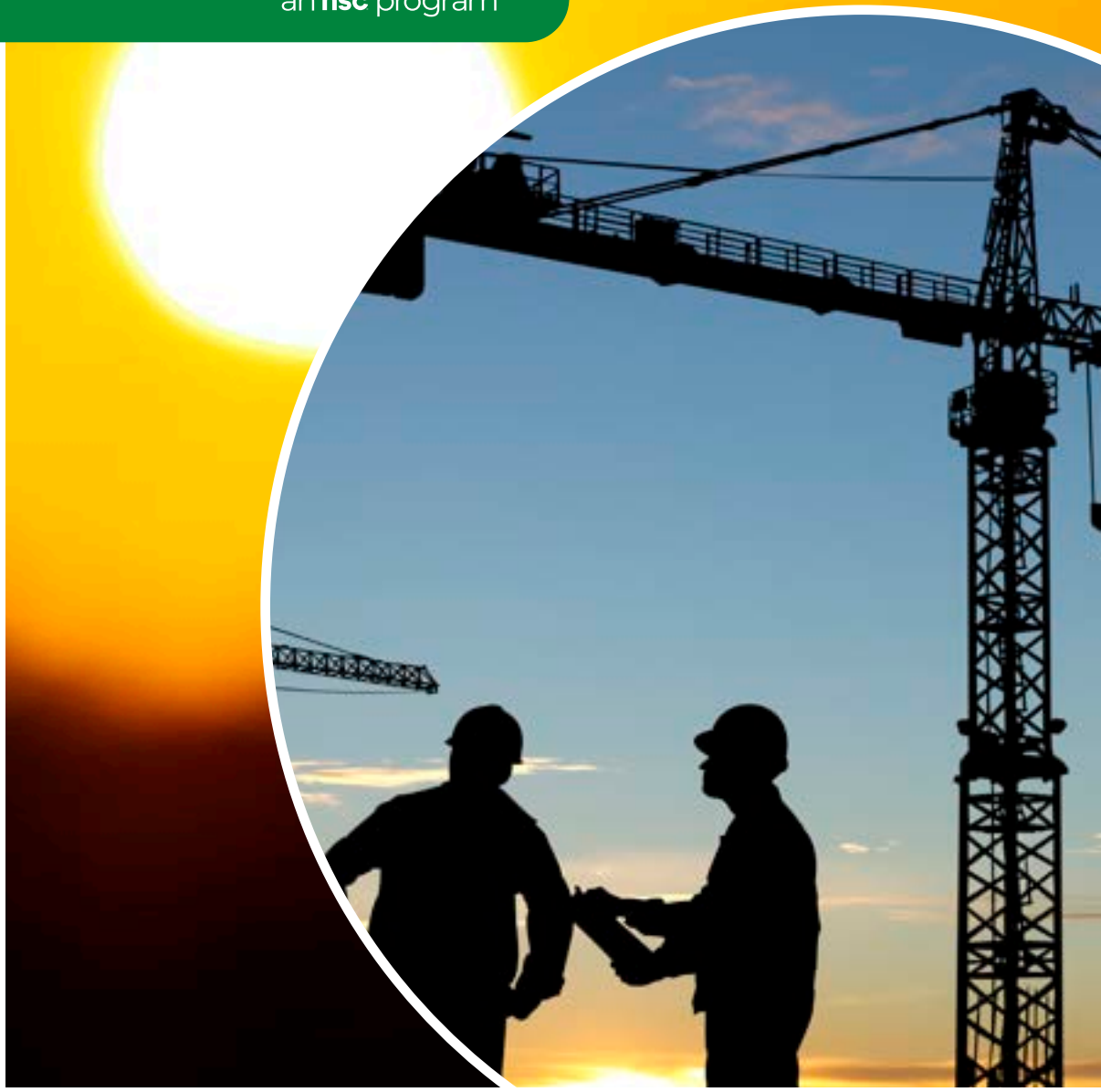
WORKtoZERO
an nsc program



Addressing Heat Stress in the Crane Industry

National Safety Council

NCCCO FOUNDATION

Introduction

Heat stress is a critical yet often overlooked hazard within the crane industry, impacting virtually everyone involved in lifting operations. Workers are frequently exposed to elevated temperatures, humidity, and physically demanding tasks, all of which heighten the risk of heat-related illnesses and injuries. This brief examines the prevalence of heat stress within the crane industry, as well as the occupational and individual risk factors that impact workers' vulnerability to heat. Finally, using the Hierarchy of Controls as the primary framework, it outlines practical interventions to mitigate heat-related risks experienced by those working in and around cranes.

