

# EVIDENCE BASE FOR ELEMENTS OF HEAT STRESS MANAGEMENT

# IAI Heat Stress Reference Document

December 2023



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# INTRODUCTION

Heat strain and associated health concerns arise when workers are exposed to hot environments – concerns that will only increase with global warming.

Occupational exposures to heat stress are an unavoidable consequence of employment in the aluminium industry, due to the processes involved. The likelihood of high heat stress exposures is also associated with high ambient temperature and humidity, both of which are experienced in many global regions where the aluminium industry is most active.

There are several aspects to the management of heat stress in the workplace, and many options for the measurement of exposure and mitigation or prevention of effects. These approaches may be found in the scientific literature, published by professional organisations, or in general use by companies in the aluminium and other sectors.

The aims of this reference document are:

- to summarise the available information on risk management approaches for heat stress
- to provide a synthesis of key heat stress management options in one place (including published literature and recommendations and practices identified by survey of IAI member companies)
- to outline the existing scientific evidence for each option so that member companies can make risk management decisions based on well-founded scientific evidence and experience
- to compile references to published literature and describe current practices.



## RATING OF LITERATURE EVIDENCE FOR ROBUSTNESS

The literature included was considered as



When there is strong evidence available, supportive evidence was not offered unless there was a special insight.

# **GRADING CRITERIA FOR HEAT STRESS MANAGEMENT OPTIONS**

GRADE	DESCRIPTION
А	Recommendation based on consistent and good-quality evidence from the peer-reviewed literature. Two or more good quality papers (Strong); or three or more limited quality papers (Supportive).
В	Recommendation based on inconsistent or limited evidence from the peer-reviewed literature., but likely to reduce the probability or severity of a heat-related illness. One good quality paper (Strong); or two limited quality papers (Supportive).
С	Recommendation based on models, consensus, usual practice, opinion or case series.
Other	A recommendation is not offered due to insufficient evidence.
Comments	Comments offered by Thomas E. Bernard (USF) based on experience and practice.

The evidence base is hyperlinked in the References section.

# EFFECTS OF HEAT STRESS IN THE WORKPLACE

Effects of exertion in a hot environment include heat illness from acute exposures, carry-over effects, acute injury and loss of productivity.

# **EXERTIONAL HEAT ILLNESS (EHI) - ACUTE EXPOSURES**

# Grade: A

# **Description**

EHIs are generally heat exhaustion and heat stroke associated with working in a hot environment.

## Recommendations

EHIs are an outcome of occupational exposures to heat stress and should be addressed in training programmes, risk management and outcome mitigation.

#### **Evidence**



Epidemiological data clearly link heat exposures to EHIs (Gubernot, Anderson, & Hunting, 2014; Spector et al., 2014; Wallace et al., 2005), including recordable EHIs (Hesketh et al., 2020).



None offered.



There is an underlying assumption in heat stress exposure assessment that EHIs would be low, with an emphasis on very low probability of heat stroke.



#### Comments

There is a clear exposureresponse association with heat stress and EHIs, but it is not readily anchored to an occupational exposure limit.

# **EXERTIONAL HEAT ILLNESS (EHI) - CARRY-OVER EFFECTS**

# Grade: A

# **Description**

A carry-over effect is the influence of previous exposures on the probability of EHI for the current day.

# Recommendations

The increased risk should be addressed in training programmes, risk management and outcome mitigation.

## **Evidence**



Three papers clearly demonstrate a carry-over effect related to the previous day(s) heat stress level (Shire et al., 2020; Spector et al., 2023; Wallace et al., 2005).



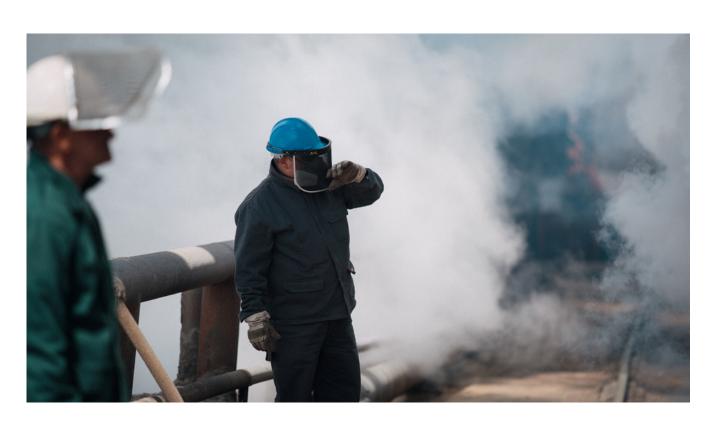
One paper offered the intervention of acclimatisation or similar precautions for heat waves (Spector et al., 2023).



