

Fire & Ice

Protecting Workers in Extreme Temperatures

By Donald J. Garvey

Work, especially in construction or infrastructure renovation, often has a time value element and must continue even in adverse weather conditions. These conditions can add yet another hazard to an already potentially hazardous occupation. From 2008 to 2014, U.S. workers suffered 109 heat-related occupational fatalities (OSHA, 2015a). While occupational fatalities due to hypothermia may be less frequent, exposure to cold can result in nonfatal injuries and may lead to an increased risk of incidents. Anticipation, recognition, evaluation and control of potential heat or cold stressors can allow the job to continue safely and productively with minimal interruption.

Heat Stress

Reasons for Concern

Heat stress includes several heat-related illnesses: heat rash, cramps and exhaustion. These are not life-threatening conditions, but can contribute to low morale, irritability and fatigue, all of which can lead to taking shortcuts or skipping procedures, which can in turn create a safety hazard.

Another serious heat-related illness is heat stroke, which is a medical emergency. A study by Gubernot (2015) indicates that the construction industry experiences the second-highest rate of occupational heat fatalities (Table 1).

NIOSH (2016b) distinguishes between classical heat stroke and exertional heat stroke. Classical heat stroke is due to exposure to a hot, humid environment especially over the course of several days. It is commonly seen in older people or those with chronic illnesses. Exertional heat stroke, more commonly seen in the workplace, is caused by intense physical activity, especially workers who are not acclimated to high temperatures. Individual characteristics (e.g., age, health status), type of activity (e.g., sedentary vs. strenuous exertion) and symptoms (e.g., sweating vs. dry skin) vary between these two classifications. This article focuses on exertional heat stress and stroke.

Regulations

Currently, no heat-stress-specific OSHA regulations exist. However, the agency has an ongoing informational campaign to prevent heat illness (OSHA, 2017c). Despite no specific regulation, OSHA uses the General Duty Clause to cite employers for exposing workers to excessive heat conditions. In one example, a worker became ill after installing electrical conduit in an unshaded trench and died from heat stroke the following day. The employer was cited for a serious violation under the General Duty Clause for failure to implement an adequate and effective heat stress program (OSHA, 2013).

Several states have issued heat-specific regulations. California, Washington and Minnesota are three examples.

Recognition & Evaluation of Potential Heat Stress Conditions

OSH professionals must evaluate three major factors when anticipating heat stress conditions:

- 1) environmental heat sources (e.g., steam tunnels, outdoor air temperature, hot equipment or materials);
- 2) metabolic heat sources (i.e., internal heat generated by physical work);
- 3) heat loss ability or lack thereof (e.g., sweating efficiency, protective clothing, convection).

One method of heat stress evaluation is wet bulb globe temperature (WBGT). The WBGT method es-

IN BRIEF

- **Fast-track projects make year-round work in adverse temperature conditions a common occurrence in construction. This article outlines the dangers of both heat and cold stress on the worker.**
- **It reviews multiple worker assessment methods, both instrumentation and observational, to help the frontline supervisor or OSH professional estimate worker risk to heat or cold stress injury.**
- **Based on the assessment, the OSH professional can select from multiple engineering, administrative and PPE controls to help maintain worker safety and health, as well as comfort during work in challenging temperature conditions.**

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timates the environmental contribution to heat stress from temperature, humidity, air movement and radiant heat sources with readings typically taken every hour. Clothing and work demands (metabolic load) must be accounted for. These factors are then used with occupational exposure limits (OEL) [e.g., NIOSH recommended exposure limit (REL)] to determine whether a heat stress situation may exist.

Use of WBGT and OELs assumes 8 hours of continuous exposure with rest breaks taken in the same work area. It also assumes the worker is wearing typical work clothing (e.g., long sleeve shirt and pants) (ACGIH, 2014). Different clothing than the typical work ensemble can significantly affect worker heat loss and must be accounted for.