This report was developed through a comprehensive review of academic research, industry publications, and grey literature, encompassing other sources such as technical reports, government and policy documents. Additionally, information on hazard controls was gathered via an online survey completed by subject matter experts identified by the NCCCO Foundation.

What is heat stress?

Heat stress occurs when the body absorbs more heat than it can release, compromising worker safety, health, and productivity (NIOSH, 2016). Under normal circumstances, the body regulates internal temperature through mechanisms such as sweating and increased blood flow to the skin (Parsons, 2019). However, exposure to high temperatures, humidity, or intense physical exertion can overwhelm these processes, reducing the body's capacity to cool itself effectively and increasing the risk of heat-related illnesses. Workers exposed to extreme heat, or those working in hot environments, are at an elevated risk for illnesses such as:

- **Heat Cramps:** Involuntary, often painful muscle spasms caused by depleted salt and moisture in the body (NIOSH, 2024a)
- **Heat Edema:** Swelling in the extremities, typically in the hands or feet, often leading to discomfort when wearing gloves or shoes (Gauer & Meyers, 2019)
- **Heat Exhaustion:** The body's response to excessive loss of water and salt, which presents as a range of symptoms including nausea, vomiting, dizziness, weakness, excessive sweating, muscle cramps, or decreased urine output (Leiva & Church, 2022)
- **Heat Rash:** A type of skin irritation resulting from obstructed sweat glands, often due to restrictive clothing (Leiva & Church, 2022)
- **Heat Syncope:** Temporary dizziness, weakness, or loss of consciousness during periods of prolonged standing or movement in a hot environment (Leiva & Church, 2022)

- **Heat Stroke:** A life-threatening condition characterized by elevated body temperature and central nervous system dysfunction (Leon & Bouchama, 2015)

Heat stress not only poses direct health risks, but it can also indirectly increase the risk of incidents and injuries due to physical and cognitive impairments (NIOSH, 2016). For example, sweaty palms or dizziness can reduce grip strength and impair coordination, compromising crane controls, rigging operations, or other critical tasks, potentially leading to unintended movements or dropped loads. Additionally, heat exposure has been shown to impair cognitive functions such as memory, reaction time, and decision-making (Piil et al., 2018), which can be particularly concerning for workers performing skilled or potentially dangerous work (Morrissey et al., 2021). Tasks requiring precise cognitive skills—such as interpreting signals, monitoring load capacities, or coordinating team efforts—can be severely impacted by heat stress and dehydration. For crane operations, even minor disruptions to focus or decision-making can result in dropped loads or structural failures, potentially compromising the safety of the entire worksite.

How prevalent is occupational heat stress?

Between 2011 and 2023, there were a total of 534 heat-related workplace fatalities across all industries and occupations in the United States (Injury Facts, 2024). In 2023 alone, 55 workers lost their lives, marking a nearly 28% increase from 2022. Workers are also experiencing heat-related injuries and illnesses at alarming rates. In 2021 and 2022, exposure to environmental heat resulted in 5,770 DART cases, defined as work-related injuries or illnesses resulting in days away from work, job restriction, or job transfer (Injury Facts, 2024).However, these figures likely underestimate the true scope of the issue, with one study estimating that environmental heat is likely responsible for a minimum of 170,000 injuries each year in the United States (Fulcher, 2022).

This underestimation largely stems from gaps in data collection and reporting. Heat-related illness and injury data primarily rely on self-reported information from employers and employees, contributing to data inaccuracies and underestimations. For example, many heat-related symptoms, such as impaired decision-making or cognitive decline, are often subtle and can be overlooked in the workplace (OSHA, 2023). The lack of standardized definitions across jurisdictions exacerbates these challenges, resulting in inconsistent medical reporting (OSHA, 2023), while mild cases—often resolved with rest or basic treatment—may go undocumented altogether (Xiang, Bi, Pisaniello, & Hansen, 2014). Additionally, employees may avoid reporting heat-related illnesses due to fear of retaliation, complicated reporting procedures, or the perception that such conditions are either insignificant or an expected part of their work (Kyung, Lee, Dancu, & Jong, 2023). Together, these factors mask the true prevalence and impact of heat stress in occupational settings.