Some companies manage forced and voluntary overtime shifts by allowing a one-day or two-day interval between overtime shifts.



- Heat stress exposure assessments assume workers are fully recovered from a previous exposure.
- There are no specific considerations for the carry-over effect.



# **ACUTE INJURY**

# Grade: A

# **Description**

Acute injuries are associated with heat stress exposures.

# Recommendations

OHS professionals should be aware that the relationship exists, and special care should be taken when there is a concurrent additional risk for serious injury (e.g. non-routine tasks).

# **Evidence**



There is strong evidence for a relationship between injury and heat stress based on two recent reviews (Fatima et al., 2021; Spector et al., 2019).



None offered.



Unknown.



- There is an exposureresponse association between heat stress and acute injury, but it is not anchored to an occupational exposure limit.
- Acute injury does not inform heat stress exposure assessment.



# **PRODUCTIVITY**

# Grade: A

# **Description**

- A loss in productivity over the course of the day is observed in field and laboratory studies.
- · A behavioral adjustment to metabolic rate can explain part of the change.

## **Recommendations**

- No adjustments for productivity changes are recommended.
- There should be an awareness that performance may change over the course of a workday.

# **Evidence**



- Literature reviews reported losses in productivity due to heat stress (Flouris et al., 2018; Ioannou et al., 2021).
- Behavioral factors partially account for lower productivity under uncompensable heat stress (Flouris & Schlader, 2015).
- Laboratory studies show the effect of heat stress on productivity and the loss accrues over the course of a day (Foster et al., 2021; Smallcombe et al., 2022).



None offered



There are no allowances in exposure assessment for the loss of productivity (lower metabolic rate) over the course of a day.



#### Comments

Because the loss in productivity cannot be assigned to behavioral changes in metabolic rate, there may be confounding effects between behavioral adjustments and loss of physical capacity.

# HEAT STRESS EXPOSURE ASSESSMENT

There are multiple well-accepted and highly-rated methods for evaluating exposure to heat.

# THERMAL WORK LIMIT (TWL)

# Grade: A

# **Description**

- Exposure assessment combines the job risk factors of environment, metabolic demands and clothing requirements, as well as acclimatisation state.
- TWL sets a limit on metabolic rate for a given environment, clothing
  ensemble and acclimatisation state with the premise that the exposure can
  be sustained for long periods.

## Recommendations

- TWL is an established method to assess heat stress.
- It is best used when there is discretion for self-pacing.

#### **Evidence**



- Rationale for TWL was developed by Australian investigators (Brake & Bates, 2002).
- With respect to its ability to distinguish sustainable from unsustainable exposures for acclimatised people, TWL has high sensitivity (> 0.9) (i.e. few false negative decisions) for a range of evaporative resistances (Bernard, Ashley, & Kapanowski, 2022).



- Some laboratory studies support the TWL.
- TWL has been used in the field with reported success.



- TWL is used by IAI members and others.
- TWL is most suited for workplaces that allow self-pacing of the work (Brake & Bates, 2002).



- TWL tables are readily available.
- Knowledge of metabolic rates of jobs is required to know when the TWL is exceeded.

# WET BULB GLOBE TEMPERATURE (WBGT)

# Grade: A

# **Description**

- Exposure assessment combines the job risk factors of environment, metabolic demands and clothing requirements, as well as acclimatisation state.
- WBGT index methods set a limit on environment based on metabolic rate, clothing ensemble and acclimatisation state, with the premise that the exposure can be sustained for long periods.

## Recommendations

WBGT is an established method to assess heat stress.