In one case, a worker wearing a chemical-resistant encapsulating suit was working outdoors in 82 °F (28 °C) air temperature, yet suffered fatal heat stroke (OSHA, 2015b). NIOSH (2016b) discusses the effect of different types of clothing on potential heat strain. Other factors may influence a specific person's susceptibility to heat stress, so professional judgement must be used in addition to WBGT and OELs. WBGT should be used as a screening tool along with other physiological and observational factors to help determine an individual worker's risk of heat stress.

Using WBGT instruments on multiple work sites can be cost prohibitive. A free alternative is the National Weather Service Heat Index (Figure 1) (NOAA, 2017). The index uses relative humidity and air temperature (available from radio, television or web sources) to determine likelihood of heat stress. OSHA's (2017b) employer guide on using the heat index includes the heat stress chart and suggested interpretation. The agency also provides a heat safety tool app for mobile devices (OSHA, 2017a).

Although the heat index is simpler to use than WBGT, employers must be cautious when using it. OSHA (2017b) notes:

NOAA devised the heat stress index values for shaded conditions and light winds. **Full sunshine can increase heat index values by up**

to 15 °F. Strenuous work and the use of heavy or specialized protective clothing [can] also have an additive effect. As a result, the risk at a specific heat index could be higher. . . . Extra measures . . . are necessary under these circumstances.

These assessment methods are for a general population. Employers may also want to look at individual physiological indicators such as oral temperature, heart rate, end-of-shift weight loss (an indication of dehydration), or the occurrence of sudden severe nausea or headaches (ACGIH, 2014). Frontline supervisors and other workers can use observational indicators of heat stress to help assess individual heat safety:

- occurrence of heat disorders—minor heat conditions such as heat cramps may indicate an increased potential for the occurrence of more serious events;
- increased incident rates or near-hits;
- complaints of chronic fatigue;
- alertness of workers—a casual conversation can help assess worker alertness;
- highly motivated workers—they may push themselves too hard to try to outperform others.

Controls for Heat Stress

Sweating is the body's primary means of removing heat. For this to be done safely, the body needs to be properly hydrated. Thirst will lag actual need for water. A worker may sweat out up to 2% of his/her body weight before spontaneous drinking (the urge to drink) occurs (U.S. Navy Environmental Health Center, 2007). It is recommended that employers plan for 1 cup of water per worker every 20 minutes for limited exposure to heat (ACGIH, 2014). For prolonged exposure (i.e., several hours), NIOSH (2016b) suggests a sports drink with an electrolyte/carbohydrate concentration less than 8% by volume. The water temperature should be between 50 °F (10 °C) and 59 °F (15 °C), and should be located in close proximity to the work site.

Workers should be trained to take several small sips over time versus occasional big gulps. In addition, supervisors must monitor and actively encour-

