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Bechel, Jeffrey P. ***The Risk of Heat Stress During Glass Furnace Operation***

Abstract

The objective of this research project was to assess the risk of heat stress and heat-related illness during the operation and maintenance of a glass furnace. The study was performed within an industrial setting at Company XYZ's, glass plant in central Wisconsin. To assess the risk of heat exposure, an analysis of two recent heat stress incidents was performed and corrective actions were assessed. The Wet Bulb Global Temperature was evaluated, which indicated high-risk exposures during normal operation and maintenance of the industrial furnace. Company XYZ's heat stress policy and procedure were also analyzed and were found to be severely lacking or absent. Although training for heat awareness was conducted in 2021, this was the only time that such had been completed in the glass production plant's history. Thus, evidence indicates that Company XYZ was inadequately prepared to control the risk of extreme heat-stress exposures. It is recommended that Company XYZ perform a training needs analysis to identify the areas in which training in heat-stress related topics must be performed. Table-top exercises along with instructor led training would prompt employees to understand the risks associated with heat-stress and the methods to mitigate such risks. Company XYZ should also begin to develop pro-active policies and programs addressing heat-stress related risk. Although a comprehensive federal regulation focusing on heat-related risk has yet to be publishes, Company XYZ may reference existing state plans as well as recommendations from federal entities regarding OSHA's National Emphasis Program for programmatic development purposes.

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Chapter I: Introduction and Problem Statement

Heat-related illness due to exposure to temperature extremes is likely a relevant concern for various high-temperature manufacturing processes, and the float glass industry may face a similar risk to its employees and assets. Heat stress is the leading cause of weather-related fatalities in the workforce (Occupational Safety & Health Administration [OSHA], n.d.). Heat-related incidents are too often under-reported, and yet such may be considered reasonably preventable. During the summer of 2021, the OSHA initiated a National Emphasis Program, which focused on identifying heat-related hazards, monitoring extreme heat environments, and sharing best practices to protect employees (OSHA, n.d.). In December of 2021, the initiative completed the comment period and move into the preliminary stages of the rulemaking process. Exactly what the contents of the regulation will look like remains unclear, but organizations may gain insight into the standards contents by examining existing OSHA state plans such as those in Minnesota and Washington. This initiative remains a priority for the Biden-Harris interagency commitment to workplace safety as research indicates that 18 of the last 19 years have been the warmest on record (TRSA, 2022).

Company XYZ is a management-owned S-Corporation, which currently leads the glass industry in the development of residential glass. The company employs over 7,000 employees in 37 manufacturing locations around the United States. These 37 locations make up the subsidiary groups consisting of the Float Glass, Custom Tempered Glass, Laminated Glass, Coated Glass, and Insulating Glass divisions. Company XYZ, the source for this study, is a float glass producing facility, located in central Wisconsin, which produces raw glass for use in residential window manufacturing. Company XYZ has been in business since 1992 and has since added six

additional float glass facilities to accommodate the demand for residential glass. During the past 30 years, Company XYZ has produced over 7 million tons of product.

Company XYZ is essentially a raw material producer for the rest of the XYZ corporation. The facility produces the raw flat glass and sells approximately 80% of this product to other XYZ corporation subsidiaries. The subsidiaries in turn add value to the flat glass by tempering, coating, laminating, or creating the insulated glass units that are sold to customers outside the Company XYZ family to construct residential windows. Company XYZ produces approximately 647 tons of raw float glass per day, which yields on average 87% (560 tons) of pristine flat glass.

The high glass demand requires that Company XYZ operates its furnace twenty-four hours per day, and furnace shutdowns for major cold repair occur once every 12 to 15 years. The cost of a full cold repair may be upwards of $50 million, and thus it is essential that a strict maintenance schedule requires employees to perform in-process work on a hot furnace. The glass furnace operates at approximately 3,000 °F, or 1,650 °C. There is little relief from the radiant furnace heat during certain maintenance activities, which poses the serious threat of health-related illness to Company XYZ employees.

Company XYZ has experienced two major employee illness-related incidents in the last six years due to the effects of extreme heat. In 2016, a hot-end operator was stationed at the downstream end of the furnace (beginning of the tin bath), performing work during an exit-end break. This required that the bath be physically opened and employees to “row” the glass to start such back on the lift-out rolls again. The employee was asked by several team members if he felt able to continue work, to which he responded in the affirmative. Shortly thereafter, the employee became disoriented and lightheaded. The designated emergency response team members placed

cold packs in the overheated employee's armpits and groin area and called an ambulance. The affected employee was eventually diagnosed with heat exhaustion.

In 2021, a furnace mason group was performing work on the port necks in an extremely hot area of the furnace. One of the employees had noticed the occurrence of minor hand cramping but thought nothing of it as he continued to work. As the day progressed, the employee was routinely hydrating, but he had not urinated at all. The employee initially decided to remove himself from the heat-related work, but then went back into the environment to finish the job with his coworkers. When the work was completed, the employee sat down in a cool room to remove wet clothing and change into dry clothes. He immediately felt lightheaded and experienced extreme cramping. An ambulance was called, and the employee was subsequently diagnosed with extreme heat exhaustion and dehydration.