# **Evidence**



- Rationale for exposure limits was developed by NIOSH investigators (Dukes-Dobos & Henschel, 1973).
- With respect to its ability to distinguish sustainable from unsustainable exposures for an acclimatised population, WBGT has high sensitivity (> 0.9) (i.e. few false negative decisions), but specificity is poor (< 0.10) (Garzón-Villalba et al., 2017a).
- Lowering the OEL by 3 °C-WBGT for unacclimatised is supported by laboratory studies (Bernard et al., 2023).
- A method to assess the effects of clothing is established (Bernard et al., 2008; Bernard et al., 2005).



There are studies that have reported on the use of WBGT-based exposure assessment in the field that are not reported here.



- WBGT is a widely used method recommended by ACGIH (ACGIH®, 2023), NIOSH (NIOSH, 2016) and ISO (ISO, 2017).
- WBGT is used by others in the aluminium industry.



- There are other Clothing Adjustment Values (CAVs) available. A proposed method to estimate the CAV is described (Bernard et al., 2017).
- The Argonne National Lab method to estimate WBGT from weather service or ambient conditions is available from the OSHA website in the forms of a web-based calculator (www.osha. gov/heat-exposure/ wbgt-calculator) or as a download for a Windows platform (https://www.osha. gov/sites/default/files/ otm\_wbgtutil.zip).

# PREDICTED HEAT STRAIN (PHS)

# Grade: A

# **Description**

- Exposure assessment combines the job risk factors of environment, metabolic demands and clothing requirements, as well as acclimatisation state.
- PHS is a heat balance approach to limit exposures that are not sustainable.

#### Recommendations

PHS is an established method to assess heat stress.

# **Evidence**



- The physiological limits of predicted rectal temperature and dehydration are supported (Malchaire et al., 2000).
- PHS was validated with extensive laboratory and field data (Malchaire et al., 2001).
- PHS has been demonstrated in time varying environments (loannou et al., 2019).



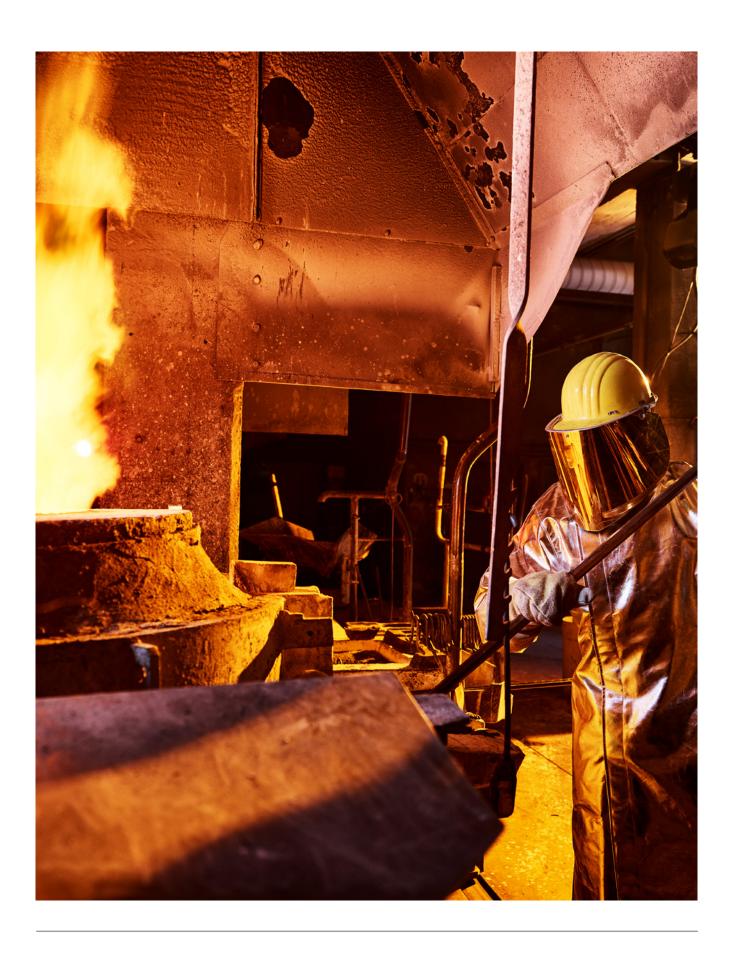
- PHS was validated for woven clothing, but it appears to work well for other clothing (unpublished data).
- PHS is protective for time-limited exposures from 30 minutes to 480 minutes. For time-limited exposures the sensitivity is greater than 0.9 (unpublished data).