Workers in the crane industry face an increased risk of heat-related hazards, stemming from both the physical demands of their work and the challenging environments in which they operate. A 2023 Work to Zero and NCCCO Foundation survey highlighted these risks, gathering responses from 2,170 NCCCO-certified field personnel. According to these results, 75% of respondents considered themselves "likely" or "very likely" to be exposed to the risk of heat stress or heat illness on the job. Heat stress was also identified as the leading systemic risk factor contributing to personal injuries (18%) and injuries experienced by others on the worksite (16%) (Work to Zero and NCCCO Foundation, 2024a).

Data from the Bureau of Labor Statistics (BLS) (2023) shows that the top five industry sectors employing crane and tower operators are Construction, Manufacturing, Wholesale Trade, Transportation and Warehousing, and Administrative and Support and Waste Management and Remediation Services. Together, these industries account for nearly 70% of heat stress DART cases (Injury Facts, 2024) and are all included in OSHA's National Emphasis Program, which targets over 70 industries identified as being at an elevated risk for heat-related injuries or fatalities (OSHA, 2022).

Table 1. Top Industries Employing Crane and Tower Operators and Associated Heat Stress Cases, 2021-2022 (BLS, 2023; Injury Facts, 2024)

Industry	Total Employees	# of DART Cases	% of Total DART Cases
Construction	17,540	770	13.3%
Manufacturing	8,860	1,110	19.2%
Wholesale Trade	5,020	150	2.6%
Transportation and Warehousing	4,200	1,250	21.7%
Administrative and Support and Waste Management and Remediation Services	2,150	750	13.0%

Who is at risk?

In most industries, occupational heat stress stems from working in harsh environmental conditions, the use of insulated or impermeable protective clothing, or performing physically demanding tasks (Arbury et al., 2014). A meta-analysis comprised of 111 studies found that working in temperatures of 77°F (25°C) increased the likelihood of heat strain for most occupations. Notably, this temperature drops to 71.6°F (22°C) when performing intense or strenuous activity (Flouris et al., 2018). The National Oceanic and Atmospheric Administration (NOAA) provides additional guidance on the likelihood of heat disorders based on outside temperature and humidity levels (see Figure 1), with four risk classifications: caution, extreme caution, danger, and extreme danger (NOAA, 2023).

Figure 1. Likelihood of Heat Disorders with Prolonged Exposure and/or Strenuous Activity (NOAA, 2023)

Likelihood of Heat Disorders with Prolonged Exposure and/or Strenuous Activity

Temperature (˚F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Caution | Extreme Caution | Danger | Extreme Danger

Levia and Church (2018) identified a number of individual factors that can also impact susceptibility to heat-related injuries, including:

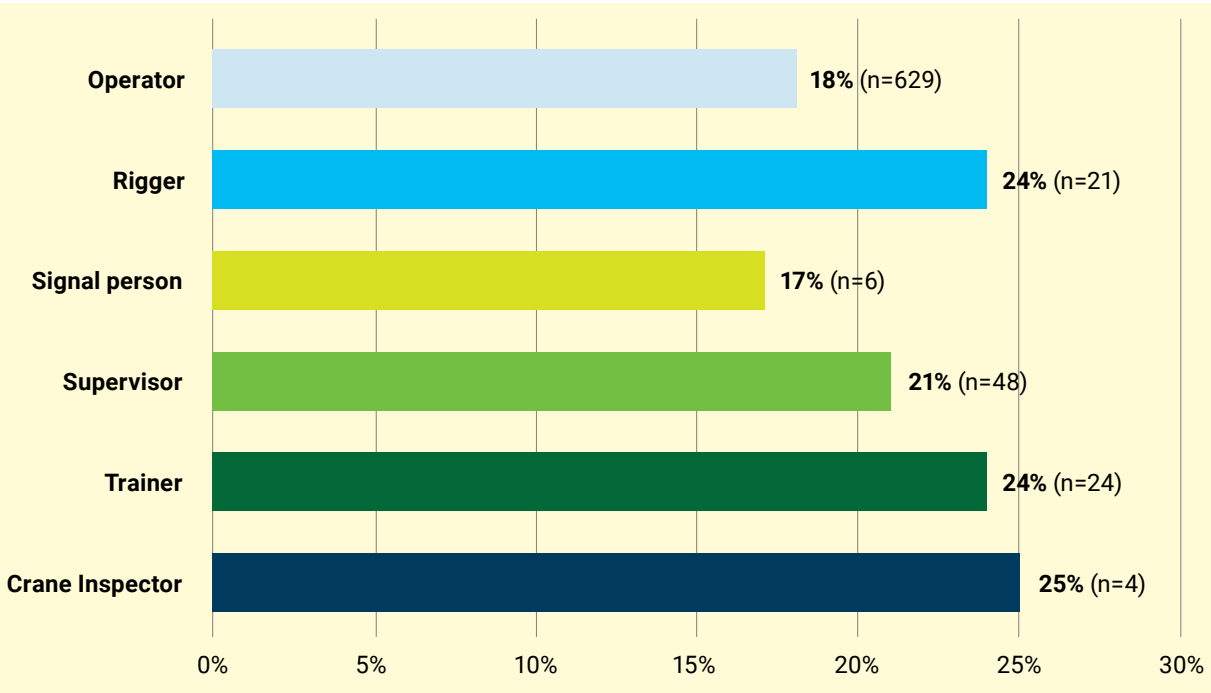
- Age (adolescents and older adults tend to be at an elevated risk)
- Wearing heavy, insulated or impermeable clothing or personal protective equipment (PPE)
- Body Mass Index (BMI) over 30
- Hydration status
- Pregnancy
- Alcohol consumption
- Substance use, including diuretics, antihistamines and amphetamines
- Low physical fitness levels
- History of heat-related illnesses
- Lack of heat acclimatization
- Comorbid medical conditions such as diabetes, heart disease or high blood pressure

Notably, workers involved in lifting operations face unique heat stress hazards due to both environmental and occupational factors. Crane operators working in enclosed cabins without air conditioning, natural breeze, or adequate ventilation can experience a "greenhouse effect," where heat becomes trapped inside the cab, significantly increasing temperatures (BC Crane Safety, 2024). Riggers and ground crews often perform physically demanding tasks under direct sunlight, making them especially vulnerable to dehydration and heat stress. This risk is further intensified when wearing heavy or impermeable PPE, which can trap heat and limit the body's ability to cool down. Signalpeople and spotters, who remain stationed outdoors to guide crane operations, face prolonged exposure to high temperatures and direct sunlight, which can impair focus, reaction time, and communication accuracy—critical factors for workplace safety.

Given these challenges, it is unsurprising that heat stress remains a significant concern across all roles in the crane industry, as evidenced by survey results from Work to Zero and the NCCCO Foundation (2024a). Figure 2 illustrates the percentage of personal injuries attributed to heat stress relative to total injuries. For example, among crane operators, heat stress contributed to 18% of the 629 reported personal injuries. Across all roles, heat-related injuries account for 17% to 25% of total reported injuries, with crane inspectors experiencing the highest percentage (25%)—likely due to their frequent work in outdoor environments or confined spaces where heat accumulates rapidly. Similarly, riggers and trainers reported elevated heat-related injury rates (24%), as riggers often perform strenuous tasks under direct sunlight, while trainers spend extended hours outdoors supervising operations.

Notably, while operators (18%) and signalpersons (17%) reported lower percentages of heat-related injuries, this likely reflects the broader range of hazards inherent in their roles. For example, operators frequently navigate risks associated with equipment failures, limited visibility, and collision hazards involving pedestrians, other equipment, and surrounding structures. Signalpersons, on the other hand, work in close proximity to heavy machinery and rely on precise communication to ensure safe operations in dynamic and high-risk environments. Although heat stress accounts for a smaller proportion of injuries in these roles, it remains a significant concern, emphasizing the need for role-specific risk assessments and targeted preventive measures to address their unique challenges.