Even though two reasonably serious heat-exhaustion related incidents have occurred in the last six years, Company XYZ has not modified its heat stress minimization guidelines. Given the occurrence of two OSHA recordable heat-exhaustion incidents, both of which involved furnace employees continued frequent exposure to elevated temperatures, Company XYZ continues to be at risk of additional employee, legal, and productivity-related losses.

Purpose of the Study

The purpose of this study is to assess Company XYZ's employees' exposure to heat-stress related situations during furnace operation and maintenance related activities.

Goals of the Study

To ascertain the breadth and depth of the continued risk of heat exposure at Company XYZ, the following goals have been included as a part of this study.

- Perform an analysis of Company XYZ heat-stress incident data within the organization's EHS incident reporting system.
- Analyze employee training, practices, and related documentation to ensure that workers are knowledgeable in hazard identification, furnace operation, and the signs and symptoms of heat-related illness.
- Compare Company XYZ's heat-stress prevention protocol with other industry standards and best practices for employees who are working in extreme heat situations.
- Perform heat-stress assessments by measuring Wet Bulb Globe Temperature (WBGT) and ambient air temperatures in the vicinity of furnace work activities.

Background and Significance

Furnace operation activities expose Company XYZ employees to significant risk for heat-related illness. The ambient temperature may reach as high as 160 °F, depending on the task the employees are performing. The highest risk heat-stress-related task is when an employee is working under the regenerator ports while performing burner work. During such activities, the employees are surrounded by heat-generating parts of the furnace with no opportunity to escape the high-temperature environment until they rotate out with another team. Furnace masons who may possess an excessive task completion mentality may experience symptoms of a heat-related illness in a relatively short period of time. There is a certain amount of relief from extreme heat as an employee moves away from the sidewalls of the furnace near cooler/fresh air through wall-mounted louvers, although it still may be excessively warm in such an area.

Of the two significant heat-related recordable incidents that were classified as heat exhaustion, the most recent event was considered severe. The technician worked until he was

cramping but went back in at the end of the shift to finish the job. He lost consciousness, was taken to the ER, and could not unclench his hands and feet. Doctors were worried that this employee would sustain permanent kidney damage. Fortunately, he made a full recovery.

Company XYZ continues to expose their employees to risk of further heat-related incidents, and if not corrected, such an event could impact the following assets:

- **people:** Heat stress can lead to a multitude of health effects, including permanent disability, to the employee and a significant cost to the employer in terms of workers' compensation.
- **product:** Not performing routine maintenance and repair because of heat-stress risk could lead to product loss, due to the occurrence of glass defects, decreased furnace efficiency, or deteriorating furnace structure. Heat stress could prompt employees to rush through a job due to extreme temperatures and, consequently, reduce the quality of the maintenance task.
- **time:** Losing employees to heat illness may delay certain projects until furnace masons and technicians are back in-house and thus expose Company XYZ to higher risk of furnace defects, equipment failure, and decreased furnace efficiency. Company XYZ may also have to enlist the help of additional furnace masons and hot-end employees from other plants to help cover their diminished manpower. Training and on-boarding are not an issue as every furnace in the division is very similar; however, there are certain nuances at each facility that outside furnace technicians would need to understand. There is a cost, associated with various travel expenses, that is usually absorbed by the facility.

- **public:** Being one of the larger employers in the area, Company XYZ takes considerable pride in its reputation. Increased total case incident rate and days away restricted time rate are visible numbers that the public as well as customers can access to assess the safety culture at Company XYZ. Having lost product or time places a significant strain on the entire company's system. Company XYZ's internal as well as external customers may feel the impact of a heat-stress-related loss with extended lead times or defective product, which would damage reliability and quality perceptions of the downstream business as well as consumers.

Assumptions of the Study

The assumptions of the study are as follows:

1. Maintenance must be performed in extreme heat situations.
2. Personal protective equipment (PPE) must be worn while performing work in hot environments. This includes a base layer garment (usually sweatpants), heat-resistant bib overalls, hot coat, hot hood, hot-mill gloves, goggles, hearing protection, safety boots and a respirator (when required). This elevates the risk of heat-related incidents by not allowing the body to cool through evaporation.
3. The researcher is assuming that the WBGT will be high in this situation due to the intense heat produced by the glass furnace. According to an article published by Elinor Aspegren, "with no wind and sunny skies, an area with 50% humidity will hit an unlivable WBGT at around 109 °F, while in mostly dry air, temperatures would have to top 130 °F to reach that limit" (Crownhart, 2021, para. 14). With the exposure scenario at Company XYZ, it is reasonable to assume that one or both conditions exist.

Definition of Terms

The following is a list of terms that will allow the reader to better understand the float glass process.

Batch

A batch is the mixture of raw materials to a given composition, which is ready for delivery to the furnace melting end (Dismatec Glass Plant Engineering Worldwide, n.d.).

Burner Block

A burner block is a refractory block with one main aperture through which the fossil fuel burners fire (Dismatec Glass Plant Engineering Worldwide, n.d.).

Checker Packs

Checker packs (i.e., checkers) are the refractory pieces installed in the regenerator chamber for the purpose of heat recovery (Dismatec Glass Plant Engineering Worldwide, n.d.).

Cross-Fired furnace

A cross-fired furnace is a tank furnace with parallel pairs of ports for fuel and air positioned along the length of the melting end with the burner flames travelling across the width of the glass bath and at right angles to the direction of glass flow (Dismatec Glass Plant Engineering Worldwide, n.d.).

