerned heat-related illnesses among employees exposed to the hot working environment in the hot end of the plant, which includes the forming department. Based on discussions with the employee requestors, the initial visit to Owens-Illinois was delayed until September 2006, following the completion of another unrelated HHE at this facility.

On September 12, 2006, we held an opening conference with Owens-Illinois management; the Glass, Molders, Pottery, Plastics and Allied Workers International Union, Local 207; and international union representatives. The meeting included an overview of the NIOSH HHE program, a review of the issues that prompted the HHE request, and a discussion of the scope of this evaluation. After the meeting, a walk-through survey of the forming department was conducted. On September 13, 2006, confidential medical interviews were conducted with all forming department employees present on the first and second shifts, and heat stress measurements were taken in the forming department.

Process Description

Owens-Illinois manufactures glass containers for the beer, spirit, juice, and tea industries at the Lapel, Indiana, facility. This plant is approximately 100 years old, and employs approximately 200 production, packing, and shipping workers. Approximately 30 employees work in the forming department. Operations are continuous, with four crews (A, B, C, and D) working 8-hour shifts that rotate weekly, and a Z crew that works an 8-hour shift Monday through Friday.

In the hot end of the glass-making process, raw materials (cullet [recycled glass], sand, soda ash, and limestone) are melted together in a gas furnace at temperatures of 2,300°F to 2,800°F. The molten glass is cut into uniform gobs and sent to one of four individual section forming machines that force the molten gobs into a mold. The glass containers are then conditioned in an annealing lehr. The glass containers are then inspected and packaged for shipment to the customer. About 500 bottles are manufactured per minute on each of the four lines.

Owens-Illinois uses various controls in the hot end of the plant during the hot summer months to reduce the risk of heat-related illness. These controls include fans which supply cooler air from the basement of the facility (man coolers), evaporative cooling fans (swamp coolers), sports drinks, two 25-minute worker rest breaks (plus additional breaks during the summer months at the discretion of management), and a review of heat safety during safety meetings or through posters. At the time of our evaluation no formalized programs were in place to determine when the controls should be implemented, nor was a formalized heat acclimatization program in place.

We evaluated the heat stress conditions in the forming department by collecting WBGT measurements using four QUESTemp°36 instruments (Quest Technologies, Inc., Oconomowoc, Wisconsin). These monitors measure temperatures of 23°F–212°F and are accurate to within ± 0.9°F. In addition to temperature, the monitors measure relative humidity of 0%–100% and are accurate to within ± 5%. The WBGT index accounts for air velocity, temperature, humidity, and radiant heat and is a useful index of the environmental contribution to heat stress. WBGT is a function of dry bulb temperature (a standard measure of air temperature taken with a thermometer), natural wet bulb temperature (simulates the effects of evaporative cooling), and black globe temperature (estimates radiant [infrared] heat load). The WBGT monitors were placed around each of the four bottle forming machines, in the break room, and outside, and were allowed to equilibrate for a minimum of 15 minutes before being read. WBGT measurements and metabolic rate estimates are compared to those listed in the NIOSH REL [NIOSH 1986]. You can find a discussion of occupational exposure limits and health effects in Appendix A.

We estimated the metabolic rates for the workers using the NIOSH table, "Estimating metabolic heat production rates by task analysis" (Appendix B) [NIOSH 1986]. This method allows for specificity in rate estimation because it breaks the job into categories that account for body position and movement, type of work, and basal metabolism. The NIOSH values are based upon a standard body weight of 154 lbs, so a weight correction factor must be applied when workers weigh other than 154 lbs. Individual results vary depending on age, sex, fitness level, current health status, and body weight. Partly because of observer variability, estimates of metabolic rates may vary by ± 10%–15% [NIOSH 1986].

We conducted confidential employee interviews with all employees working in the forming department on the first and second shifts. Logs of Work-Related Injuries and Illnesses (OSHA's Form 300) were also reviewed from years 2004, 2005, and 2006.

Individual WBGT measurements are reported in Table 1. The highest WBGT reading in the forming department was 87.2°F, with a dry bulb temperature of 87.0°F and a globe temperature of 115.7°F. The results indicate that most surfaces in the forming department were at an elevated temperature and served as radiant heat sources. In the hot end break room, where employees normally take their breaks, the WBGT reading was 70.3°F, with a dry bulb temperature of 75.5°F. During the NIOSH evaluation the outdoor WBGT reading was 64.5°F, with a dry bulb temperature of 65.5°F, indicating the temperatures were unseasonably cool and not an indication of normal summer weather [NOAA 2004]. These cooler than normal ambient temperatures may have lessened the heat stress hazard in the forming department on the day of our evaluation.