Figure 2. Percentage Of Total Personal Injuries by Role Attributed to Heat Stress (Work to Zero and NCCCO Foundation, 2024a)



Regulations

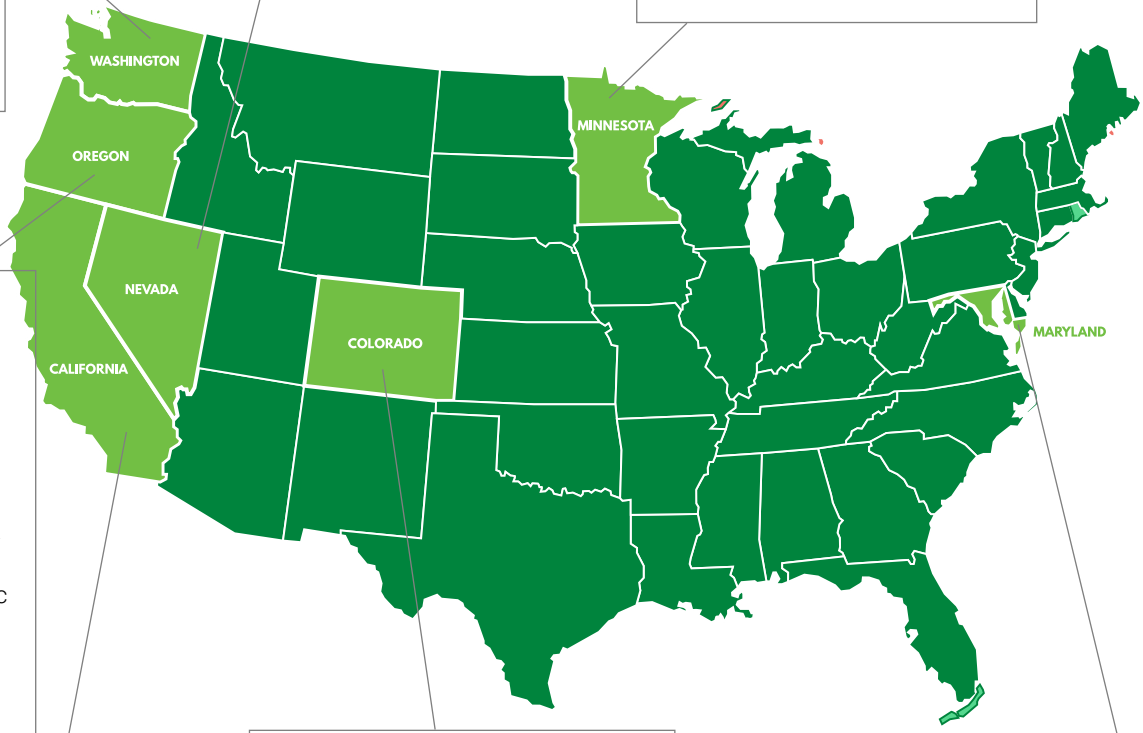
At the time of this report, OSHA does not currently have explicit, industry-wide standards for heat stress mitigation. However, the General Duty Clause (Section 5[(a]) outlined in the OSHA Act of 1970 (H.R. 1195) requires employers to provide a workplace free from recognized hazards that cause, or are likely to cause, death or serious harm, including heat-related hazards. In 2023, OSHA issued a heat hazard alert and announced plans to intensify enforcement and increase inspections in high-risk industries, with a heavy emphasis on construction and its subsectors (U.S. Department of Labor, 2023). Building on these efforts, in July 2024 OSHA announced a proposed rule aimed at protecting workers from extreme heat in both indoor and outdoor settings. The proposed standard would require employers to create, develop and implement a heat injury and illness prevention plan, including measures to assess and mitigate heat-related hazards in the workplace (OSHA, 2025). The standard would apply to all employers and be triggered when employees are exposed to a heat index of 80°F or higher for more than 15 minutes within any 60-minute period. For indoor worksites, employers would be required to identify areas where the heat index could reach 80°F or above and establish a temperature monitoring plan as part of their written heat safety program (OSHA, 2025).

