



Safe Working in a Hot Environment



A printed or saved copy is an UNCONTROLLED copy.
Check that it is the latest available version before use.

Title:	SAFE WORKING IN A HOT ENVIRONMENT
Number:	GM-11-036-03
Version Number:	9.0
Date Revised:	10 December 2015
Owner:	Ben Morgan
Authoriser:	Melanie Jensen
Reasons for Creating or Amending Document:	Full Review of Document
Actual Change Details:	Hyperlinks updated, new owner, no changes to content required. Updated control block and header/footer.

TABLE OF CONTENTS

REGULATORY FRAMEWORK.....	3
1. INTRODUCTION.....	3
2. HEAT STRESS FACTORS.....	4
3. EFFECTS OF THERMAL STRESS ON THE BODY	5
4. METHODS FOR REDUCING HEAT STRESS (LOAD).....	6
5. EVALUATION OF HEAT STRESS (LOAD).....	6
6. MINIMISING THE POTENTIAL FOR HEAT STRAIN.....	7
6.1 WATER CONSUMPTION.....	7
6.2 HEAT ACCLIMATISATION.....	7
6.3 PHYSICAL CONDITION	7
6.4 CLOTHING.....	8
6.5 SCHEDULING PHYSICAL ACTIVITY	8
6.6 WORK RATES AND PHYSICAL ACTIVITY	8
6.7 OTHER FACTORS.....	8
7. REFERENCES.....	9
APPENDIX 1 - ACCLIMATISATION AND EVALUATION PROCEDURES	10
APPENDIX 2 - COMMONLY USED HEAT STRESS INDICES.....	11



Safe Working in a Hot Environment



TABLES

Table 1 - Effects of Thermal Stress on the Body 5

REGULATORY FRAMEWORK

Provision in the Regulations for hot environments is covered in the Occupational Safety and Health Regulations 1996 is as follows.

3.15. Air temperature

An employer must ensure:

- a. that work practices are arranged so that employees are protected from extremes of heat and cold; and
- b. if the workplace is in a building or structure that, as far as practicable, heating and cooling are provided to enable employees to work in a comfortable environment

1. INTRODUCTION

There are great variations in temperature found in Western Australia from the cool areas in the South West to the high summer temperatures in the North and inland areas. The effects of heat may be encountered during:

1. work in confined workplaces without adequate ventilation
2. work where there is direct exposure to solar radiation
3. work in hot and humid conditions
4. work performed in the vicinity of hot sources such as furnaces, heaters and ovens
5. heavy physical work in moderately hot and humid conditions ♦ work situations where protective clothing has to be worn; and
6. any situation where an employee has previously shown signs of heat related effects (e.g. dizziness, fainting and heat cramps)

Working in high heat environments can put workers at risk of impaired performance, heat illnesses and heat stroke. Impaired performance may result in unsafe acts and heat may also tend to promote accidents due to sweaty palms or impairment of vision through fogging of safety glasses.

By way of further introduction this guideline refers to:

1. **Heat Stress** - which is the burden or load of heat that must be dissipated if the body is to remain in thermal equilibrium
2. **Heat Strain** – which is the normal physiological or abnormal pathological change resulting from heat stress

The physiological condition referred to as heat strain is characterised by increases in deep body temperature, heart rate, blood flow to the skin and water and salt loss due to sweating.

Most adverse effects arise from a failure of the body's cooling mechanisms or as a result of overloading of the system.



Safe Working in a Hot Environment



Normally, several physical and physiological mechanisms assure transfer of excess body heat to the environment. Even when the body is at rest, heat is generated by normal metabolism. With exercise, the heat produced by muscle activity rises rapidly.

This generated heat is moved to the skin by the blood with the aim of transferring body heat to the environment. Heat may then be lost through convection, evaporation of sweat, radiation and conduction.

To maintain the appropriate body temperature three issues are essential:

1. The metabolic heat produced must be transferred to the skin via the circulation for dissipation
2. The sweat glands must be able to produce the necessary amount of sweat; and
3. The sweat must be able to evaporate

Failure in any of these mechanisms for heat transfer may cause the body core temperature to rise, leading to heat strain and subsequent heat illness.

Additionally, for the successful maintenance of the thermoregulatory system, adequate fluids must be consumed to prevent dehydration. When the air temperature is above skin temperature (around 36°C), evaporation of sweat is the main mechanism for the body to lose heat.