Table 1. Heat Stress Measurements in the Forming Department on September 13, 2007

Individual Section Forming Machine	Time (hh:mm)	Indoor WBGT (°F)	Wet Bulb Temp. (°F)	Dry Bulb Temp. (°F)	Globe Temp. (°F)	Relative Humidity (%)
A1	17:38	85.5	75.5	86.4	109.3	38
A1	17:39	76.4	70.0	74.4	90.3	49
A1	17:39	75.6	68.6	72.8	92.1	60
A1	17:40	72.7	69.0	76.6	81.6	53
A2	17:17	71.7	67.2	77.1	81.7	54
A2	17:15	87.2	75.1	87.0	115.7	38
A2	17:18	81.9	74.6	83.2	99.5	31
A2	17:16	76.3	70.4	83.5	89.4	43
B1	16:47	71.4	67.4	75.8	80.8	56
B1	16:49	80.6	72.6	79.6	99.3	42
B1	16:50	83.2	73.4	82.7	106.7	46
B1	16:51	76.3	70.3	83.2	90.2	46
B2	18:03	68.8	66.2	70.7	74.7	58
B2	18:04	74.5	69.6	80.1	85.6	50
B2	18:02	82.9	73.2	78.3	105.4	44
B2	18:00	85.9	74.2	83.2	113.1	43
Break room	19:21	70.3	68.3	75.5	75.0	74
Outside	19:19	64.5	63.9	65.5	65.9	90

The metabolic heat produced by forming department employees was estimated using NIOSH guidelines [NIOSH 1986]. Using this method, the average energy expenditure of a standard male worker (154 pounds with a body surface of 19.4 square feet) was calculated to produce approximately 186 kcal/hour, corresponding to a light workload rate. The WBGT results and metabolic rate estimates for a standard male were then compared to those listed in the NIOSH RELs to determine a work/rest schedule [NIOSH 1986]. This comparison yields a recommendation of continuous work for acclimatized and unacclimatized workers when environmental conditions are similar to those on the day we evaluated.

The metabolic rate estimates were also assigned a light workload category and compared to the ACGIH screening criteria [ACGIH 2006]. The ACGIH screening criteria for heat stress also provides recommendations on work/rest schedules according to WBGT temperatures measured in the work areas. These criteria also suggest a continuous work schedule for acclimatized workers with light workloads in environments with a WBGT between 81.5°F and 83.3°F, which is similar to temperatures measured in the forming department at the time of our visit. Both the NIOSH REL and ACGIH TLV assume a normal work/rest regimen of a 5-day workweek and an 8-hour workday with short morning and afternoon breaks (approximately 15 minutes each) and a longer lunch break (approximately 30 minutes).

These metabolic heat rate estimates reflect work/rest regimens that would be applicable had the employees rested in the same temperature as the work environment and were tending to the forming machine for the entire hour. However, this may not be the case for all employees. Some employees were observed performing maintenance work that may be classified as a moderate or high workload. It is important to remember that the NIOSH RELs were calculated for a standard worker, these work/rest regimens vary from employee to employee, and an hourly estimate of metabolic heat rate and WBGT provides a more accurate recommendation for work/rest regimens.

On September 13, 2006, we interviewed all 18 forming department employees working first and second shifts. The average age of the workers was 45 years (range: 21 to 60 years) and the average number of years worked in the hot end of the plant was 20 years (range: 3 months to 35 years). None of the 18 workers reported consulting a medical provider for a heat-related illness. During the 3 months prior to the site visit, two employees reported having experienced heat-related symptoms on a hot day during their shift (one experiencing an episode of heart racing and lack of sweating, the other experiencing persistent headache). One employee reported having experienced symptoms consistent with heat exhaustion in the summer of 2005, and going outside to cool off. Another employee reported having experienced heat exhaustion during his shift in the summer of 2004, going home, and was off work for 2–3 days. Neither employee sought medical care. Two additional employees experienced heat-related cramping and nausea at work 15 and 27 years ago, but not recently.

Ten of the 18 interviewed employees had no problems with the heat in the hot end. Employees reported that when the weather gets hot, the company generally provides electrolyte-containing fluids and heat breaks for employees. However, some workers mentioned that because of the lack of company guidelines to trigger heat stress prevention procedures, employees have to ask that these procedures be initiated. Employees reported that the swamp coolers, while more effective than the man coolers, were not well maintained and some were not functional.