Hot Spot

The hot spot is the melting-end temperature zone of a tank furnace having the highest temperature (Dismatec Glass Plant Engineering Worldwide, n.d.).

Melter

The melter is the chamber of a tank furnace in which the glass batch is melted (Dismatec Glass Plant Engineering Worldwide, n.d.).

Port

The port is the opening in a furnace superstructure through which fuel or flame enter or exhaust gases escape (Dismatec Glass Plant Engineering Worldwide, n.d.).

Regenerator

The regenerator is a cyclic heat interchanger that alternately receives heat from the gaseous products of combustion and transfers heat to the combustion air before combustion (Dismatec Glass Plant Engineering Worldwide, n.d.).

Reversal

Reversal is the process where the direction of fuel, combustion air flow, and exhaust gases are reversed (Dismatec Glass Plant Engineering Worldwide, n.d.).

Wet Bulb Globe Temperature

Wet Bulb Globe Temperature is a measure of the effect of temperature, humidity, wind speed, and sunlight on the human body. (National Oceanic and Atmospheric Administration, 2022).

Limitations of the Study

The limitations of this study are as follows:

- Due to time constraints, this study was performed during the late summer/fall months.
- The high average temperature in Central Wisconsin was between 50 °F and 80 °F during the study.
- The research/data collection being performed during the study was schedule dependent.

Methodology of the Study

The researcher's direct employment is a safety manager for a glass manufacturing facility. The issue of heat stress and furnace operation is a real-world scenario that has extreme risk to health, facility, legal, and financial assets. The researcher found the topic to be relevant with OSHA's impending heat standard and therefore beneficial to Company XYZ. To understand the justification for OSHA's Nation Emphasis Program, state plans such as those in the states of Washington and Minnesota were reviewed as well as the emphasis program itself. It was clear that indoor, as well as outdoor, risks associated with heat stress are to be accentuated in the final OSHA ruling. This is of special interest for industries with an inherent risk for heat stress, as it will be a constant threat to its resources.

To ascertain the risk associated with heat stress during furnace operation at Company XYZ, an analysis of incident data was conducted through Company XYZ's Velocity EHS incident reporting software. As the employed safety manager for Company XYZ, the researcher has administrative rights to the software and information contained in such, which allowed for redacting all reports that were examined. During the analysis, two incidents were reported that related to heat stress. The root causes for these two incidents were reviewed, and the respective corrective actions were evaluated.

Heat-stress employee training, practices and documentations were examined to ensure that workers were knowledgeable in hazard identification, furnace operation, and the signs and symptoms of heat-related illness. Training documentation from the company's learning management system (LMS) were provided to the researcher showing completed training from an outside source in heat-related illness signs and symptoms and the basic first aid involved in such cases. The LMS also showed that training in hazard recognition was completed by the training

team in-house during new-hire orientation and annually thereafter. Training checklists were also provided, which demonstrated employees' knowledge in furnace operation and tasks linked with heat stress.

This researcher attempted to assess Company XYZ's heat-stress prevention protocol, but such was found to be non-existent. No documentation exists that instructs employees on the processes, procedures, and policies regarding the identification, education, and mitigation of heat-stress-related situations. This subject will be addressed later in this report.

During the study, a Vlike MS6508 digital temperature and humidity meter was used to monitor ambient temperature, as well as WBGT temperature during furnace operations. This researcher relied on instrumentation rather than subject data for this study. Measurements were taken throughout the day to monitor the environment that furnace workers would be subjected to during a normal workday. Many sources were referenced, which outlined the guidelines for WBGT work/rest circumstances. The researcher will consider this data when making recommendations later in this report.

Chapter II – Results and Discussion

The purpose of this study is to assess the risk of Company XYZ's employees' exposure to heat-stress situations during furnace operation. Heat-related illness due to exposure remains a serious safety concern for high temperature manufacturing processes, especially in a continuous process furnace operation facility. Heat-stress incidents, although preventable are too often under-reported allowing a false sense of security in high-risk environments. To assess the risk at Company XYZ, incident loss data was analyzed, training documentation, policy and procedures, best practices from other similar facilities, and WBGT temperature readings were analyzed to determine susceptibility to a heat-stress event.

Results of the Study

The first goal consisted of performing an analysis of Company XYZ's heat-stress incident data within its EHS incident reporting system. A general analysis of the heat-stress event information within Company XYZ's EHS incident reporting system revealed the responses and corrective actions that were performed for a heat-related illness in 2020, which involved heat exhaustion due to prolonged exposure in an extreme-heat environment. To accomplish this, a root cause analysis (RCA) was performed. A root cause analysis consists of assessing the key players as well as the safety manager, the employee's supervisor and others who were involved in the incident. A root cause analysis diagram is created, which begins with a timeline of events. Under each point in time, details associated with that point in time are listed. To conduct a thorough RCA, the investigator must continue to ask, "Why?" until an actionable item has been reached. Once complete, the person involved in the incident is asked to examine the entire diagram and pinpoint the one thing that could have led to incident avoidance. If this can be

accomplished, then a root cause has been identified (see Appendix A). As a result, several action items were noted. These action items include the following:

- Emergency Response Team (ERT) monitoring of hot projects
- providing nutritionist information during hot-project preparation
- providing heat-related illness training for Technical Group, Hot-End Technicians and Maintenance personnel.
- developing pre-project bulletins, perform pre-job inspections, and provide employee safety talks to raise awareness to heat-related risk.

