A Guide to Manage Heat Stress–Related Injuries and Illness in the Iron and Steel Industry

Hazards are ever-present in the steel plant environment, and a heightened awareness and emphasis on safety is a necessary priority for our industry. This monthly column, coordinated by members of the AIST Safety & Health Technology Committee, focuses on procedures and practices to promote a safe working environment for everyone.

Authors

Rupkatha Bardhan
Assistant Professor, Occupational Safety and Health Department, Murray State University, Murray, Ky., USA

Melina Eaker
Student, Occupational Safety and Health Department, Murray State University, Murray, Ky., USA

William R. Gaskins
Student, Occupational Safety and Health Department, Murray State University, Murray, Ky., USA

Jacob Crissup
Student, Occupational Safety and Health Department, Murray State University, Murray, Ky., USA

Comments are welcome. If you have questions about this topic or other safety issues, please contact safetyfirst@aist.org. Please include your full name, company name, mailing address and email in all correspondence.

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Heat stress poses a substantial risk to iron- and steelworkers worldwide. Previous studies have shown that iron and steel industry workers are likely to suffer from a heat-related illness (HRI), and casting and melting workers face a particularly high risk of HRIs.

Heat stress can cause serious heat-related illness including heat stroke, heat exhaustion, heat cramps, heat rash and heat syncope. Heat stress can also cause fatigue and distress in employees, which may result in distractions, causing injuries at work. The indoor workplace has high levels of environmental heat from ovens and molten metal. Wearing heavy protective clothing to prevent skin burns from molten metal can exacerbate the heat stress effects. Working extended hours near a furnace or oven can also be a risk factor for heat stress. Environmental heat measurements underestimate the risk of HRI in these situations.

Workers are at risk of heat-related illness when they are new to jobs, have chronic health conditions or they are reassigned to warmer job tasks from job tasks in a colder environment. This paper identifies risk factors for heat stress in iron- and steelworkers and provides recommendations to manage heat stress through assessment, control and training.

Implementation of a Heat Stress Management Program

All employers should have a written heat stress management program that addresses assessment, control and training components as shown in Fig. 1.

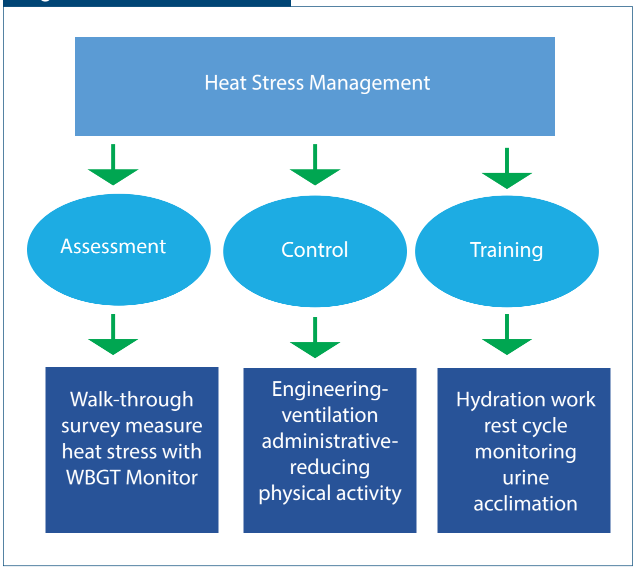
Several steps are required to implement an effective heat stress management program in a workplace. The steps for heat stress management are:

- Step 1: Safety walk-through of the worksite.
- Step 2: Measurement of heat stress using wet bulb globe temperature (WBGT) monitor.
- Step 3: Adjusting clothing factors to WBGT readings.
- Step 4: Determining metabolic rate and work/rest schedules for employees based on type of work performed and WBGT values.
- Step 5: Determining if exposure is above the threshold limit values (TLV).
- Step 6: Implementing controls.
- Step 7: Training employees on heat stress.

Step 1: Safety Walk-Through of the Worksite — A walk-through survey of the worksite should be conducted to assess high-heat areas where employees work for extended hours. Murray State University students along with their faculty mentor conducted a heat stress assessment of a steel mill in April 2021 and identified casting, melting and reheat furnace area as indoor high-risk areas for heat stress in employees in the iron and steel industry.

Step 2: Measurement of Heat Stress Using WBGT Monitor — Jobs with high risk of heat stress were identified and heat stress was measured

Figure 1



Heat stress management.

using WBGT monitors. TSI Quest Temp 36 (intrinsically safe) and TSI Quest Temp 44 were used to monitor heat stress by the Murray State University students.

The WBGT meter was placed on a tripod 3.5 feet from the ground and close to a worker standing position. Workers were advised to not stand too close to the meter and not to block the radiant heat.