When asked about heat stress training, employees gave a wide range of answers. New employees reported watching a 3-hour safety training video that included heat stress prevention information. Other employees reported getting heat stress information from the senior employees as part of their on-the-job training. Others reported having no heat stress training.

A few workers reported that lack of sufficient staffing on second shift (4 p.m.–12 midnight) during the summer months or when machines were changed to a different product, led to fewer breaks. Additionally, employees mentioned that new hot end employees typically started in June and were not given enough time to acclimatize to the heat, resulting in some quitting the job.

Logs of Work-Related Injuries and Illnesses (OSHA's Form 300) were reviewed for years 2004, 2005, and 2006. Of the 43 entries in 2004, one involved heat exhaustion in June with no lost work days. The logs contained no heat-related illness entries for 2005 or 2006.

Conclusions

Although environmental temperature measurements and workload assessments on the day of the NIOSH evaluation showed that workers in the forming department were not exposed to heat stress in excess of the occupational screening criteria, some interviewed workers reported that they had developed heat strain symptoms during their shifts on previous hot summer days; one reported missing days of work due to heat exhaustion.

Environmental temperatures may be warmer than those on the days of the NIOSH evaluation [NOAA 2004]. During periods of higher temperatures, NIOSH and ACGIH screening criteria are more likely to be exceeded, thereby raising the potential for heat stress and strain among employees. Employee reports of heat strain symptoms on previous hot days confirm that this is a potential hazard at this facility.

Recommendations

The following recommendations help identify potential heat stress and strain risks and how to limit heat-related illnesses in hot end workers.

1. Place the fans that supply cooler air from the basement of the facility (man coolers) and the evaporative cooling fans (swamp coolers) on a preventive maintenance schedule to ensure they are operational throughout the summer months.
2. Develop a heat-acclimatization program to decrease the risk of heat-related disorders. Such a program involves exposing workers to hot work environments for progressively longer periods. NIOSH recommends that workers who have had previous experience in jobs where heat levels are high enough to produce heat stress (CBT and heart rate increase, but do not exceed recommended levels) should work in the environment 50% of the shift on day one, 60% on day two, 80% on day three and 100% on day four. New employees who will be similarly exposed should start with 20% on day one, with a 20% increase in exposure each additional day [NIOSH 1986]. The duration of exposure required for full acclimatization is highly variable between individuals, and some workers may be able to work a full shift before

this process is completed. The body's acclimatization will continue to improve each day in that environment for up to 3 weeks.

3. Develop continuing education programs to ensure that all employees potentially exposed to hot environments and physically demanding job activities stay current on heat stress and heat stress prevention information. Employees working in the hot end area should have continuing education at least yearly. An effective heat stress training program should include at least the following components:

    - Knowledge of the hazards of heat stress
    - Recognition of predisposing factors, danger signs, and symptoms
    - Awareness of signs and symptoms of heat-related illness and first-aid procedures for treatment
    - Employee responsibilities in avoiding heat stress
    - Medical conditions that may increase the risk of heat-related illnesses
    - Dangers in using drugs, including therapeutic ones, and alcohol in hot and physically demanding work environments
    - Preventive measures that can be taken to reduce heat stress
    - Instructing workers to monitor themselves and others for heat strain signs and symptoms following guidelines in Appendix C
    - Encouraging workers to take their breaks in a cool location such as the break room

4. Monitor environmental heat exposures during the hottest months using a WBGT monitor at, or as close as possible to, the area where the workers are exposed. Break areas and other areas in which the employees may be working that differ in temperature should also be measured; results should be used to calculate hourly TWA WBGTs. Make at least hourly WBGT measurements during the hottest part of each shift, during the hottest months of the year, and when heat waves occur or are predicted to occur. If two sequential measurements exceed the applicable criteria (NIOSH RAL or REL, or ACGIH TLV), then work conditions should be modified until two more sequential WBGT measurements

are within the exposure limits. On these days, administrative controls such as increasing the number of breaks and employees in the hot end, use of cooling methods, and additional awareness training can be implemented to help reduce the risk of heat-related illness.