The ERT monitoring action item was addressed immediately. Since the latest incident, non-routine work in extreme heat, as well as projects in which mason assistance is brought in from other plants, will be monitored by two ERT members who are trained in first aid, CPR and AED operation. The Heat-Related Illness Training was also accomplished utilizing Life Safety Resources, which is an organization that specializes in medical, first aid and CPR training. Heat-Related Illness training for all Hot-End, Technical Group, and Maintenance employees was conducted in October of 2021. While assessing the documentation, the exact content of the training was unclear, although the documentation revealed that heat-related illness preventative care, as well as sudden illness, were the primary topics. In speaking with the on-site training coordinator, it was confirmed that heat-related illness signs, symptoms and first aid have been addressed, and training sign-in sheets are available in the company's learning management system.

The previous incident in 2016 resulted in similar action items as the 2020 incident, however, this incident involved a furnace emergency called an exit-end break emergency in which the glass breaks at the exit end of the tin bath. This situation exposes technicians to

extreme heat for what could potentially be an extended period of time. During an exit-end break the glass exiting the tin bath is pulled from the bath by large lehr rollers. In this case, the glass broke prior to reaching the rollers and was stranded in the tin bath. As glass continued to exit the furnace through the canal, glass began to overload the tin bath causing an overflow situation. In a situation such as this, it is imperative to get the glass back on the rollers and start the flow of glass out of the tin bath. To accomplish this, technicians open the side of the hot tin bath by removing side seals. Using long pokers, they begin to “row” glass, which is to pull the molten glass to the tin bath exit and onto the rollers. At this point, the rollers should take over and a normal ribbon pull occurs. In the 2016 incident, however, an upstream water cooler had been installed, cooling the glass and creating an uneven draw, which caused the pull from the rollers to thin the glass to where it repeatedly separated. This went on for several hours until the cooler was ultimately removed. The root cause analysis for this event indicates an action item was developed for modifying a ribbon pull procedure, but there is no evidence that a ribbon pull procedure was updated or made available to employees following the incident. Training for these types of emergencies is on the list for completion in 2022.

Documentation confirms that pre-project briefings are being conducted to address the concern of extreme heat during non-routine projects. The briefings include the project manager, safety manager, ERT monitors and all personnel contributing to the project. The briefing did not examine the specifics related to extreme heat. Rather, it addressed employees watching out for one another in alignment with their recently completed training and paying attention to their bodily responses to the high-heat conditions. Congruent to the incident RCAs related to heat-related illness, during these briefings employees were informed where the hydration stations are and instructed to routinely take breaks to hydrate.

The second goal of this study involved an analysis of employee training, practices, and related documentation to ensure that workers are knowledgeable in hazard identification, furnace operation, and the signs and symptoms of heat-related illness. Employees receive extensive training on furnace operation according to the furnace training documentation, which was assessed through the company's LMS system. The training program was modified in 2020 and converted to the LMS system for completion and tracking. Prior to 2020, documentation was tracked via paper copy training and document control was sporadic at best. Furnace emergency training is explained in the basic and secondary levels of the training, but there is no documented evidence of any practical training or tabletop-type exercises related to the training contents.

The basics of hazard identification are covered, utilizing the LMS computer-based training, but such instruction fails to cover anything heat-stress related. Topics, which are covered include crystalline silica and sulfur dioxide hazards. These are legitimate concerns for technicians, but for the purpose of this study, the training falls short of accomplishing the goal of instructing employees on the risks that are associated with heat stress. Training on heat-related illness was provided via an outside source in October of 2021 as mentioned earlier.

The third goal involved a comparison of Company XYZ's heat-stress prevention protocol with other industry standards and best practices for employees who are working in extreme heat situations. As no heat-stress protocol exist at Company XYZ, no comparison to other industry standards could be drawn. This issue will be addressed during the discussion section, although other sources as well as existing state plans from the states of Washington and Minnesota were analyzed.

OSHA has previously addressed the issue of heat-related illness through the General Duty Clause, which requires employers to protect workers from all forms of recognized hazards.

In the case of Company XYZ, heat stress is a recognized hazard since the furnace constantly operates at approximately 3,000 degrees Fahrenheit. OSHA's new federal regulation may resemble the already existing state plans and "may mandate break times and require that employers monitor employees' level of heat acclimatization as well as temperature and humidity levels" (Malveaux, 2021, para. 3). The author notes that this would be the responsibility of the employers in melting facilities to lower temperatures in environments where "furnace operating temperatures are over 500 degrees" (Malveaux, 2021, para. 4).

In 1997 Minnesota OSHA (MNOSHA) updated Rule 5205.0110, Subpart 2 Enforcement of Indoor Ventilation and Temperature in Places of Employment from the use of effective temperature to WBGT as a means to screen for heat stress (Office of the Revisor of Statutes, 2014). A two-hour time weighted average was adopted based on the American Conference of Governmental Industrial Hygienists threshold limit values assessed in 1996. It is likely that OSHA will follow a similar format during the development of the federal regulation regarding indoor and outdoor heat stress.