The findings of the WBGT meter were accessed in a computer through the TSI Quest Detection Management Software. The WBGT meter automatically calculates adjusted temperature using the sensor data inputs and programmed equations. To calculate WBGT outdoors, the formula is:

$$WBGTout = 0.7Tnwb + 0.2Tg + 0.1Tdb \qquad \text{(Eq. 1)}$$

For indoor environments, the meter does not use the dry-bulb temperature since the globe and the dry-bulb should be equal without radiant heat. The formula for indoor WBGT is:

$$WGBTin = 0.7Tnwb + 0.3Tg \qquad \text{(Eq. 2)}$$

where:

Tnwb = natural wet bulb (evaporative cooling),
Tg = black globe thermometer (radiant heat) and
Td = dry bulb (ambient temperature).

High WBGT readings were identified, as shown in the asterisk in Table 1 in casting (indoor average WBGT of 39.1°C), and in reheat furnace area (indoor average WBGT of 34.7°C). The WBGT indoor temperature was above the ACGIH (American Conference of Governmental Industrial Hygienists) TLV limits (28°C) for moderate work in casting and reheat areas.

However, in the meltshop, heat stress equipment was kept farther from the furnace and 6 to 8 feet from where employees stand to protect the equipment from molten metal splash and radiant sparks. The WBGT number (17.6°C) is low probably because the equipment measured was kept at a distance and may not represent true worker heat exposure. Workers may be exposed to more heat as they were standing closer to furnace while working. The WBGT area measurements were taken in April and may not reflect the worst-case scenario.

Measurements need to be taken in July and August when outdoor temperature increases in the U.S. and there is potential for increase in the WBGT readings. Physiological monitoring of employees is also recommended to further determine the personal exposure of employees (heart rate variability, core body temperature) to heat stress. Heart rate in excess of 180 beats per minute and body temperature of 38°C (100.4°F) or higher when working in extreme heat conditions is a great risk factor for employee to suffer from heat-related illness. Immediate rest in cool area, effective first aid and medical help will eliminate the risk of severe heat exhaustion or heat stroke.

Step 3: Adjusting Clothing Factors to WBGT Readings — Clothing adjustment factors can be determined from ACGIH chart by adding WBGT to determine WBGT effectiveness in Celsius. WBGTeff = WBGTin + Clothing Adjustment Factor (CAF) (Celsius). All employees in the casting and melting areas wore standard cotton clothing and flame retardant (FR) jacket/coveralls. For flame-retardant shirt and pants with a single-layer jacket: long-sleeve shirt and pants with jacket made from FR9 treated cotton fabric CAF 2.0 should be adjusted.[6] There are no significant differences among the FR coveralls and cotton work clothes, and the proposed clothing adjustment for FR coveralls clothing is 0°C.

Step 4: Determining Metabolic Rate and Work/Rest Schedules for Employees Based on Type of Work Performed and WBGT Values — Work/rest schedules are determined from ACGIH TLV® based on WBGT values in Celsius and type of work employees performed (light, moderate, heavy, or very heavy work). Metabolic work rate based on work demand is determined from ACGIH TLV chart from TLVs and

Table 1

Heat Stress Measurements

Plant locations	WBGT dry avg. (min–max)	WBGT wet avg. (min–max)	WBGT globe avg. (min–max)	WBGT indoor avg. (min–max)	Humidity avg. (min–max)	Heat index avg. (min–max)
Casting (close to operator near the torch table and the billet area)	32.7°C (29.2°C–39.1°C)	27.8°C (26.5°C–29.8°C)	65.7°C (61.5°C–71.7°C)	39.1°C* (37.0°C–42.2°C)	28.2% (23.0%–69.6%)	29.0°C (29.0°C–32.5°C)
Reheat furnace area (next to the operator station)	23.9°C (16.9°C–28.4°C)	32.9°C (18.4°C–42.0°C)	38.8°C (20.3°C–51.3°C)	34.7°C* (18.9°C–44.7°C)	29.3% (20.0%–55.0%)	20.4°C (19.0°C–27.5°C)
Meltshop near the furnace	14.7°C (13.8°C–16.6°C)	17.2°C (15.9°C–23.2°C)	18.7°C (16.9°C–28.7°C)	17.6°C (16.2°C–24.6°C)	48.3% (42.0%–52.0%)	—

Biological Exposure Indices (BEI). With this chart, metabolic work rate for light work is up to 200 kcal/hour, moderate work is 200–350 kcal/hour, and heavy work is 350–500 kcal/hour (which is sustainable for 8 hours with nominal breaks). Table 2 shows the temperature and work and rest cycles. For acclimatized workers, moderate continuous work in casting and melting is fine for a temperature of 28°C or less. For a WBGT temperature of 29°C, for moderate work, 75% work and 25% rest is recommended (45 minutes work and 15 minutes rest every hour). For a WBGT temperature of 30°C for moderate work, 50% work and 50% rest (30 minutes work and 30 minutes rest every hour) is recommended.