2. HEAT STRESS FACTORS

There are six factors influencing a person's capacity for heat exchange with the environment:

1. **Air temperature (dry bulb).** Above 36°C the body can gain heat from the environment
2. **Absolute humidity (wet bulb temperature).** When the absolute humidity is high, evaporation of sweat is reduced, thereby reducing the body's opportunity to lose its heat
3. **Radiant heat** from objects such as the sun, furnaces, and other hot surroundings. The direction of heat transfer depends on the absolute temperature difference between the body and the surrounding surfaces. It is not affected by the air temperature or humidity
4. **Air movement.** This can influence both convection and evaporation and can have a marked effect on heat exchange at the exposed skin surfaces (face, arms, legs). Convective heating or cooling does depend on the air temperature. Air movement assists with the evaporation of sweat from the skin and hence cooling capacity
5. **Muscular activity.** This is the most significant as it imposes a variable heat load. Work rates may increase heat production up to ten times the resting level and can cause a rapid body heat rise if this cannot be lost to the surroundings
6. **Clothing.** This can have a major effect on the amount of heat transfer from the body. Clothing may limit convective exchange and may interfere with the body's capacity to lose heat through evaporation of sweat. However clothing can reduce the radiant heat to the body from surrounding surfaces (firefighters, furnace operators, underground motors and machinery)



Safe Working in a Hot Environment



3. EFFECTS OF THERMAL STRESS ON THE BODY

The body core temperature is significantly affected by body activities and by the ability of the body to lose this core heat. The extent of any rise is related to the physical work level. Skin temperature on the other hand depends on several environmental conditions.

Increased blood flow through the skin allows body core heat to be dissipated at the body surface. Evaporation of sweat cools the skin and in conjunction with increased skin blood flow assists in achieving thermal balance.

The body uses its own water reserves to generate sweat, so maintaining body temperatures within safe limits. Sweat loss if not replaced leads to dehydration which in turn puts a strain on the circulation causing the heart to beat at a higher rate additionally sweat rate is reduced, so affecting thermoregulatory capacity and adaptation.

Repeated exposure to heat over a period (usually not less than 7 days) produces physiological changes enabling a person to respond more efficiently to the heat demands - this is acclimatisation. This increases water requirement, reduces strain, improves performance and comfort. There are reductions in core temperature and heart rate reached at the same rate of work as before, there is an increase in blood volume, the body sweats more readily and the salt content of sweat is decreased.

A description of the symptoms of the various effects is tabulated below.

Adverse Effect	Description
Skin problems (e.g. prickly heat)	Caused by blockage of sweat ducts and associated inflammation of the skin.
Heat strain	This is the change in pulse, body temperature and sweating. It may lead to heat illness if the heat load continues
Heat illness	This is a feeling of weakness, dizziness and nausea. The person loses concentration. Safety awareness and performance may deteriorate
Heat exhaustion	If there is insufficient replacement of water loss from sweating, progressive dehydration occurs. These can be pallor, profuse sweating, hypotension, rapid heart rate, alteration of consciousness, thirst and increase in body temperature. Blood pooling may cause fainting Salt deficiency, especially following long periods of sweating may also produce a form of heat exhaustion and can cause muscle cramps
Heat stroke	This is more severe and may be life threatening. A person may become irritable, confused and apathetic before a life threatening stage is reached. The person may also have fits. The body temperature is high (over 40°C) and the skin may be hot and dry. Heat stroke can occur if treatment is not given immediately. Any increase in body core temperature beyond that point is life threatening and must be treated accordingly

Table 1 - Effects of Thermal Stress on the Body

4. METHODS FOR REDUCING HEAT STRESS (LOAD)

Excessive heat load can be due to radiation, convection, unsuitable clothing or, body metabolism.

Consistent with the hierarchy of control measures generally applied to health and safety hazards, the employer should ensure that exposure to heat is limited by:

1. not exposing employees to heat so far as is practicable
2. isolating sources of heat, so far as is practicable, through shielding, containment and remote handling techniques, if applicable
3. providing engineering controls, such as ventilation, to reduce heat loads
4. adopting safe work practices and appropriate administrative procedures such as job rotation, and
5. if other means of controlling exposure are not practicable or adequate, by providing personal protection equipment

The radiant heat load may be reduced by insulation (shielding) or relocation of heat sources, use of barriers or reflective screens with aprons and covering exposed parts of the body.

The convective heat load may be reduced by lowering the air temperature and increasing the air velocity (e.g. fans).

For extreme conditions, (e.g. during certain confined space maintenance activities) air or ice cooled clothing may be used. In general, clothing is chosen to allow ready evaporation of sweat.

Reducing the effect of metabolism can be accomplished by reducing the physical demands of the work (e.g. mechanisation, automation), sharing the work load (particularly during peak heat periods) and increasing rest time.