- PHS is an ISO standard (ISO 7933) (ISO, 2004) (update should be approved soon) and recommended for detailed analysis by ACGIH (ACGIH®, 2023).
- PHS is used by some for exposure assessment most recently by European investigators in the HEAT-Shield project.



- A copy of PHS software for a Windows platform is available free at www. famelab.gr/research/ downloads/.
- The current version (2004) is somewhat more protective than the draft version (2023) exposure assessment.



# HEAT STRESS HYGIENE PRACTICES

Heat stress hygiene practices include

- Self-limitation of exposures
- Hydration
- Acclimatisation/acclimation and re-acclimatisation
- Lifestyle: Understanding how lifestyle affects heat
- Health status: Understanding how acute illness and chronic illness affect heat tolerance

# SELF-DETERMINATION / SELF-LIMITATION / SELF-PACING

# Grade: A

# **Description**

Self-directed exposures give some latitude to individuals to set the pace of work and to take unscheduled breaks to manage the heat stress exposure.

# Recommendations

- Allowing self-directed exposures is likely to be an effective control.
- It is listed as a heat stress hygiene practice because it relies on the individual to make a decision.
- There may be limits to effectiveness if there are incentives to continue; especially among new workers.

#### Evidence



None found.



- Papers report on the success of self-pacing with training (Al-Bouwarthan et al., 2020; Bates & Schneider, 2008; Mairiaux & Malchaire, 1985).
- One study pointed out that self-pacing in new workers may not be reliable (Gun, 2019).



- Workplaces often allow workers to seek relief if they are experiencing the early symptoms of a heat-related illness.
- Self-pacing was reported as a common administrative control (loannou et al., 2021).



- When working in teams, the least tolerant worker may not be the one setting the pace or scheduling breaks.
- Many workplaces allow some self-direction but do not include it in a written policy.

# **HYDRATION**

# Grade: A

# **Description**

Adequate hydration (water loss < 2% of body weight per day) supports the cardiovascular capacity and sweating required to meet thermal regulatory needs

## Recommendations

- Provide sufficient fluids to replace water lost to sweating (about 6L/day).
- Encourage frequent drinking of small amounts to avoid discomfort.
- · Cool, flavoured drinks and easy access can encourage drinking.

# **Evidence**



- It is clear that adequate hydration supports the ability to tolerate heat stress (Périard, DeGroot, & Jay, 2022; Périard, Eijsvogels, & Daanen, 2021; Trangmar & González-Alonso, 2019).
- Fluid replacement is commonly practised in many countries (loannou et al., 2021).
- Limit caffeine to 400mg/day; higher levels (6mg/kg) do not show an effect (Armstrong et al., 2007; Del Coso, Estevez, & Mora-Rodriguez, 2009).



Study that demonstrated preferences for fluid replacement that favoured electrolyte drinks over water (Clapp et al., 2002; Clapp, Bishop, & Walker, 1999).



- A general guideline is to provide 1 litre (1qt) of water per person per hour. There may be a practical limit of 6 litres per day.
- NIOSH recommends drinking 8oz (225mL) every 15 to 20 minutes (up to 1 litre per hour) (NIOSH, 2016).



- Flavoured drinks fill a middle ground between water and electrolyte drinks.
- Exposure assessment is based on adequate hydration.
- PHS accounts for dehydration when drinking is restricted.

# **ACCLIMATISATION**

# Grade: A

# **Description**

- Acclimatisation (also known as acclimation) is a physiological adaptation to heat stress known to improve heat stress tolerance and performance.
- While significant changes occur in one week, full adaptation can take two or more weeks.
- Acclimatisation is lost during periods without heat stress exposures and the loss is accelerated by illness.

#### Recommendations

- The first week of work under heat stress conditions for new and returning workers should allow for progressive increases in exposure over the first week.
- For new workers for whom learning the job carries risk, the progressive increase should start at lower levels of exposures.
- The acclimatisation period provides an opportunity for increased vigilance of individual ability to tolerate heat stress.
- Allow for re-acclimatisation of returning workers based on period away from heat stress and the cause of the absence. An example is provided in the appendix.