Step 5: Determining if Exposure Is Above the Threshold Limit Values — Using metabolic rate and WBGTeff, it should be determined if the TLV has been exceeded (Table 2), which indicates that the worker is exposed to excessive heat stress. Other factors can be considered such as an employee experiencing heat stress symptoms, feeling light-headed and short of breath.

Step 6: Implementing Controls — Control methods are recommended to the industry management based on exposure level. Control methods need to be implemented in high-heat areas such as casting, melting and reheat furnace where exposure level could be above TLV, especially during the hot summer months.

1. Engineering Controls: To control heat in work environments, a wide variety of techniques can be utilized. General ventilation is used to dilute hot air with cooler air. When dealing with smaller areas, local exhaust systems may be more effective. Air conditioning is an effective but expensive method. An alternative method can be use of chillers to circulate cool water through heat exchangers. Convection fans can be set up in hot areas and can increase heat exchange and evaporation. Heat shields can be used to reduce radiant heat when placed between a heat source and the workers.
2. Administrative and Work Practice Controls: Adjusting the work-rest cycle (i.e., shorten the duration of each heat exposure and increase rest time in cool places), distributing workload among more people and training workers on symptoms of heat stress will allow workers to self-limit exposure. Acclimation or acclimatization is the process of a body adapting to a change in temperature, and can take two weeks for new employees. A good rule of thumb for workers exposed to extreme temperatures is to expose them to approximately 20% on each day for five days. While working in the hot environments, workers can sweat as much as three gallons of sweat. Drinking one cup (8 oz.) of water or other fluids every 15–20 minutes will be helpful for replacement of the fluids lost by sweating.
3. Personal Protective Equipment (PPE): Reflective clothing which can vary from aprons and jackets to suits that can completely enclose the worker from neck to feet, can stop the skin from absorbing radiant heat. However, since most reflective clothing does not allow air exchange through the garment, the reduction of radiant heat must more than offset the corresponding loss in evaporative cooling. Reflective clothing should be worn as loosely as possible. Use of personal cooling garments to prevent heat stress has gained attention in recent years. Effects of protective equipment like chemical protection suits or respirators that increases heat stress must be considered when determining work/rest cycles and workloads.

Step 7: Training Employees on Heat Stress — All employees should be trained in heat stress. Training materials should include information on work/rest

Table 2

Work Rest Values Adapted From ACGIH (American Conference of Governmental Industrial Hygienists) TLV (threshold limit values)® Based on WBGT (wet bulb globe temperature)°C

Allocation of work in a work/rest cycle	Acclimatized				Action limit (unacclimatized)			
	Light	Moderate	Heavy	Very heavy	Light	Moderate	Heavy	Very heavy
75–100%	31.0	28.0	—	—	28.0	25.0	—	—
50–75%	31.0	29.0	27.5	—	28.5	26.0	24.0	—
25–50%	32.0	30.0	29.0	28.0	29.5	27.0	25.5	24.5
0–25%	32.5	31.5	30.5	30.0	30.0	29.0	28.0	27.0

Note: Assumes 8-hour workday in a 5-day workweek with conventional breaks. TLVs assume that workers exposed to these conditions are adequately hydrated, are not taking medication, are wearing lightweight clothing and are in good conditions.

cycles, taking breaks to get hydrated and monitoring urine color and urine output, identifying symptoms associated with heat stress, proper use and care of heat protective equipment and PPE, procedures for responding to heat stress symptoms, contacting emergency medical services after recognizing heat stress symptoms, and acclimatization to heat. Employers can provide bottled water and sports drinks for their employees and implement a fruit program during summer months to promote hydration and good diet among employees. Supervisors should be advised to allow employees to take breaks from work when needed aside their regular scheduled breaks to eliminate heat stress related injuries and illness.

Conclusion

Heat stress is prevalent in the casting, melting and reheat furnace areas of the iron and steel industry. Extended exposures to heat extremes may bring about a wide variety of heat induced disorders. To prevent heat-related injuries and illness, implementation of an effective heat stress management program is essential. Managers and supervisors should ensure that all workers exposed to potential heat be trained in the signs and symptoms of the heat stress disorders and understand how to prevent them. Engineering controls, administrative controls and PPE should be used along with physiological monitoring to prevent heat-related injuries and illness.

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