At the time of this publication, the future of OSHA's proposed rule remains uncertain. However, employers can proactively implement its guidance to strengthen heat stress prevention programs and ensure compliance with the General Duty Clause. Additionally, seven states have adopted their own heat-related standards that go beyond federal OSHA requirements:

Nevada: Nevada requires that businesses with more than 10 employees perform a one-time job hazard analysis for heat stress risks. If hazards are identified, employers must implement written safety plans, provide training, and establish emergency procedures to mitigate heat-related illnesses or injuries (Nevada Department of Business and Industry, 2024)

Minnesota: Minnesota's Indoor Ventilation and Temperature in Places of Employment Rules mandate that indoor workplaces must have sufficient airflow and maintain specific temperature conditions for employee safety (Minnesota Department of Labor and Industry, 2008)

Washington: Washington's Outdoor Heat Exposure Standard provides regulations for providing shade, implementing high heat procedures, employee training and emergency response (Washington Division of Occupational Safety and Health, 2023)



Oregon: Oregon's General Occupational Safety and Health Standard provides regulations for several industries such as construction, agriculture, maritime activities and forestry. It mandates engineering and administrative controls for work in high-heat environments, as well as requirements for specific rest break schedules (Oregon Department of Consumer and Business Services, 2022)

California: California's Heat Illness Prevention Standard requires employers to provide adequate training, water, shade and planning when the temperature rises to 80°F or above (82°F for indoor settings) (California Code of Regulations, 2005)

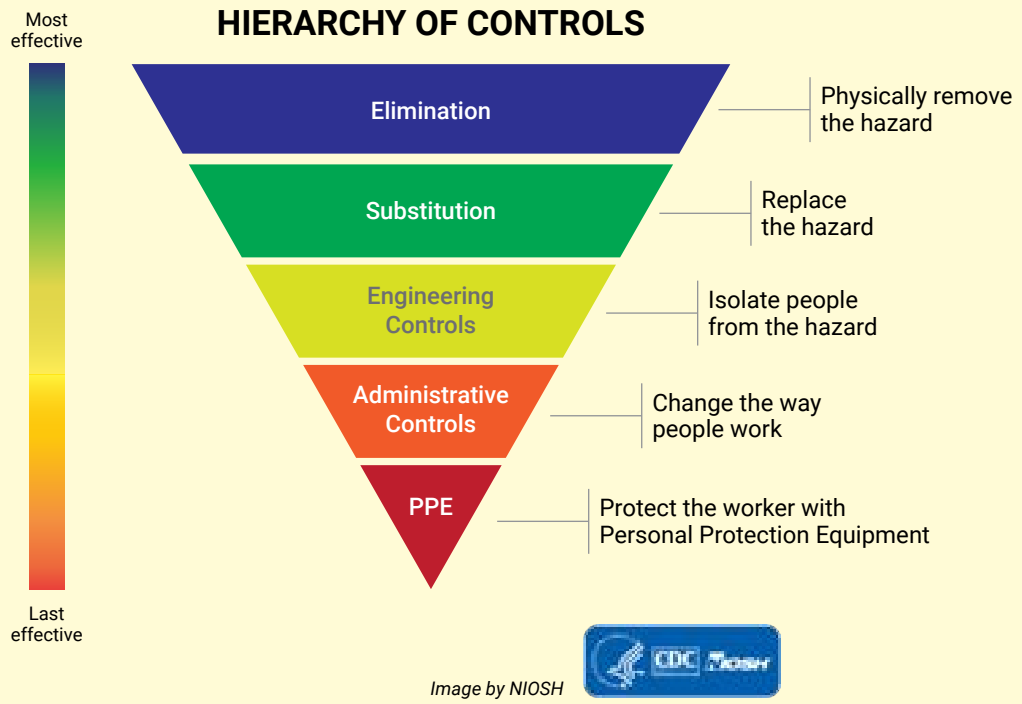
Colorado: Colorado's Agricultural Labor Conditions Rules establish regulations to protect agricultural workers from heat-related illness and injuries, including requirements for shade, monitoring and response protocols (Colorado Code of Regulations, 2022)

Maryland: Maryland's Heat Stress Standards applies to both indoor and outdoor workers exposed to a heat index of 80°F or higher. The standards include requirements for heat illness prevention plans, training, acclimatization protocols, access to shade and drinking water, and emergency response procedures (Maryland Occupational Safety and Health, 2024)

Heat stress mitigation strategies

Managing heat stress in the workplace requires a strategic approach to minimize risks and protect workers. The following interventions are organized according to the Hierarchy of Controls, a framework that prioritizes hazard mitigation strategies from most effective (eliminating the hazard) to least effective (personal protective equipment) (NIOSH, 2024b). While elimination of hazards is the ultimate goal, in complex work environments, layered and complementary solutions are often necessary to ensure a holistic approach to controlling excessive heat exposure.