# **Evidence**



Three reviews of acclimatization reported on the benefits of acclimatisation (Périard, Racinais, & Sawka, 2015; Taylor, 2000; Tyler et al., 2016).



None offered.



- Acclimatisation is accounted for in WBGT-based methods (ACGIH®, 2023; ISO, 2017; NIOSH, 2016), TWL (Brake & Bates, 2002) and PHS (ISO, 2004).
- Acclimatisation is recommended by most heat stress management offerings.
- Acclimatisation is practised by member companies for new and returning employees.



#### Comments

Acclimatisation practices are widely recognised as protective during a more vulnerable period (at least the first week for new and returning workers) and is an opportunity for increased vigilance in general.

# **LIFESTYLE**

# Grade: B

# **Description**

Practise a healthy lifestyle: adequate sleep, limited alcohol use, only medications recommended by health care provider, and healthy diet.

# Recommendations

Description of healthy lifestyle for heat stress should be part of heat stress training.

## **Evidence**



There is modest evidence that sleep loss affects thermoregulatory function based on literature review (Keramidas & Botonis, 2021).



None offered



- The NIOSH criteria document list inadequate sleep as a risk (NIOSH, 2016).
- The NIOSH criteria document (NIOSH, 2016), ACOEM guidelines (Tustin et al., 2021) and the US Army manual (USArmy, 2022) list alcohol and other drugs as a cause of heat intolerance.



- Lifestyle is a heat stress hygiene practice in the context of avoiding nontherapeutic drugs and alcohol prior to heat stress exposures.
- Adequate sleep and limited off-duty exposures to heat stress is assumed under exposure assessment.
- Diet is important in that it be well-balanced. Special diets, such as for weight loss, should be supervised by a health care provider.



# **HEALTH STATUS**

Chronic health conditions or acute illness may affect individuals' tolerance to heat.

# REDUCED HEAT TOLERANCE DUE TO CHRONIC DISEASE

# Grade: A

# **Description**

Chronic health conditions are a personal risk factor for heat-related illnesses.

#### Recommendations

At a minimum, heat stress training should inform workers that there are many chronic conditions that affect the ability to work in the heat.

# **Evidence**



- ACOEM published a guidance document that includes personal risk factors with a list of drugs that may affect heat tolerance, and promotes preplacement medical exams (Tustin et al., 2021).
- The US Army has a guidance document that lists personal risk factors including chronic disease and treatments that affect heat tolerance (USArmy, 2022).
- NIOSH criteria document lists drugs that may affect heat stress (Table 4.2), which cites an earlier version of the US Army list, and the importance of preplacement medical examinations (Chapter 7) (NIOSH, 2016).



None offered.



The practice ranges from no particular action to informing workers of risks to assigning review to internal medical department.



#### Comments

Workers should at least understand that chronic disease may affect their tolerance for heat stress. They should be encouraged to consult their personal provider or the company medical department for counselling.

# REDUCED HEAT TOLERANCE DUE TO ACUTE ILLNESS

# Grade: A

# **Description**

Acute illness can reduce the person's capacity to deal with heat stress exposures by affecting the thermoregulatory centre or hydration among others.

### Recommendations

Presenteeism, when a person reports to work while suffering an acute illness, should be addressed by the company and guidance provided to supervisors.

## **Evidence**



- The US Army describes acquired risk factors for heat illness. The factors include acute conditions such as fever, inflammation, dehydration due to gastrointestinal disorders (e.g. vomiting, diarrhea, nausea), and sunburn (USArmy, 2022).
- ACOEM guidelines (Tustin et al., 2021) and NIOSH criteria document (NIOSH, 2016) also mention acute illness.



None offered.



None offered.



#### Comments

Because acute illnesses associated with fever and fluid loss significantly degrade heat tolerance, developing a plan to address presenteeism should be considered in heat stress managment.



# HEAT TOLERANCE TESTS

# Grade: B

# **Description**

Heat Tolerance Tests (commonly called HTT) are designed to predict who can tolerate heat stress from the population or among those who have experienced a severe heat illness.

# Recommendations

HHT is not recommended because the required time and equipment is not balanced by good sensitivity and specificity.