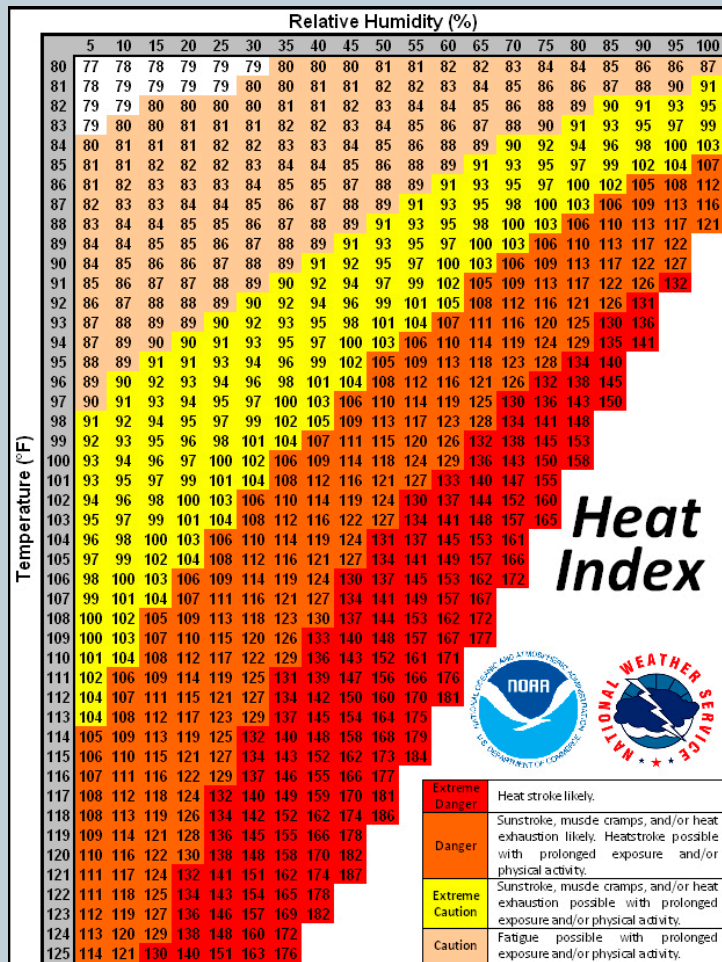
TABLE 1

Occupational Heat-Related Fatality Rates in the U.S. by Industry, 2000-2010

Industry	Average annual fatalities	Average annual rate per million workers
Agriculture	6.8	3.06
Construction	12.0	1.13
All other industries	10.5	0.09

Note. Adapted from Occupational Heat-Related Mortality in the United States, 2000-2010: Epidemiology and Policy Recommendations [Doctoral dissertation], by D.M. Gubernot, 2015.

FIGURE 1
NWS Heat Index



Note. National Weather Service heat index by National Oceanic and Atmospheric Administration, 2017.

age workers to drink regularly. A study by Cal/OSHA (2007) of 25 heat illness cases indicates 88% of the work sites studied had water on hand and available. U.S. Army's (U.S. Army Public Health Center, 2007) urine color test chart can help workers evaluate their hydration status. Employers can place the cards in restrooms or outhouses for workers to use.

Water coolers are the common source of water on many construction sites. Employers should follow proper sanitation practices to ensure that the coolers do not become a source of occupational illness. Safe practices include marking containers as

potable or nonpotable water, no open tops, filling, cleaning and storing in a clean location, and single-use cups. California Conference for Directors of Environmental Health (CCDEH, 2004) suggests that employers clean and sanitize drinking water coolers every 24 hours.

Acclimatization can be critical to worker safety. Of the 25 heat illness cases noted, nearly 50% were workers on their first day on the job; 80% were at work four or fewer days (Cal/OSHA, 2007). Most people can acclimate to higher temperatures in 7 to 10 days. NIOSH (2016b) recommends that employers limit worker exposure to 20% of the usual duration of work in hot environments for the first day and increase 20% over the next 5 days. NIOSH also offers recommendations for reacclimating previously acclimatized workers and for maintaining worker acclimatization.

Potential administrative controls include implementing work/rest schedules to reduce the metabolic load and allow time for the body to offload heat. Several charts suggest work/rest times based on WBGT and workload (ACGIH, 2014; NIOSH, 2016b). Other controls to consider include a buddy system for workers to keep watch on each other's condition, scheduling hot or physically demanding jobs for the coolest part of the day, and worker/supervisor training on heat stress and precautions to take. Heat-stress training for workers and supervisors/leads should cover heat stress hazards, predisposing factors (e.g., medication use, previous heat illness), signs and symptoms, general first aid, precautions and PPE use.

Examples of engineering controls on construction sites include shade canopies to reduce solar load, spot cooling (e.g., air conditioned trailer) and power tools to reduce manual labor. For indoor or enclosed locations, fans can be a solution. However, they must be used with caution, as air temperatures above 95 °F and air speed above 300 ft per minute may increase worker heat load due to convection.