5. Establish criteria for the declaration of a heat alert. For example, a heat alert may be declared if the area weather forecast for the next day predicts a maximum air temperature of 95°F or above, or 90°F if this is 9°F above the maximum reached in any of the preceding 3 days. Procedures to follow during the state of heat alert include:

    - Increase the number of workers in each team to reduce each worker's metabolic rate
    - Increase rest allowances
    - Remind workers to drink small amounts of water frequently to prevent dehydration and maintain body weight, and to weigh themselves before and after the shift
    - Check workers' oral temperature and pulse during their most severe heat-exposure period
    - Exercise additional caution on the first day of a shift change to make sure workers are not overexposed to heat, because they may have lost some of their acclimatization over the weekend and during days off
    - Restrict overtime work

6. Develop a heat-related illness surveillance program, which includes establishing and maintaining accurate records of any heat-related disorder events and noting the environmental and work conditions at the time of disorder. Such events may include repeated accidents, episodes of heat-related disorders, or frequent health-related absences. Job-specific clustering of specific events or illnesses should be followed up by environmental and personal monitoring and medical evaluations.

7. Ensure that employees stay hydrated and do not lose more than 1.5% body weight during their shift. Always provide cool (50°F–60°F) water or any cool liquid (except alcohol and

caffeinated beverages) and encourage employees to drink small amounts frequently, e.g., one cup every 20 minutes. Drinking from individual containers improves water intake over the use of drinking fountains. Although some commercial drinks contain salt, this is not a necessary requirement because most people add enough salt to their diets to accommodate working in this environment.

8. Create a buddy system so that employees can monitor each other for symptoms of heat disorders. A buddy system will help to ensure that each buddy has had enough water and food and is feeling well enough to continue. If a coworker appears to be disoriented or confused, or suffers inexplicable irritability, malaise, or flu-like symptoms, the employee should be removed for rest in a cool location with rapidly circulating air and kept under skilled observation. Immediate emergency care is necessary if sweating stops and the skin becomes hot and dry.

9. Allow employees to take unscheduled breaks if they report feeling weak, nauseated, excessively fatigued, confused, and/or irritable during hot temperatures. These heat strain symptoms, and any other signs of heat overexposure, should be reported by employees to their supervisor for investigation and follow-up.

REFERENCES

ACGIH® [2006]. Documentation of the threshold limit values and biological exposure indices. 7th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists; 2002–2006 Suppl.

NIOSH [1986]. Criteria for a recommended standard: occupational exposure to hot environments, rev. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-113.

NOAA [2004]. Climatography of the United States report No. 20: Anderson Sewage Plant, Indiana. Asheville, NC: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service.

Appendix A: Occupational Exposure Limits & Health Effects

In evaluating the hazards posed by workplace exposures, NIOSH investigators use both mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents as a guide for making recommendations. OELs have been developed by Federal agencies and safety and health organizations to prevent the occurrence of adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. However, not all workers will be protected from adverse health effects even if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Also, some substances can be absorbed by direct contact with the skin and mucous membranes in addition to being inhaled, which contributes to the individual's overall exposure.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STEL or ceiling values where health effects are caused by exposures over a short-period. Unless otherwise noted, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday, and the ceiling limit is an exposure that should not be exceeded at any time.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits, while others are recommendations. The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits enforceable in workplaces covered under the Occupational Safety and Health Act. NIOSH RELs are recommendations based on a critical review of the scientific and technical information available on a given hazard and the adequacy of methods to identify and control the hazard. NIOSH RELs can be found in the NIOSH Pocket Guide to Chemical Hazards [NIOSH 2005]. NIOSH also recommends different types of risk management practices (e.g., engineering controls, safe work practices, worker education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects from these hazards. Other OELs that are commonly used and cited in the U.S. include the TLVs recommended by ACGIH, a professional organization, and the WEELs recommended by the American Industrial Hygiene Association, another professional organization. ACGIH TLVs are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2007]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2007].

Employers should understand that not all hazardous chemicals have specific OSHA PELs, and for some agents the legally enforceable and recommended limits may not reflect current health-based information. However, an employer is still required by OSHA to protect its employees from hazards even in the absence of a specific OSHA PEL. OSHA requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970 (Public Law 91–596, sec. 5(a)(1))]. Thus, NIOSH investigators encourage employers to make use of other OELs when making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminate or minimize identified workplace hazards. This includes, in order of preference, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection).

Heat Stress

NIOSH defines heat stress exposure as the sum of the heat generated in the body (metabolic heat) plus the heat gained from the environment (environmental heat) minus the heat lost from the body to the environment, primarily through evaporation. Many bodily responses to heat stress are desirable and beneficial because they help regulate internal temperature and, in situations of appropriate repeated exposure, help the body adapt (acclimatize) to the work environment. However, at some stage of heat stress, the body's compensatory measures cannot maintain internal body temperature at the level required for normal functioning. As a result, the risk of heat-induced illnesses, disorders, and accidents substantially increases. Increases in unsafe behavior, behavior that may lead to accidents, are also seen as the level of physical work of the job increases [NIOSH 1986].