# **Evidence**



From recent reviews, there is strong evidence that heat stress tolerance testing is a weak predictor of ability or capacity to deal with heat stress (Butler et al., 2023; Mitchell et al., 2019).



- · There are other studies to demonstrate weak sensitivity and specificity for a specific test (Armstrong et al., 1987; Moran, Erlich, & Epstein, 2007).
- · A test for occupational exposures with protective clothing has been offered (Watkins, Gibbons, et al., 2018).
- · A pretest in a neutral environment can predict outcome for heat tolerance test in a hot environment with sensitivity of 0.54 and specificity of 1.0 (Northway, Jones, & Buono, 2023).



- Heat stress tolerance testing is a practice in the military for return-to-duty decisions.
- · At best, it might be used as an adjunct for a return-to-work decision (Tustin et al., 2021).



#### Comments

Heat tolerance testing can be an adjunct to return to work decision for a heat stroke or repeated heat exhaustions but it should not be the sole determinant.

# **RETURN-TO-WORK GUIDELINES**

# Grade: B

# **Description**

There are some guidelines on the return-to-work/duty.

# Recommendations

- The company-based medical department may develop internal guidelines.
- There should be an awareness that performance may change over the course of a workday.

## **Evidence**



None offered.



- ACOEM recommends: "Before clearing affected workers for RTW, ensure they are asymptomatic and that any abnormal biomarkers (e.g. serum creatinine) have returned to normal." (Tustin et al., 2021).
- US Army stages return to work based on the severity of the heat-related illness ranging from two weeks to two months with provisions for longer periods (see AR 40-501, 2019, pg 31, Table 3-2) (USArmy, 2022).
- One paper offers some guidance based on experience with military and sports (Butler et al., 2023; see Table 3).



None noted.



#### Comments

A returning worker after an exertional heat illness (EHI) should be closely observed until they demonstrate the ability to tolerate the heat stress.

# GENERAL HEAT STRESS PRACTICES

General practices are those actions common to any heat stress management programme.

# TRAINING PROGRAMME

# Grade: B

# **Description**

Training is essential for workers to understand what heat stress and strain are, how it affects them, and what they can do to mitigate the effects.

#### Recommendations

Training should be offered to all employees and first line supervisors. The minimum content should include:

- causes of heat stress and resulting heat strain
- signs and symptoms of heat-related disorders
- description of heat stress hygiene practices
- local policies and practices (e.g., controls) with respect to heat stress
- early recognition of heat-related disorders with first aid and emergency response.

# **Evidence**



One paper argues well for the role of training in heat stress management with acceptable study design (McCarthy, Shofer, & Green-McKenzie, 2019).



None offered.



- NIOSH (NIOSH, 2016), ACOEM (Tustin et al., 2021) and ACGIH (ACGIH®, 2023) recommend training programmes.
- Training in occupational health and safety is a well-recognised practice.
- Member companies have heat stress training programmes.



#### Comments

Training is a common denominator in virtually all heat stress management programmes.

# FIRST AID AND EMERGENCY RESPONSE

# Grade: A / C

# **Description**

The essential element to mitigate the consequences of heat-related disorders is early recognition and treatment.

# Recommendations

Provide training and support materials to include

- signs and symptoms of exertional heat illness (EHI)
- prevention methods in context of heat stress hygiene
- first aid and emergency response with emphasis on early recognition.

# **Evidence**



For heat stroke, immediate and aggressive cooling (e.g. ice water immersion) has the best outcomes for heat stroke first aid (Filep et al., 2020).



None offered.



The recognition and treatment of heat-related disorders are described in practice documents (NIOSH, 2016; Tustin et al., 2021; USArmy, 2022).



## **Comments**

The evidence is Grade A for heat stroke treatment: and first aid for other heat-related disorders is consistent and prevalent among practice documents.



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# HIERARCHY OF CONTROLS

The hierarchy of controls for health and safety is: Elimination - Substitution - Engineering Controls -Administrative Controls - Personal Protection.

# **ENGINEERING CONTROLS**

# Grade: C

# **Description**

- Engineering controls change the level of heat stress by changing the environment, metabolic rate or clothing requirements. They can include:
  - lowering metabolic rate by mechanising the task
  - lowering the humidity and temperature by mechanically cooling the air through spot cooling or space cooling, or by providing distributed cooling stations
  - fans/misters
  - evaluating protective clothing and equipment to lower heat stress while maintaining acceptable protection.
- Engineering controls remain the highest priority in occupational health and safety management systems

#### Recommendations

Consideration of engineering controls should be part of heat stress management.