5. EVALUATION OF HEAT STRESS (LOAD)

This can be complex because of the numerous indices in use with each one providing a differing assessment of heat stress. Thermal load and the body's response to it, is influenced by seven important factors:

1. radiant heat
2. air temperature
3. air movement
4. humidity
5. intensity of physical work
6. clothing worn; and
7. individual acclimatisation



Safe Working in a Hot Environment



There are several heat stress indices in use, incorporating these seven factors to varying degrees (for additional information see Appendix 2).

One index used currently in Western Australia for measuring environmental factors is the Wet Bulb Globe Temperature (WBGT). This is the most universally applied heat stress index. The American Conference of Government Industrial Hygienists (ACGIH) has recommended Threshold Limit Values (TLVs) for differing workloads using this index. Additionally, the ACGIH recommends accommodation to be made for un-acclimatised workers and suggests a correction factor for clothing (Appendix 2).

A hand held instrument for assessing WBGT is available. It is emphasised that the WBGT index was developed for workers in temperate climates and that interpretation is required when attempting to adapt it to hotter climates.

However, as stated earlier, the degree of activity or workload (metabolic rate) heavily influences body heat load. Therefore, an index that recognises this work activity may be considered more appropriate.

6. MINIMISING THE POTENTIAL FOR HEAT STRAIN

6.1 WATER CONSUMPTION

Sweat rates can be as high as two (2) litres per hour; for those performing heavy physical labour in the heat. Therefore water must be readily available and should be consumed before the shift, and then subsequently at regular intervals thereafter (such as half hourly). Thirst indicates that moderate dehydration is already established.

The water must be palatable by being cool (6-15°C) and can be flavoured for example, with weak cordial.

Proprietary carbohydrate/electrolyte beverages are not required if the diet contains the normal amount of salt.

A simple spot urine test can be undertaken which assesses the specific gravity of the urine. The result determines whether a person is well hydrated, partially dehydrated or unacceptably dehydrated. Simply put, dark yellow urine could indicate already established dehydration; urine should be the colour of water.

6.2 HEAT ACCLIMATISATION

Through acclimatisation, employees have the ability to increase tolerance to work in heat. Full acclimatisation takes 7-14 days with 3 hours activity per day. Acclimatisation usually increases water requirements as acclimatisation increases sweating, but reduces salt loss. Additional information on acclimatisation is provided in Appendix 1.

6.3 PHYSICAL CONDITION

Good physical condition will reduce the likelihood of heat strain. Those that are more than 20% overweight are more prone to developing heat illness symptoms. Those that are fit will most readily acclimatise and have some 'protection'.



6.4 CLOTHING

Clothing that is both loose fitting and made from cloth that "breathes" may be appropriate. Artificial fibre cloth such as nylon is not recommended in heat stress situations. It is important not to obstruct evaporation from the skin.

Protective covering such as hats, long sleeved shirts and shoes is recommended in situations where radiant heat is likely to be a problem, such as outdoors.

6.5 SCHEDULING PHYSICAL ACTIVITY

Where practicable, adjustment of work schedules and hot jobs may need to be made. Activities in the earlier part of the day (before 10 am) and later in the day (after 3 pm) should be considered to avoid the maximum heat conditions found in the middle of the day.

Consideration may need to be made to re-scheduling work according to weather conditions. In hot conditions relative humidity over 75% contributes a substantial risk to heat injury.

6.6 WORK RATES AND PHYSICAL ACTIVITY

Sustained physical activity can cause a rapid rise in body core temperature which may exceed the body's capacity to dissipate this heat to the environment. It may be necessary to provide adequate and regular rest periods to minimise heat production, or to provide for self paced work. The provision of air conditioned retreats and cooled fluids may also assist in maintaining appropriate body temperature. Resting or performing other tasks in cool (<25°C), low to moderate humidity surroundings reduces considerably the effects of hot work. Rest areas should be located close to the hot work areas in order to encourage their use.

6.7 OTHER FACTORS

Other issues that need to be considered include:

1. Age. The older a person is, the less capacity they have for coping in heat stress
2. Obesity. This is a factor in a persons ability to reduce body core temperature
3. Physical Fitness. The fitter a person the better they manage in heat stress conditions
4. Medical conditions and medications. These influences a persons ability to acclimatise and cope in hot conditions

Medical conditions for consideration include: heart disease, high blood pressure on medication, asthma on medication, kidney disease. Medications for concern include the use of steroid (cortisone, prednisolone) tablets, blood pressure tablets and diuretics.



Safe Working in a Hot Environment



7. REFERENCES

Bates, G.; Heat Stresses at Work and their Management. Thesis, Curtin University of Technology.

Chesson, B.J.; Heat Stress Control, Evaluation of Personal Cooling Systems. Masters Thesis 1984. Curtin University of Technology.