PPE for heat stress considerations may include light-colored wicking fabric clothing, vented full brim hard hats and items incorporating phase change materials (e.g., bandanas).

Cold Stress

Hypothermia fatalities averaged two annually across all industries in the U.S. from 2011 to 2014 (BLS, 2015). While perhaps less common than heat stress, cold stress can cause significant occupational injury or be a catalyst for other occupational injuries.

Recognition & Evaluation of Potential Cold Stress Conditions

The primary factors in evaluating the cold stress environment are air temperature and movement. Humidity can also be a factor. The most common way to evaluate cold conditions is the national wind chill index.

Like the heat index, the wind chill index combines air temperature and wind speed to determine an equivalent perceived temperature (i.e., how cold it would feel to a person outside). The index temperature can be used with the NOAA Wind Chill Chart (Figure 2) to estimate how soon frostbite

would begin to appear on bare skin at the index temperature.

Canadian Center for Occupational Health and Safety (CCOHS, 2017) recommends that employers monitor temperature and wind speed in cold work environments (Table 2).

Cold Stress Injuries

Cold stress can result in several adverse health effects.

- Frostbite: a localized freezing of the skin and underlying tissue. Triggers include temperatures of 32 °F (0 °C) or less, contact with cold metals or volatile chemicals (e.g., gasoline), inadequate or tight clothing, and previous hand-arm vibration syndrome (HAVS) or secondary Raynaud's Syndrome. Early symptoms include numbness in the toes or fingers, progressing to a waxy skin color, aching stinging and bluish skin. Prevention methods include wearing proper clothing; loose-fitting boots with clean socks; and gloves, especially if contacting cold metal or volatile liquids.

- Trench foot: an injury to the feet after prolonged exposure to wet and cold. Air temperature as high as 59 °F (15 °C) may still be a risk factor. Other risk factors include damp socks and boots, or tightly fitting boots. Symptoms include cold, numb feet progressing to hot, shooting pain, and later swelling, redness and blisters. Prevention methods include wearing waterproof insulated boots; clean, dry feet; a thin polypropylene inner sock layer and outer thicker layer that is changed when wet. Wiping and drying the inside of boots daily also can be helpful.

- Hypothermia: the opposite of heat stroke; occurs when the body core temperature is dangerously low. The particularly dangerous factor in hypothermia is that the victim may not be able to reliably assess that it is occurring. Early symptoms include fatigue and confusion. Later signs may be no shivering and bluish skin color.

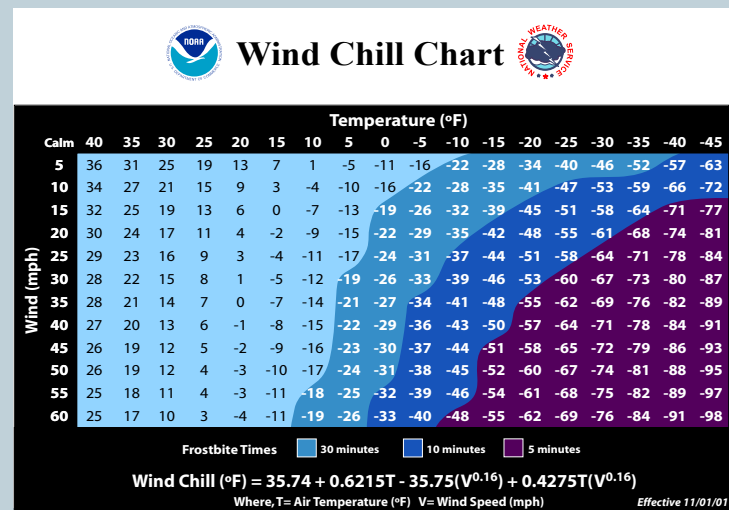
Additional potential adverse health reactions to excessive cold include loss of manual dexterity, discomfort to respiratory tract, dehydration due to high energy expenditure, no motivation to drink water, slips and trips from icy surfaces, and altered response to some medications (U.S. Navy Environmental Health Center, 2007).