#### Evidence



No systematic review of engineering controls was found.



There are case studies or small laboratory studies on some aspects of engineering controls.



- Engineering controls are promoted by NIOSH (NIOSH, 2016) and mentioned by ACGIH (ACGIH®, 2023) and ACOEM (Tustin et al., 2021).
- Engineering controls are high priority controls in ISO 45001 and ANSI Z10.
- · Engineering controls are used by member companies.



#### Comments

OSHA uses the Water Rest Shade campaign (www.osha.gov/heatexposure/water-restshade) to encourage recovery. The shade is an engineering control best understood as a cooler recovery area.

# **ADMINISTRATIVE CONTROLS**

# Grade: A / C

# **Description**

- · Administrative controls manage the risk when engineering controls are not feasible. For heat stress, administrative controls include:
  - prescribed work/rest cycles (described under Work/Rest Cycles based on WGBT - see page 26)
  - self-directed work (e.g. self-paced or self-limited) (described under Heat Stress Hygiene Practices - see page 14)
  - prescribed work time
  - overtime practices.
- · Administrative controls remain the second priority after engineering controls in occupational health and safety management systems.

#### Recommendations

Consideration of administrative controls should be part of heat stress management.

#### **Evidence**

• Prescribed time limits:



- PHS (ISO, 2004) was designed to prescribe time limits and it applies to higher vapour resistance than originally validated (unpublished data from USF).
- A paper proposes time limits based on WBGT (Bernard & Ashley, 2009) and is similar to the US Navy PHEL time limits.
- Prescribed work/rest cycles are based on time-weighted averages from WBGT exposure assessment. The extensive literature is described under Work/Rest Cycles Based on WBGT (see page 26).



None offered.



- Administrative controls are promoted by NIOSH (NIOSH, 2016) and mentioned by ACGIH (ACGIH®, 2023) and ACOEM (Tustin et al., 2021).
- Administrative controls are second priority controls in ISO 45001 and ANSI Z10.
- Administrative controls are used by member companies.
- Some companies manage forced and voluntary overtime shifts by allowing a one-day or two-day interval between overtime shifts.



#### Comments

Some employers use administrative controls to manage risk if work is somewhat above the exposure limit.

# **WORK/REST CYCLES BASED ON WBGT**

# Grade: A

# **Description**

- Work/rest cycles are prescribed periods of work in a hot environment followed by a recovery period. This is in contrast to self-directed work and recovery.
- Prescribed work/rest cycles are usually based on time-weighted averages (TWAs) of wet bulb globe temperature (WBGT) and metabolic rate (M).

# Recommendations

- · Continue to use TWAs to prescribe work and recovery.
- Recognise that they are not as protective of the population as the WBGT-based exposure limits based on constant exposures.
- TWAs can set some expectations in the context of self-directed work.

#### **Evidence**



- Work and recovery cycles, often with TWAs referenced to WBGT-based exposure assessments, have been investigated in the laboratory over decades. The evidence generally supports the effectiveness of work and recovery cycles based on group responses (and not individual responses).
- University of Ottawa (uOttawa) investigators first started reporting problems with some individuals as well as groups demonstrating increasing core temperature using prescribed work and recovery cycles in the same environment (TWA-M). University of South Florida investigators examined the uOttawa papers and others for evidence to support TWAs for M alone, WBGT alone, and both M and WBGT. These investigators concluded that work/rest cycles based on TWAs are not as protective as the WBGT-based OEL for steady work (Bernard, Flach, & Ashley, 2023).
- The US Army provides guidance for military training activities (US Army, 2022)



#### N/A.



- Work/rest cycles are common recommendations for managing exposures to heat stress (NIOSH, 2016; Tustin et al., 2021).
- Work/rest cycles are used among member employers to manage exposures to heat stress.
- Laboratory studies show the effect of heat stress on productivity and the loss accrues over the course of a day (Foster et al., 2021; Smallcombe et al., 2022).