OSHA already addresses several topics of interest in its Heat Illness Prevention Campaign. Such topics include the following:

- planning and supervision, which describes what elements to include in a Heat-Illness Prevention Plan and information regarding day-to-day supervision
- new worker protections, which concentrates on acclimatization and work duration for employees who are new to the job or are returning from an extended leave away from heat-stress levels
- heat-hazard recognition, which promotes understanding of the factors that contribute to heat hazards such as environment, physical activity levels and personal factors

- engineering controls, work practices, and PPE, which are briefly discussed to help better understand what can be done to reduce the risk of heat stress
- heat-stress calculator, which allows employers to unofficially assess whether a worker's heat stress is above or below the recommended limit
- water, rest, and shade initiative, which examines the work/rest cycle based on the WBGT, hydration and recovery suggestions

There are copious amounts of information on the OSHA website for employers to base a proactive Heat-Illness Prevention program around. The site also offers signage and infographics that may assist in the educational piece of program implementation and training.

The fourth goal of this study involved performing heat-stress assessments using a WBGT device and an ambient air temperature measurement instrument. Temperatures were measured at key points around the furnace area, which are noted in Table 1. These four areas are where much of the furnace work is likely to be performed. A Vlike MS6508 Digital Temperature Humidity Meter was placed to the areas noted in the table and measurements taken to ultimately assess the WBGT.

Table 1

Temperature Readings During Data Collection at Company XYZ

Location	Ambient temp	Relative humidity	WBGT
Tweel	102 °F	15%	60.04 °F
Ports	181 °F	9.8%	99.39 °F
Port necks	256 °F	10%	143.10 °F
Waste area	118 °F	12%	66.32 °F

The WBGT readings were collected and assessed by using the Work Intensity Levels as presented in Table 2. The activities listed in Table 2 are meant as examples and thus employers must use judgement and draw comparisons to the listings in the table and work being performed. Once the WBGT, along with the work intensity level, has been determined, the employer will weigh the results against the Work/Rest and Water Intake Chart (see Figure 1) to determine the work/rest break schedule and water intake recommendation. Figure 1 provides employer and employees with the guidelines necessary to reduce the risk of experiencing a heat-stress-related illness. Following these guidelines allows employees to rest, recover and hydrate in order to prepare their bodies for continued work.

Table 2

Work Intensity Levels

Example number	Light work	Moderate work	Heavy work
1	Operating equipment	Jack-leg drilling	Climbing
2	Inspection work	Installing ground support	Carrying equipment/supplies weighing 40 pounds or more
3	Walking on flat, level ground	Loading explosives	Installing utilities
4	Using light hand tools	Carrying equipment/supplies weighing 20-40 pounds	Using hand tools for extended periods
5	Travel by conveyance	Using hand tools for a short period of time	

Figure 1

Work/Rest and Water Intake Chart

Heat Risk Category		Wet Bulb Globe Temp	Light Work		Moderate Work		Heavy Work	
			Work/Rest	Water Intake (quart/hr)	Work/Rest	Water Intake (quart/hr)	Work/Rest	Water Intake (quart/hr)
No Risk	Unacclimated	78 – 79.9	50/10 min	½	40/20 min	¾	30/30 min	¾
	Acclimated	78 – 79.9	continuous	½	continuous	¾	50/10 min	¾
Low	Unacclimated	80 – 84.9	40/20 min	½	30/30 min	¾	20/40 min	1
	Acclimated	80 – 84.9	continuous	½	50/10 min	¾	40/20 min	1
Moderate	Unacclimated	85 – 87.9	30/30 min	¾	20/40 min	¾	10/50 min	1
	Acclimated	85 – 87.9	continuous	¾	40/20 min	¾	30/30 min	1
High	Unacclimated	88 – 90	20/40 min	¾	10/50 min	¾	avoid	1
	Acclimated	88 – 90	continuous	¾	30/30 min	¾	20/40 min	1
Extreme	Unacclimated	> 90	10/50 min	1	avoid	1	avoid	1
	Acclimated	> 90	50/10 min	1	20/40 min	1	10/50 min	1

Note. This figure provides a guide to work and rest times in minutes based on wet bulb globe temperature category and whether you are acclimated or unacclimated to the heat level. From *Wet Bulb Globe Temperature: What It Is and How To Use It*, by A. Sutherland, 2015 (http://blog.mesonet.org/agriculture/wet-bulb-globe-temperature-what-it-is-and-how-to-use-it/). Copyright 2022 by Mesonet.

In regard to the information that is presented in Figure 1, an acclimated employee performing moderate work near the ports with a WBGT reading of 99.39 would only be able to work for 20 minutes and then must rest for 40 minutes with recommended water intake noted as one quart per hour. During normal operating situations at Company XYZ, employees are tasked to work in extreme heat-stress areas in very short bursts, usually less than 10 minutes. However, non-routine tasks may require employees to remain in the extreme heat longer and, therefore, require monitoring by personnel trained in heat-illness prevention and first-aid measures. As employees are performing repair and maintenance work, they are being observed by trained personnel to monitor rest breaks, hydration, and recovery. The furnace masons are acclimated to the environments and continue to monitor each other during the different situations that arise. As each day presents new challenges from a heat perspective, acclimation and adaptability are key elements to mitigating risk for heat exposure illness.