Cold Stress Controls

Proper materials and layering of clothing are among the most important controls. NJHSS (1999) recommends the following combination:

- Layer 1 (closest to the skin): polypropylene or similar wicking material. This helps draw sweat away from the body to keep the skin dry.

FIGURE 2
Wind Chill Chart



Note. Wind Chill Chart, by NOAA, 2001.

TABLE 2
Frequency for Monitoring Air Temperature for Cold Stress

Temperature	Action
32 °F to 60 °F (0 °C to 16 °C)	Monitor for further temperature changes
Less than 32 °F (0 °C)	Monitor air temperature and wind speed every 4 hours

Note. Adapted from Cold Environments—Working in the Cold, by Canadian Centre for Occupational Health and Safety, 2017.

- Layer 2 (middle layer): an insulating layer of wool or polar fleece type materials. This provides insulation even when wet. Cotton should not be used as the insulating layer as it quickly loses its insulation properties when wet.

- Layer 3 (outer layer): a nylon or similar material to block the wind.

Zipper openings for all three layers minimizes and vents sweat by customizing the insulation properties to the specific environment.

Prescreening workers for susceptibility to cold may help prevent exposing more susceptible workers to a potentially hazardous environment. Screening criteria may include asthma or bronchitis; diabetes or diarrhea (which may contribute to dehydration); medications that affect sweating, circulatory systems, metabolic rate and thermostatic regulation; a history of using vibrating tools or diagnosis of HAVS (RMCAO, 2013).

Similar to the methods used to address heat stress, a work-rest regimen can help rewarm workers after cold exposure. It is based on 4-hour work periods with moderate to heavy work load, and assumes a 10-minute warm up time per break, that clothing is kept dry and that an extended break (e.g., lunch) will occur around the 4-hour mark. Employers can use ACGIH (2014) warm-up tables.

During warm-up periods, workers should remove outer layers of clothing and open the middle layer to vent sweat and prevent overheating. Dehydration can occur in a cold environment due to several factors: low air humidity, increased metabolic rate

to maintain core temperature, and poor or limited access to water. As noted, thirst may not be a good indicator of dehydration. Regular fluid intake during warm-up breaks (warm, sweet beverages, not caffeinated) can help avoid dehydration and reduce hypothermia risk (CPWR, 2013).

Other controls may include reducing drafts and installing windbreaks when temperatures are below 39 °F (4 °C); balancing the workload by avoiding high-physical-demand work followed by prolonged periods of low activity; using relief workers for prolonged or demanding tasks; and radiant heaters for spot heating. Precautions should be taken when refueling vehicles to avoid splashing, handling metal tools or components bare-handed at temperatures below 32 °F (0 °C) (ACGIH, 2014, NIOSH, 2016a).

Worker and supervisor training should include the hazards of working in cold environments; initial signs and symptoms of cold stress; basic first aid for cold stress, especially frostbite and hypothermia; use of the buddy system; reducing sweating and wearing clothing loose, dry and layered.

As with hot conditions, the body will acclimate to cold conditions over about a 10-day period (U.S. Navy Environmental Health Center, 2007). However, acclimatization to cold is much less pronounced than it is to heat, and primarily results in delayed shivering and some increased blood flow to the extremities.

Conclusion

Workers, particularly in construction environments, can be exposed to excessive environmental conditions, both heat and cold. With proper anticipation and evaluation of the environment, worker screening and training, and implementation of good work practices, construction workers can continue to function in a safe and productive manner. **PS**

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Disclaimer

This information is based on current OSHA requirements 29 CFR 1910 and 1926. U.S. state or other country requirements may be different. Requirements may change in the future. This article contains general information as of the date of this publication and should not be relied on to make specific decisions. No warranties are made, as this article only presents suggested procedures that may be applicable for work in these environments. The employer has ultimate responsibility for assessing the work site and implementing adequate safety precautions.

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