Many heat stress guidelines have been developed to protect people against heat-related illnesses. The objective of any heat stress index is to prevent a person's CBT from rising excessively. The World Health Organization concluded that, "it is inadvisable for CBT to exceed 100.4°F or for oral temperature to exceed 99.5°F in prolonged daily exposure to heavy work and/or heat" [WHO 1969]. According to NIOSH, a CBT of 102.2°F should be considered reason to terminate exposure even when CBT is being monitored. This does not mean that a worker with a CBT exceeding those levels will necessarily experience adverse health effects; however, the number of unsafe acts increases as does the risk of developing heat stress illnesses [NIOSH 1986].

NIOSH recommends controlling total heat exposure so that unprotected healthy workers who are medically and physically fit for their required level of activity are wearing, at most, long-sleeved work shirts and trousers or equivalent, and are not exposed to metabolic and environmental heat combinations exceeding the applicable NIOSH criteria. These criteria state that most healthy employees who work in hot environments and are exposed to combinations of environmental and metabolic heat less than the NIOSH RALs for non-acclimatized workers (Appendix D, Figure 1) or the NIOSH RELs for acclimatized workers (Appendix D, Figure 2), should be able to tolerate total heat stress without substantially increasing their risk of incurring acute adverse health effects. Also, no employee should be exposed to metabolic and environmental heat combinations exceeding the applicable ceiling limits of Figures 1 or 2 without being provided with and properly using appropriate and adequate heat-protective clothing and equipment [NIOSH 1986].

ACGIH guidelines require the use of a decision-making process that provides step-by-step situation-dependent instructions that factor in clothing insulation values and physiological evaluation of heat strain [ACGIH 2006]. ACGIH WBGT screening criteria factor in the ability of the body to cool itself (clothing insulation value, humidity, and wind) and, like the NIOSH criteria, can be used to develop work/rest regimens for acclimatized and unacclimatized employees. The ACGIH WBGT-based heat exposure assessment was developed for a traditional work uniform of long-sleeved shirt and pants, and represents conditions under which it is believed that nearly all adequately hydrated, unmedicated, healthy workers may be repeatedly exposed without adverse health effects. Clothing insulation values and the appropriate WBGT adjustments, as well as descriptors of the other decision-making process components can be found in ACGIH's Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices [ACGIH 2006]. The ACGIH TLV for heat stress provides a framework for the control of heat-related illnesses only. Although accidents and injuries can increase with increasing levels of heat stress, it is important to note that the TLVs are not directed toward controlling these [ACGIH 2006].

NIOSH and ACGIH criteria can only be used when WBGT data for the immediate work area are available and must not be used when workers wear encapsulating suits or garments that are impermeable or highly resistant to water vapor or air movement. Further assumptions regarding work demands include an 8-hour work day, 5-day work week, two 15-minute breaks, and a 30-minute lunch break, with rest area temperatures the same as, or less than, those in work areas, and at least some air movement. It must be stressed that while NIOSH and ACGIH guidelines distinguish between safe and dangerous levels, professional judgment must be used in administering a heat stress management program to ensure adequate protection. The OSHA technical manual's section on heat stress refers back to the ACGIH document for guidelines to evaluate employee heat stress and how to investigate the workplace [OSHA 1999].

Health Effects of Exposure to Hot Environments

Heat disorders and health effects of individuals exposed to hot working environments include (in increasing order of severity) skin disorders (heat rash, hives, etc.), heat syncope (fainting), heat cramps, heat exhaustion, and heat stroke. Heat syncope (fainting) results from blood flow being directed to the skin for cooling, resulting in decreased supply to the brain, and most often strikes workers who stand in place for extended periods in hot environments. Heat cramps, caused by sodium depletion due to sweating, typically occur in the muscles employed in strenuous work. Heat cramps and syncope often accompany heat exhaustion, or weakness, fatigue, confusion, nausea, and other symptoms. The dehydration, sodium loss, and elevated CBT (above 100.4°F) are usually due to performing strenuous work in hot conditions with inadequate water and electrolyte intake. Heat exhaustion may lead to heat stroke if the patient is not quickly cooled and rehydrated.

While heat exhaustion victims continue to sweat as their bodies struggle to stay cool, heat stroke victims cease to sweat as their bodies fail to maintain an appropriate core temperature. Heat stroke occurs when hard work, hot environment, and dehydration overload the body's capacity to cool itself. This thermal regulatory failure (heat stroke) is a life-threatening emergency requiring immediate medical attention. Signs and symptoms include irritability, confusion, nausea, convulsions or unconsciousness, hot dry skin, and a CBT above 106°F. Death can result from damage to the brain, heart, liver, or kidneys [Cohen 1990].