- Prescribed work and rest (recovery) cycles are most common in the context of WBGT assessments.
- PHS should not be used to prescribe work and recovery because the recovery time is likely to be insufficient.

# PERSONAL PROTECTION

# Grade: A

# **Description**

Personal cooling provides a microclimate that promotes heat loss. Two other personal cooling methods are included here: forearm cooling in a cold water bath and drinking ice slurries.

## Recommendations

Personal cooling should be considered in terms of acceptance and practicality. Some suggestions are offered here.

- Ice cooling vests worn over the innermost layer of clothing. These can be effective but may have a limited service time of around 30 minutes.
- · Forearm cooling prior to and after a work period. It has demonstrated effectiveness as a method of recovery in the military and firefighting.
- Providing breathing grade air that can be circulated under the clothing during periods of standby or recovery. Adding vortex cooling enhances the benefit.

#### **Evidence**



- Excellent review of personal cooling ca. 1985 (Speckman et al., 1988) There is a US Army review of personal cooling that described the importance of surface area covered and the capacity of the heat sink as important considerations.
- A review of personal cooling for firefighters reported effectiveness of forearm cooling and circulating air and water systems (McEntire, Suyama, & Hostler, 2013).



- The use of ventilated garments emerged from a multi-country study (Ioannou et al., 2021).
- Ren et al summarised technology for personal cooling garments but do not discuss quantitative cooling capacity (Ren, Han, & Fang, 2022).
- Drinking of ice slurry prior to exposures helps reduce heat strain (Watkins, Hayes, et al., 2018).
- The effectiveness of precooling was reported (Watkins, Hayes, et al., 2018).
- Ice vest, phase-change vest and ice vest with ice slurry drink were effective in reducing heat strain (Bach et al., 2019) and work capacity (Ren, Han, & Fang, 2022).
- There are many reports on various personal cooling strategies that are not cited here.



Personal cooling is suggested by the NIOSH criteria document (NIOSH, 2016) and mentioned by the ACGIH TLV (ACGIH®, 2023)



- USF has unpublished data that indicates that underclothing circulating air, liquid cooling of about 50% of the body surface, and ice vests provided significant cooling in that order.
- Phase change materials come in a wide range of materials. Those that require freezing in a freezer are more likely to have sufficient heat transfer and heat sink capacities.

# PHYSIOLOGICAL MONITORING

# Grade: A

# **Description**

Physiological monitoring includes any means to assess a physiological change due to heat stress that may impact the ability to tolerate an exposure to heat stress

# Recommendations

- Because the exposure limits for physiological monitoring may not be well-designed, validated or evaluated for sensitivity and specificity, it should be used as an adjunct to self-directed exposures.
- · Physiological monitoring can be useful for behavior modification

## **Evidence**



- Two studies that explore the sensitivity and specificity of some physiological monitoring offer reasons for concern (Davey et al., 2021; Garzón-Villalba et al., 2017b).
- Two reviews look to the future and the need for good sensitivity and specificity (Buller et al., 2021; Dolson et al., 2022)



There are papers on individual methods, often with limited results or no evaluation of decision quality.



- NIOSH offers a positive outlook for the future of physiological monitoring (NIOSH, 2016).
- ACGIH offers some physiological limits based more on practice than a strong evidence base (ACGIH®, 2023).
- ACOEM offers a careful approach to monitoring core temperature (Tustin et al., 2021).
- Member companies are using various forms of physiological monitoring.



- Physiological monitoring is widely promoted and used.
- A vendor should provide the validation data for a proposed physiological monitor, and ideally a presentation of decision quality in terms of sensitivity and specificity.

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# **APPENDIX**

# **ACCLIMATISATION**

# Re-Acclimatisation Schedule for Returning Employees

The schedule represents the professional opinion for Thomas E. Bernard (USF) and may provide useful guidance for developing a programme of acclimatisation for returning employees.

Routine		Exposure Sequence			
Absence (days)	Illness (days)	Day 1	Day 2	Day 3	Day 4
<4	-	100%			
4-5	1-3	R/E*	100%		
6-12	4-5	80%	100%		
12-20	6-8	60%	80%	100%	
>20	>8	50%	60%	80%	100%

<sup>\*</sup>Reduce expectations, some loss of capacity