During furnace work, the employees are required to wear heat resistant and fire-retardant PPE (see Figure 2).

Figure 2

PPE Required for Furnace Work

Note. Image of PPE required for furnace work.

Such protective clothing may often increase the risk of heat-related illness and:

- Reduce the body's ability to naturally cool itself through sweating and evaporation,
- Retain heat, increase body temperature, and increase the body's core temperature, and
- Increase effort required to perform tasks due to cumbersome and restrictive equipment.

When PPE requirements are a part of the job, employers must assess the PPE required and adjust the WBGT accordingly. One tool provided in the OSHA Heat-Illness Prevention campaign is to use a clothing adjustment factor as presented in Table 3. Once the WGBT has been calculated, using the information found in Table 3, the employer would draw comparisons based on the PPE listed in the table and add the adjustment factor noted to the measured WBGT. This will provide the employer with an effective WBGT based on the PPE being worn.

Table 3

Clothing Adjustment Factor

Type of clothing	Clothing adjustment factor – This amount must be added to the measured WBGT when determining heat stress
Normal work clothes (e.g., long sleeve shirt and pants	0
Cloth (woven) coveralls	0
Polypropylene coveralls	0.9 °F (0.5 °C)
Polyolefin coveralls	1.8 °F (1 °C)
Double layer of clothing	5.4 °F (3 °C)
Limited-use vapor barrier coveralls	19.8 °F (11 °C)

Note. Adapted from *Criteria for a recommended standard: Occupational exposure to heat and hot environments* (p.19), by Jacklitsch et al., 2016 (https://www.cdc.gov/niosh/docs/2016-106/). In the public domain.

Coupled with work/rest breaks, other steps may be taken to reduce the risk of heat illness as a result of heat retention due to the PPE. According to the WBGT Work/Rest and Water Intake Chart (see Table 3), it is necessary to implement rest breaks, which limits the amount of time an employee is subjected to extreme heat environments. According to the National Institute for Occupational Safety and Health (NIOSH), “a heat-stressed employee’s core body

temperature decreases relatively slowly and simply ceasing hard work will not cause an immediate reduction in core temperature. Therefore, increasing the rate of heat removal from the body by using wearable personal cooling systems may reduce the risk for heat-related illness" (National Institute for Occupational Safety and Health, 2020, para. 3). Recommendations from this source indicate that during rest breaks, employees should replace PPE and saturated base-layer clothing with a dry base layer to assist in wicking moisture away from the body. Affected personnel should perform active cooling (e.g., wet cloth, ice packs) or passive cooling (e.g., move to cooler air, air conditioning). Personal cooling systems, such as an ice vest or cool water circulation system may also be used as an option for active cooling.

Discussion

The float glass making process at Company XYZ is nearly identical as the process at a similar company (i.e., Pilkington Glass), where the float process was invented by Sir Alastair Pilkington in 1952 (NSG Group, n.d.). Molten glass at temperatures near 1,000 ^{o}C (1,832 ^{o}F) is poured from an industrial furnace into a bath of molten tin. The tin allows the glass to flow to a natural thickness of approximately 3.9 mm, but the thickness may be manipulated by the speed in which the glass is drawn from the bath and by the machines that pull the glass toward the outside walls of the tin bath, thinning the product. The opposite may be performed to thicken the glass. Company XYZ produces several different thicknesses of glass ranging from 2.2 mm to 5.7 mm. The glass furnace is continuously fired with natural gas and has a life span of 15 to 20 years with regenerators, a melter, and a refiner. The regenerators allow for the inflow of ambient air, which is super-heated by hot chimney blocks and forced through a port neck, which blends with atmospheric air and natural gas inside the furnace to cause combustion. The opposite side regenerator allows for the exhaust of hot gases, which heat the chimney block and prepare for the

furnace reversal. Every 18 minutes, gas flow is reversed from one side to the other to allow the consistent wear and prolonged life of the furnace. The gas furnace is in continuous operation for 15 to 20 years at temperatures of approximately 1,648 ºC (3,000 ºF).

The effects of heat acclimation within the indoor environment, such as the case with Company XYZ, has been troublesome. Due to the nature of glass production and furnace maintenance activities, a small contingency of their employees are periodically involved in extreme-heat situations. These employees are generally acclimated to the ultra-warm environment they are tasked to work in and have been trained in the signs and symptoms of heat stress in alignment with the CDC recommendations for the control of heat stress. The CDC recommends that employee training be tailored to the worksite conditions including causes, signs and symptoms, and effects of extreme heat ((NIOSH Heat Stress Topic Page, 2020). There was a certain amount of evidence that Company XYZ had taken the initiative to perform employee heat risk training in 2022, as a response to the latest heat-related illness in the facility.

The Biden Administration has taken an aggressive approach to environmental issues and the effects of indoor and outdoor heat are near the top of the list. To assist in protecting employees, employers can use the WBGT heat-stress assessment tool to identify when the work environment is too stressful, and thus mitigation measures must take place. Company XYZ experiences WBGT temperatures well above the recommended threshold of 80 ºF for actionable mitigation procedures (see Tables 1 and 2). As outlined in the OSHA Heat Illness Prevention campaign, employers should at a minimum provide water, rest, and shade (OSHA, n.d.). Company XYZ has taken these basic steps and will continue to expand their processes as the company moves through the policy and procedure phase of heat-stress control program development. As the time of this report, Company XYZ was awaiting early-stage program

templates from its Corporate Safety Director as a preemptive means to develop an effective initial standard.