Howes, M.J.; Application of Refrigeration in Mines. Trans. Instn. Min. Metall., 92 April 1983.

Keilblock, A.J., Schutte PC; Human Heat Stress: Basic Principles, Consequences and its Management. Minesafe 1993. Proceedings p119-134.

Stewart, J.; Fundamentals of Human Heat Stress. Environmental Engineering in South African Mines. The Mine Ventilation Society of South Africa 1982. Ch. 20 p495-533.

Commonwealth Department of Science and Technology. Thermal Comfort at Work. Working Environment Series No. 14 Australian Government Publishing Service Canberra 1987.

Threshold Limit Values for Chemical Substances and Physical Agents; 1994-1995. American Conference of Governmental Industrial Hygienists.

World Health Organisation. Health factors involved in working under conditions of heat stress. Tech. Rep. Series No. 412 Geneva.



APPENDIX 1 - ACCLIMATISATION AND EVALUATION PROCEDURES

The acclimatisation and evaluation procedures listed in the body of this guideline are not regulations and compliance with them is not mandatory. However, adherence to the recommended procedures should ensure a high level of worker health protection. Acclimatisation and evaluation procedures different from those set out in the guideline may also be acceptable. In preventing heat strain, the importance of ensuring that employees appreciate the need for water intake, proper clothing and the need to be able to recognise early signs of distress cannot be over-emphasised.

Acclimatisation Procedures

Some of the characteristics of acclimatisation to heat can be summarised as follows:

1. Acclimatisation begins with the first exposure, progresses rapidly and may be well developed in about one week for some
2. Acclimatisation can be induced by short, intermittent work periods in the heat for two hours daily. Resting or inactivity in the heat produces only slight acclimatisation
3. Subjects in good physical condition acclimatise more rapidly and are capable of doing more work in the heat. Good physical condition, however, does not in itself confer acclimatisation. Also, individuals differ widely in their ability to acclimatise
4. Acclimatisation to high heat loads will enhance performance at less severe conditions, but will only provide partial benefits for more severe conditions
5. Acclimatisation to heat is well retained during periods of no exposure for about one week; thereafter, acclimatisation is lost at a rate that varies among individuals. Within about three weeks to a month, acclimatisation effects are lost and hardly any traces are to be found after a few months. Staying in good physical condition helps retain acclimatisation

By way of example, the American National Institute of Occupational Safety and Health (NIOSH) recommend the following acclimatisation routine:

1. Un-acclimatised employees should be acclimatised over a period of 6 days. The acclimatisation schedule should begin with 50 percent of the anticipated total work load and time exposure of the first day, followed by daily 10 percent increments building up 100 percent total exposure on the sixth day
2. Regular acclimatised employees who return from nine or more consecutive calendar days of leave, should undergo a four-day acclimatisation period. The acclimatisation schedule begins with 50 percent of the anticipated total exposure on the first day, followed by daily 20 percent increments building up to 100 percent total exposure on the fourth day
3. Regular acclimatised employees who return from four consecutive days of illness should have medical permission to return to the job, and should undergo a four-day re-acclimatisation period as in (2) above.



APPENDIX 2 - COMMONLY USED HEAT STRESS INDICES

Wet Bulb Globe Temperature (WBGT)

Considered the simplest of indices to use (hence its continued recommended use by NIOSH, NH&MRC, ACTU). The index was devised for use in US military field operations. The index is sensitive to dry bulb, radiant and natural wet bulb temperatures, and air velocity. It can be adjusted to take into account clothing, work rate or duration of exposure.

Effective Temperature (ET) and Corrected Effective Temperature (CET)

ET and CET were devised originally as a comfort scale. This index combines the effects of globe temperature (radiant and dry bulb), wet bulb and air velocity, though not under hot, humid conditions.

Heat Stress Index (HSI)

Heat Stress Index (HSI) of Belding and Hatch is based on the physical analysis of heat exchange. The index equates the amounts of heat required to be dissipated by evaporation of sweat with the maximum possible evaporative capacity. This index tends to overestimate the environmental heat load, and is too complex for daily use.

Predicted Four Hour Sweat Rate (P4SR)

This is the quantity of sweat, in litres, likely to be produced under specific thermal conditions. It takes into account the metabolic rate and to a lesser extent the clothing worn, along with dry bulb, radiant temperature, wet bulb and air velocity. This index is also complex and requires a nomogram to obtain corrected figures.

The Wet-Kata Thermometer

This is the measure of the cooling power of the environment. This index correlates well with body responses in hot, humid conditions, but is less meaningful in hot dry conditions and with un-acclimatised people.