Prolonged increases in CBT and chronic exposures to high levels of heat stress are associated with disorders such as temporary infertility (male and female), elevated heart rate, sleep disturbance, fatigue, and irritability. During the first trimester of pregnancy, a sustained CBT greater than 102.2°F may endanger the fetus [ACGIH 2006]. In addition, one or more occurrences of heat-induced illness in a person predisposes him/her to subsequent injuries and can result in temporary or permanent loss of that person's ability to tolerate heat stress [NIOSH 1986; OSHA 1999].

The level of heat stress at which health effects occur is highly individual and depends upon the heat tolerance capabilities of each individual. Age, weight, degree of physical fitness, degree of acclimatization, metabolism, alcohol or illicit drugs, over the counter and prescribed medications, and a variety of medical conditions, such as hypertension and diabetes, all affect a person's sensitivity to heat. At greatest risk are unacclimatized workers, people performing physically strenuous work, those with previous heat illnesses, the elderly, people with cardiovascular or circulatory disorders (diabetes, atherosclerotic vascular disease), those taking medications that impair the body's cooling mechanisms, people who use alcohol or are recovering from recent use, people in poor physical condition, and those recovering from illness. With regard to prescribed medications, β-adrenergic receptor blockers and calcium-channel blockers, used to treat hypertension, limit maximal cardiac output and alter normal vascular distribution of blood flow in response to heat exposure. Diuretics, such as caffeine, can limit cardiac output and affect heat tolerance and sweating; antihistamines, phenothiazines, and cyclic antidepressants can impair sweating. A CBT increase of only 1.8°F above normal encroaches on the brain's ability to function [ACGIH 2006].

Acclimatization

When workers are first exposed to a hot environment, they show signs of distress and discomfort, experience increased CBTs and heart rates, and may have headaches and/or nausea. On repeated exposure there is marked adaptation to the hot environment known as acclimatization. Acclimatization is the process that allows the body to begin sweating sooner and more efficiently, reduces electrolyte concentrations in the sweat, and allows the circulation to stabilize so that the worker can withstand greater amounts of heat stress while experiencing reduced heat strain signs and symptoms.

Acclimatization begins with consecutive exposures to working conditions for 2 hours at a time, with a requisite rise in metabolic rate. This will cause the body to reach 33% of optimum acclimatization by the fourth day of exposure. Cardiovascular function will stabilize, and surface and internal body temperatures will be lower by day 8 when the body has reached 44% of optimum acclimatization. A decrease in sweat and urine electrolyte concentrations is seen at 65% of optimum (day 10); 93% of optimum is reached by day 18, and 99% by day 21 [ACGIH 2006].

The loss of acclimatization begins when the activity under those heat stress conditions is discontinued, and a noticeable loss occurs after 4 days. This loss is usually rapidly made up so that by Tuesday, workers who were off on the weekend are as well acclimatized as they were on the preceding Friday. Chronic illness, an acute episode of mild illness (e.g., gastroenteritis), the use or misuse of pharmacologic agents, a sleep deficit, a suboptimal nutritional state, or a disturbed water and electrolyte balance may reduce the worker's capacity to acclimatize [ACGIH 2006].

Fluid Replacement

Palatability of any fluid replacement solution is important to ensure adequate rehydration. Evidence shows that adding sweeteners to drinks leads to increased consumption. Glucose-electrolyte solutions have been shown to facilitate sodium and water absorption. Also, the glucose in these solutions provides energy for muscular activity in endurance events that require vigorous exercise [Rolls 1990]. However, workers should be cautioned to avoid drinking large amounts of sugar-laden beverages in hot climates as this causes an osmotic diuresis that increases fluid loss through urination. Caffeinated beverages and alcohol intake also increase urinary fluid loss and should be avoided. The temperature of the drink also influences consumption of fluids. Ideally, fluids should be ingested at temperatures of 50°F–60°F, in small quantities (5–7 ounces), and at frequent intervals (every 15–20 minutes).

Average Americans consume adequate, if not excessive, amounts of sodium in their usual diet such that for mild dehydration, only water replacement is needed. However, in moderate dehydration or when involved in events resulting in prolonged sweating, electrolyte (i.e., sodium) replacement is indicated. Many oral electrolyte replacement formulas such as Gatorade® are available. Salt tablets are not recommended as they can irritate the stomach, leading to vomiting, which can exacerbate fluid losses and do not address water replacement needs. Those with nausea and vomiting from heat stress may require intravenous saline administration to replace their water and sodium.