Summary

Although Company XYZ is somewhat ill-prepared to protect its employees from the effects of heat, the organization is not alone. This researcher has attended several conferences and meetings where this topic is of interest, and various facets of general industry are feeling the pressure to understand and proactively address the issue of heat stress. The consensus is that it is unreasonable for OSHA to conduct a National Emphasis Program and perform inspections without guidance as to what employers could be held accountable. Nevertheless, it is in the employees' best interest for respective employers to control the effects of heat stress. Company XYZ is initiating a comprehensive heat-stress control program, but it requires determination to overcome the past 30 years of less-than-ideal furnace operation standards. The team at Company XYZ is highly motivated and takes the safety of the employees and protection of other physical assets seriously.

Chapter III – Conclusions and Recommendations

This study was conducted with the purpose of assessing Company XYZ's employees' exposure to heat-stress related situations during furnace operation and maintenance related activities. The goals to assess said risk were to analyze loss data, examine training and practices, analyze internal heat stress protocol, and to collect WBGT measurements. The goals were accomplished through an examination of documentation related to incident loss data, by assessing training content and documentation, through a review of existing policies and procedures related to heat stress, and by collecting WBGT measurements. The predominant result of this study revealed a lack of policy and procedures to protect employees from the severe effects of prolonged exposure to heat.

Conclusions

Following the assessment of heat stress hazards, it was noted that Company XYZ is lacking in protecting the employees from a known risk associated with working in extreme heat environments. The following conclusions were drawn from this study.

- In the two heat-related incidents reviewed for this study, the root cause analyses indicated that there was a need for Company XYZ to consider the risk of extreme heat stress within the facility. In both cases, several action items were noted with little or no evidence of completion. Credit may be given for implementing the Emergency Response Team monitoring process for non-routine work; however, it was unclear when or who would identify the need for trained monitors to be in place.
- Although, there was training in heat-related illness for key members of the team, the training was minimal and did not address subjects such as pre-job inspection and heat-stress mitigation. Reviewed documentation revealed that training was completed

in heat related illness, signs, and symptoms; however, the details of this instruction were not readily available.

- Company XYZ has no formal safety program that addresses the concern of extreme heat exposure, and a related policy/procedure was not documented and available for the employees. Essentially, there was no plan to address the issue of heat-stress-related risk. for over 30 years. With the OSHA National Emphasis Program on Outdoor and Indoor Heat Hazards in effect and an OSHA federal standard looming, as well as Company XYZ's recent heat-stress-related events, this programmatic deficiency can no longer be ignored.
- Measurements, taken in key areas around the furnace, point directly to the need for a detailed Heat-Stress Management Program. In the four areas where measurements were collected, the WBGT readings, combined with the work intensity level and clothing adjustment factors, require significant work/rest breaks along with applying other mitigating factors.

Recommendations

During research at Company XYZ, management was made aware of several steps that could be taken to address the issues surrounding the risk for heat stress. These steps include:

- **training:** It is understood that a certain amount of heat-illness training was performed in relation to the glass furnace operation, but such instruction should be global in relation to this situation. Excessive heat-stress will not only affect the "hot" portion of the plant, but throughout the facility as such is not climate controlled. Company XYZ should consider hiring a subject matter expert to address the unique situation that exists in a 24-hour furnace operation facility. It may be wise to supplement the

training with signage and educational material to raise awareness of the ever-present risk associated with working in this type of industrial setting. Conducting tabletop emergency exercises would allow personnel to understand, not only how to keep themselves from becoming a heat casualty, but also how to monitor their co-workers for signs of heat-related illness and what to do if that situation exists.

- **policy:** Develop a policy and procedures for times that employees must work in extreme-heat environments. Company XYZ has initiated work on an extreme heat environment policy, but this internal standard is far from being complete. It is recommended to bring in an outside source, such as local technical college experts, the Red Cross, or local emergency services to assist with the policy/procedure development process. Currently, this is a moving target until OSHA's final regulation is delivered. However, being proactive and beginning to develop policy, processes and procedures, which may be revised at a later date to meet the regulations would be a solid first step.
- **program:** Lastly, develop a comprehensive safety program that outlines all of the upcoming OSHA regulation expectations. This is difficult, as OSHA has yet to release any details or hints of their policy's content; however, Company XYZ may lean on existing state plans and be proactive in their approach to managing heat stress. Things to consider including are WBGT Work/Rest rates, acclimation to heat-stress environments, Emergency Response Team monitoring for non-routine tasks, training, and documentation. These would be positive first steps to a successful campaign to effectively address the risks of heat-stress in the work environment.

Areas of Further Research

Following are areas of further research that Company XYZ should consider:

- Company XYZ would benefit from examining state plans, CDC recommendations, and the OSHA NEP that relate to heat stress. Although these sources may not be all-inclusive, such would likely be adequate for developing a comprehensive program until the final OSHA regulations are published.
- Company XYZ should continue to research ways to reduce or update the existing PPE requirements. Finding clothing that does not retain as much heat, or which may increase the protection of employees from the heat source would be a significant benefit. Company XYZ should continue to research ways to mitigate heat-stress through the use of cool-down rooms, tents, and personal cooling systems.
- Company XYZ should perform a training needs analysis to identify the employees who require instruction for heat-related stress.