Figure 3. Hierarchy of Controls (NIOSH, 2024b)



Elimination

Eliminating heat stress hazards in crane operations requires removing workers from exposure to elevated temperatures or external heat sources. Autonomous robot cranes (ARCs), equipped with artificial intelligence, can perform tasks autonomously or be remotely controlled by human operators. These systems often feature object detection capabilities, allowing them to identify and avoid nearby pedestrians, equipment or objects. Despite their potential in industries like freight and logistics, ARCs face significant barriers to widespread adoption. High upfront costs, the need for specialized infrastructure, and reliance on stable energy supplies and connectivity—such as GPS, WiFi, or cellular networks—limit their feasibility in remote sectors like mining, agriculture, or forestry (Global Infrastructure Hub, 2020).

In addition to ARCs, other advanced technologies can play a critical role in hazard elimination. For instance, drones are increasingly being used for site inspections and lift planning to capture high-definition photos and live videos of worksites from various angles and elevations. This technology eliminates the need for workers to be physically present in hazardous environments, including those exposed to extreme heat, without relying on potentially outdated aerial views via Google Maps or other services (Work to Zero and NCCCO Foundation, 2024b).

Substitution

Substitution involves replacing heat-intensive equipment and processes with safer, more worker-friendly alternatives. For example, upgrading traditional cranes to modern models equipped with built-in cooling systems or energy-efficient technology can significantly reduce the ambient heat generated during operation. Incorporating heat-resistant materials, such as high-temperature alloys for hooks or ceramic-coated pulleys for heat dissipation, further enhances safety by minimizing the risk of equipment failure and reducing workers' exposure to hazards like ambient heat or burns.

Engineering Controls

Engineering controls play a crucial role in isolating workers from heat hazards by modifying the work environment to reduce heat exposure. For crane operators, air-conditioned cabs provide a critical barrier against both outdoor heat and the ambient heat generated by machinery. In addition, proper cab insulation and ventilation can help maintain a safe working temperature and prevent heat buildup inside enclosed operator stations. Employers should also establish designated cooling stations—climate-controlled or shaded areas where workers can take breaks. These stations should be equipped with fans, misting systems, or air conditioning to help lower body temperature quickly, along with cold drinking water and electrolyte-replenishing beverages to prevent dehydration.

To further reduce radiant heat exposure, reflective or heat-absorbing shields can be placed on equipment, rigging areas, and machinery surfaces, providing relief for riggers, signalpersons, and other crew members working near cranes and heavy equipment. Additionally, using heat-dissipating materials in work platforms and staging areas can minimize heat absorption from sun-exposed surfaces.

Administrative controls

Administrative controls are essential for reducing heat stress risks by modifying work practices, schedules, and policies to limit prolonged exposure to heat. One approach is scheduling lifting operations during cooler parts of the day, such as early mornings or late afternoons, to minimize direct heat exposure. Additionally, structured work/rest cycles allow workers to take regular recovery breaks in shaded or air-conditioned areas, ensuring access to water, electrolyte solutions, and other hydrating beverages to prevent dehydration. These cycles should be customized based on environmental factors such as temperature, humidity, and sunlight intensity, with enhanced precautions during extreme heat or drought conditions (NIOSH, 2017a).

Another important consideration is whether workers are acclimatized to hot conditions. For those who are not, NIOSH recommends a gradual increase in work time over a period of 7 to 14 days to allow the body to adapt. Notably, after one month away from heat exposure, most workers' heat tolerance will return to baseline, necessitating a re-acclimatization period before resuming full workloads (NIOSH, 2017b). Reducing the physical demands of tasks—such as using equipment to minimize manual strain or increasing the number of workers assigned to challenging jobs—can also help distribute workload more effectively and reduce individual heat strain.