References

ACGIH® [2006]. Documentation of the threshold limit values and biological exposure indices. 7th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists; 2002–2006 Suppl.

ACGIH® [2007]. 2007 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [2007]. 2007 Emergency response planning guidelines (ERPG) & workplace environmental exposure levels (WEEL) handbook. Fairfax, VA: American Industrial Hygiene Association.

CFR. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Cohen R [1990]. Injuries due to physical hazards. In: LaDou J, ed. Occupational medicine. East Norwalk, CT: Appleton & Lange.

Minard D [1961]. Prevention of heat casualties in Marine Corps recruits. Mil Med 126(44):261–272.

NIOSH [1986]. Criteria for a recommended standard: occupational exposure to hot environments, rev. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-113.

NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

NIOSH [2005]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-149.

OSHA [1999]. Heat stress. In: OSHA technical manual. Sec 3 Chap 4. Washington, D.C. U.S. Department of Labor, Occupational Safety and Health Administration, TED 1-0.15A.

Roetzheim R [1991]. Overhydration. Physician Sports Med 19:32.

Rolls BJ, Kim S, Federoff IC [1990]. Effects of drinks sweetened with sucrose or aspartame on hunger, thirst and food intake in men. Physiol Behav 48 (1):19–26.

Rolls BJ [1993]. Palatability and fluid intake. In: Mariott BM, ed. Fluid and heat stress. Washington DC: National Academy Press, pp. 161–167.

Singer GG, Brenner BM [1998]. Fluid and electrolyte disturbances. In: Fauci AS, Brunwald E, Isselbacher KJ, Wilson JD, Martin JB, Kasper DL, Hauser SL, Longo DL, eds. Harrison's principles of internal medicine, 14th ed. New York: Mc-Graw Hill.

WHO [1969]. Health factors involved in working under conditions of heat stress. Geneva, Switzerland: World Health Organization. Technical Report Series No. 412.

APPENDIX B: ESTIMATING METABOLIC HEAT PRODUCTION RATES BY TASK ANALYSIS

A. Body Position and Movement	**kcal/min**	
Sitting	0.3	
Standing	0.6	
Walking (uphill)	2.0–3.0 (add 0.8 kcal/meter rise in elevation)	
B. Type of Work	**Average (kcal/min)**	**Range (kcal/min)**
Hand work:		*0.2–1.2*
Light	0.4	
Heavy	0.9	
Work, one arm:		*0.7–2.5*
Light	1.0	
Heavy	1.8	
Work, both arms:		*1.0–3.5*
Light	1.5	
Heavy	2.5	
Work, whole body:		*2.5–9.0*
Light	3.5	
Moderate	5.0	
Heavy	7.0	
Very heavy	9.0	
C. Basal Metabolism	1.0	

The sum of A, B, and C is equal to the estimated metabolic production per task. Estimates are for a standard male worker of 154 lbs body weight and 19.4 square feet body surface.

Sample calculation for forming department employees:

Task	**kcal/min**
A. Standing	0.6
B. Light, work with both arms	1.5
C. Basal metabolism	1.0
Metabolic rate total per minute	*3.1 kcal/min*
Metabolic rate total per hour	*186 kcal/hour*

References

NIOSH [1986]. Criteria for a recommended standard: occupational exposure to hot environments, rev. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-113.

Appendix C: Use of Personal Monitoring Methods to Reduce Heat-Related Illness

Periodic monitoring of the heart rate, oral temperature, extent of body weight loss, and/or recovery heart rate should always include the determination of baseline values for deciding whether individuals are fit to continue work that day.

Heart Rate: Calculate your heart rate limit by subtracting your age from 180. Your heart rate at peak work effort should not exceed this number for more than 3 or 4 minutes. If it does, stop work immediately, find some shade, drink, and rest until your heart rate returns to a more normal pace. Repeat as necessary.

Oral Temperature: Use a clinical thermometer right after stopping work but before drinking anything. Try to avoid open-mouth breathing prior to inserting the thermometer. If the oral temperature taken under the tongue exceeds 99.7°F, shorten the next work cycle by one third, and maintain the same rest period. An oral temperature of 100.4°F (deep body temperature of 102.2°F) should be considered reason to terminate exposure even when temperature is being monitored.