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Appendix A

Root Cause Analysis on 2021 Incident

RCA, Heat Exhaustion/Dehydration during Port Neck Work- Velocity # IN-20210920-008

Incident Date: 9/20/21 – 8:00pm

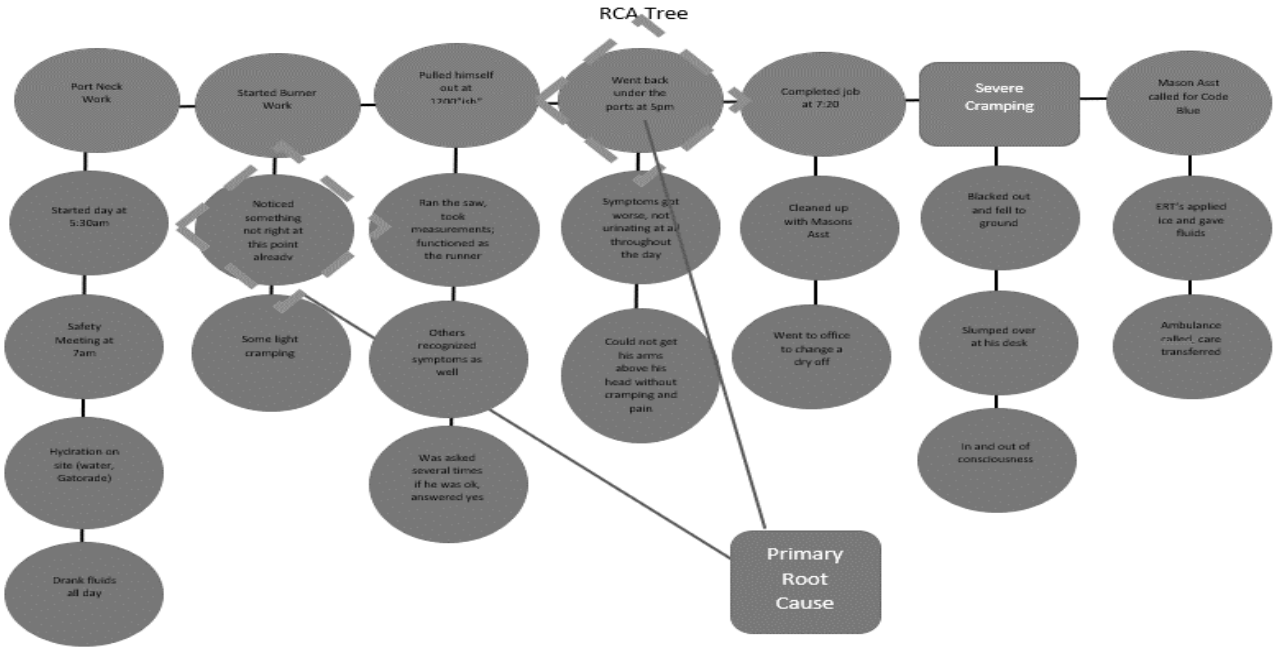
Incident Description:
Mason Tech was working on Port Neck in the heat for the majority of the day. Employees did notice some cramping throughout the day but was drinking plenty of water (ER member was filling water jug and replenishing Gatorade and water bottles). Tech completed work and was sitting down to change when he started to cramp up and become disoriented. Mason assistant came out and initiated a code blue. ERT members applied ice and gave more fluids but cramping continued and pain got worse. At this point supervisor mad the decision to call EMS. ERT members continued to apply ice and give fluids until ambulance arrived.

Root Cause Analysis:
A Root Cause Analysis (RCA) was performed on 9/23/2021. The Safety Manager, safety team members, and the affected employee conducted the RCA. We were able to determine a timeline of events with two root causes for the incident

Primary Root Cause:
The employee felt like something was not right at the beginning of the project but continued to work. He was drinking plenty of fluids. He pulled himself out of the heat at around noon and took on more of a role outside the heat. At 5pm he made the decision to go back under the ports and continue to work in extreme temperatures.

Lessons Learned:
- Listen to your body and understand the signs and symptoms of heat related illness

Action Items:
- ERT monitoring for Hot Projects
- Nutritionist Information on Hot Project preparation
- Heat Related Illness training for Tech Group and Hot End techs.
- Pre project bulletins to raise awareness.


RCA Tree
Port Neck Work
Started Burner Work
Pulled himself out at "20ft"
Went back under the ports at 5pm
Completed job at 7:20
Severe Cramping
Mason Asst called for Code Blue
Started day at 5:30am
Noticed something not right at this point already
Ran the saw, took measurements; functioned as the runner
Symptoms got worse, not urinating at all throughout the day
Cleaned up with Masons Asst
Blacked out and fell to ground
ERT's applied ice and gave fluids
Safety Meeting at 7am
Some light cramping
Others recognized symptoms as well
Could not get his arms above his head without cramping and pain
Went to office to change a dry off
Slumped over at his desk
Ambulance called, care transferred
Hydration on site (water, Gatorade)
Was asked several times if he was ok, answered yes
In and out of consciousness
Drank fluids all day
Primary Root Cause