Finally, comprehensive workplace policies are essential for effectively managing heat stress. Implementing heat alert programs, buddy systems for monitoring signs of heat stress, and clear response protocols provides a structured approach to recognizing, preventing, and addressing heat-related illnesses. To maximize preparedness, workers and supervisors should receive training on identifying, preventing, and responding to heat-related illnesses before starting work in a hot environment and ahead of rising heat index levels. According to NIOSH (2016), an effective heat stress training program should include the following:

- Recognizing the signs and symptoms of heat-related illnesses
- Understanding the causes of heat-related illnesses and applying risk-mitigation strategies to prevent or mitigate injuries
- Proper use of heat-protective clothing and equipment, including awareness of the additional heat load imposed by PPE
- Understanding the individual factors that affect heat tolerance
- Implementing clear reporting and response procedures for heat-related hazards or incidents

Personal Protective Equipment (PPE)

Finally, PPE can also serve as an important safeguard against heat stress, particularly when other controls cannot fully eliminate exposure. Personal cooling apparel, such as cooling vests, neck wraps, hydration packs and cooling rags can help regulate core body temperature and reduce the risk of heat-related illnesses. Notably, some types of PPE—particularly heavy or non-breathable gear—can intensify heat stress by trapping heat and restricting airflow. Employers should assess these risks and implement heat-mitigating alternatives, such as ventilated helmets, lightweight clothing, and moisture-wicking fabrics, to enhance comfort and improve body temperature regulation in high-heat environments.

Finally, more advanced tools, such as vital signs monitoring wearables and lone worker devices, can provide real-time hazard identification and alerts, serving as an additional safeguard for workers. In the context of heat stress, vital signs monitoring wearables track key physiological indicators, including heart rate, core body temperature, fluid loss, and external environmental conditions. For workers, these personalized insights enable proactive decision-making, allowing them to adjust their exposure to heat and take immediate action if symptoms of illness or injury arise. For employers, this data serves as a valuable resource for refining heat mitigation strategies to proactively inform the organization's heat mitigation practices (Work to Zero, 2024b). Lone worker devices or mobile applications, while less tailored to heat stress hazards, can provide critical two-way communication for those working alone or in isolated locations. Many of these tools also feature advanced capabilities including downed worker monitoring, digital gas monitoring, and biometric sensors, offering an added layer of protection in high-risk work environments (Work to Zero, 2023).

Table 2. Controls for Heat Stress Hazards

Elimination	• Automate high-heat processes to eliminate worker exposure to heat
Substitution	• Where possible, adopt less heat-intensive tools, processes or equipment
Engineering Controls	• Install fans, air conditioning, or ventilation systems on the worksite, in designated break areas, and/or in cool-down stations • Use equipment with in-cab air conditioning units • Use reflective or heat-absorbing shields or barriers • Provide cooling systems such as portable fans or misting devices • Set up tents, canopies, or shaded structures over work area
Administrative Controls	• Schedule work during times when the heat index is the lowest (i.e., early morning, late afternoon, or evening) • Provide cool, potable water and electrolyte replacement drinks in accessible locations • Train supervisors and workers to identify and respond to heat stress symptoms • Institute a heat acclimatization plan for new or returning workers • Implement work/rest cycles based on air temperature, sunlight exposure, and humidity levels • Activate a heat alert program during periods of excessive heat or drought • Reduce the physical demands of the job by implementing tools to reduce manual strain and/or increasing the number of workers per task • Institute a buddy system where workers observe one another for signs and symptoms of heat stress • Keep a first aid kit on site, including access to an automated external defibrillator (AED) • Assign a field team member trained in first aid, CPR, and AED operation. This individual should be capable of climbing the crane, if necessary, to provide aid or report on the operator's status and rescue conditions. • In case of an incident, designate an individual knowledgeable of site logistics to contact emergency services and manage preparations for their arrival
PPE	• Adopt vital signs monitoring wearables or lone worker monitoring systems to ensure timely interventions if a worker is displaying signs of heat illness • Provide personal cooling apparel, such as cooling vests, cooling rags, or hydration packs • Provide ventilated helmets and lightweight, loose-fitting, moisture-wicking clothing • Provide sunscreen and sun-protective clothing

Conclusion

Heat stress poses a significant threat to worker health, safety, and productivity in the crane industry, requiring proactive and comprehensive mitigation strategies. Elevated temperatures, high humidity, and physically demanding tasks amplify these risks, not only contributing to direct health impacts but also impairing cognitive and physical performance, increasing the potential for workplace incidents. Addressing these hazards requires a comprehensive approach that combines innovative solutions, tailored work practices, and robust safety policies. By prioritizing proactive measures to minimize heat exposure, implementing effective hazard controls, and enhancing risk management practices, organizations can create safer work environments, protect their workforce, and promote the long-term sustainability of crane operations.

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