Body Weight: Monitor hydration status on a regular basis. Thirst is a poor indicator of hydration because significant dehydration has already taken place when the thirst sensation occurs. Workers should be familiar with their weight when they are fully hydrated and should strive to maintain this weight. Weight loss should not exceed 1.5% of total body weight in a work day. If it does, fluid and food intake should increase. Alcohol and caffeinated beverages should always be avoided when working under heat stress conditions. Workers should attempt to rehydrate themselves until they achieve their baseline weight. Body water loss can be measured by weighing the worker at the beginning and end of each work day and by using this equation:

(pre-activity weight – post-activity weight) ÷ pre-activity weight x 100 = percent body weight loss

Recovery Heart Rate: Following a normal work cycle, compare a pulse rate taken after 3 minutes of seated rest, P3, with the pulse rate taken after 1 minute of rest, P1. Interpret the results using the following table:

Heart Rate Recovery Pattern	P3		P1 minus P3
Excessive heat strain:	$\geq$ 90 BPM	and	$\leq$ 10 BPM
Moderate strain:	$\geq$ 90 BPM	and	$\geq$ 10 BPM
Sufficient recovery:	<90 BPM	and	>10 BPM

References

NIOSH [1986]. Criteria for a recommended standard: occupational exposure to hot environments, rev. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-113.

ACGIH® [2006]. Documentation of the threshold limit values and biological exposure indices. 7th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists; 2002–2006 Suppl.

Appendix D: NIOSH-Recommended Heat-Stress Alert and Heat-Stress Exposure Limits

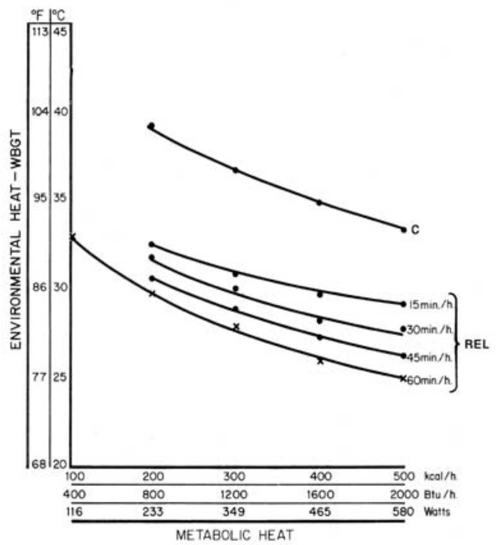

Figure 1. Recommended Heat-Stress Alert Limits (unacclimitized workers)

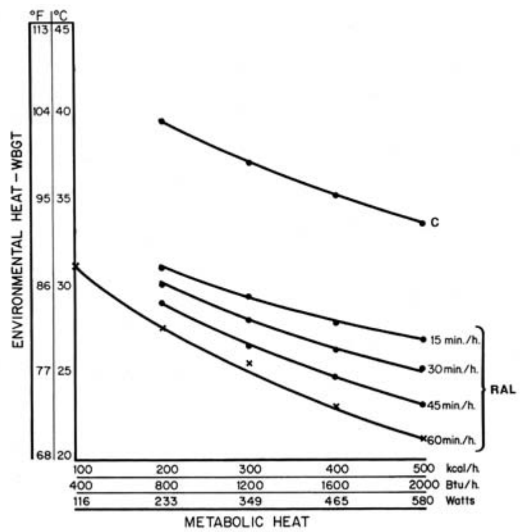

Figure 2. Recommended Heat-Stress Exposure Limits (acclimatized workers)

The figures' curves indicate recommended work/rest regimens of external heat (measured as wet-bulb globe temperatures) and internal (metabolic) heat. The 'C' curve is the Ceiling Limit, indicating that workers should not be exposed to such conditions without adequate heat-protective clothing and equipment.

References

NIOSH [1986]. Criteria for a recommended standard: occupational exposure to hot environments, rev. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 86-113.

Acknowledgements and Availability of Report

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employers or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

This report was prepared by Chad H. Dowell and Loren C. Tapp of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Industrial hygiene field assistance was provided by Andrea M. Markey. Medical field assistance was provided by Bich Dang. Desktop publishing was performed by Robin Smith. Editorial assistance was provided by Ellen Galloway.

Copies of this report have been sent to employee and management representatives at Owens-Illinois; Glass, Molders, Pottery, Plastics and Allied Workers International Union Local 207; and the OSHA Regional Office. The report may be viewed and printed from the following internet address: http://www.cdc.gov/niosh/hhe. Copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161.

This is a recommended citation for this report.
NIOSH [2007]. Health Hazard Evaluation Report: evaluation of heat stress at a glass bottle manufacturer, Owens-Illinois, Lapel, Indiana. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA No. 2003-0311-3052.

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