

GUIDELINES FOR THE MANAGEMENT OF

WORK IN

Extremes of Temperature



Published by the Occupational Safety and Health Service
Department of Labour
Wellington
New Zealand.

First edition: September 1997

ISBN 0-477-03605-8

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Foreword

These guidelines are a supporting document to assist employers to comply with the Health and Safety in Employment Act 1992 as it relates to the hazard of work in extremes of temperature.

The information in these guidelines will be of use to three groups: those responsible for managing staff who work in extremes of temperature, the staff who work in those environments, and the personnel who provide medical support.

The OSH staff who compiled these guidelines (Nick Matsas, Dora Smith, Murray Thompson, and Dr Ian Bisset) gratefully acknowledge the assistance of Keith Briggs from Woodward Clyde New Zealand Ltd (for the “Cold Stress” section), Eric Greenslade from the Council of Trade Unions, and Paul Jarvie from the Employers and Manufacturers Association.

Introduction

Humans are warm-blooded, that is, we have the physiological ability to regulate our body's internal temperature, which is kept at $37^{\circ}\text{C} \pm 2^{\circ}\text{C}$. If the body's core temperature either rises or falls beyond this, then serious illness or even death may result.

Our behaviour also plays a role in regulating our temperature. We can remain in a warm area on a cold day, or seek out shade on a hot day. We can wear heavyweight or lightweight clothing, depending on the weather conditions. As a result of our behaviour, humans have been able to settle and live in every climate on planet Earth, including ones that our physiological temperature control alone would not allow.

In work and play, we can also choose to behave in ways that puts extra stress on our body's temperature control mechanisms. We can, for example, run a marathon in summer heat, or work in a factory with a very hot furnace. We can participate in outdoor recreational activities in winter, or work in a freezer store. Sometimes we can place our bodies under so much stress from the thermal environment that certain medical conditions occur, or ultimately we lose the ability to control our core temperature.

This booklet deals specifically with work situations where there is a risk of heat-related or cold-related medical conditions, or where extreme thermal conditions cause a significant shift in a person's core body temperature. It should be noted that these medical conditions are more serious than the discomfort many people experience in their places of work in summer or winter. Likewise,

the conditions that cause the medical conditions are more extreme than those which cause discomfort.

It is important to note that, in the work situation, employers have a legal obligation under the Health and Safety in Employment Act 1992. The Act requires employers to have a safe place of work, and to identify and control hazards. This guideline will help employers to identify, assess and control the hazard of work in extremes of temperature.

1 Management of Work in Extreme Hot and Cold Environments

REQUIREMENTS OF THE HSE ACT

The Health and Safety in Employment Act 1992 (HSE Act) requires that employers and others manage their safety and health hazards. Briefly, in terms of hazard management, the Act requires the following:

1. Employers are to identify hazards.
2. Employers are to determine whether hazards are significant.
3. Employers are to control significant hazards, by means of:
 - Elimination; or
 - Isolation, where elimination is not possible or practicable; or
 - Minimisation, where isolation is not possible or practicable.

Appendix A contains a more detailed summary of the Health and Safety in Employment Act 1992.

All information in this guideline is provided to help employers and employees in meeting their obligations under the Act.

Tables 1 and 2 (overleaf) can be used for assistance in working through the management of heat and cold hazards.

Figure 1: Hazard Management Flowchart

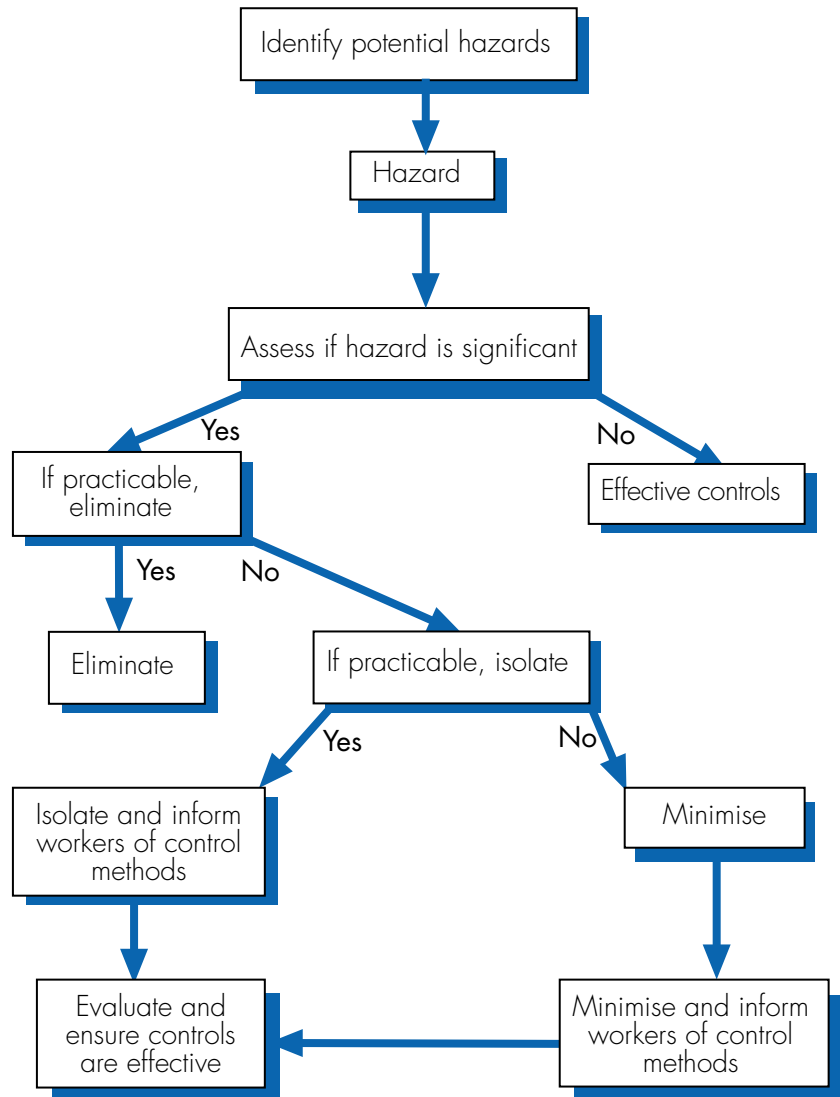


Table 1: The Hazard Identification Process as it Relates to Hot Environments

Hazard Identification Step	Hot Environment
Identify hazards	<p>There is little risk of heat causing harm when heat is directly caused by the weather <i>only</i> (with employees wearing appropriate clothing with a low or moderate activity rate).</p> <p>Heat is likely to be a hazard if, in addition to the weather (or sometimes on its own), the work process has:</p> <ul style="list-style-type: none"> • High radiant heat (e.g. from a dryer, an oven or a furnace); • High humidity (e.g. from a kitchen or laundry); • A high worker metabolic load; • A person wearing clothing (such as protective clothing) that means they cannot lose heat to the environment. <p>Any work with these four factors should be noted as a hazard.</p>
Assess hazards to determine if they are significant	<p>There are a number of tools you can use to assess the heat hazard to determine if it is significant. These include:</p> <ul style="list-style-type: none"> • Visual assessment. Simply being in the area in question for a few minutes can tell you much. • Measuring the environment with a heat stress monitor (wet bulb globe thermometer or WBGT). Using these measurements with the WBGT index, you can determine if the thermal environment is a significant hazard. • Use of the required sweat rate index, for some situations when WBGT readings are higher than the WBGT index allows for. • Direct physiological measurements such as core body temperature and heart rate.
Carry out control measures	Some options for elimination, isolation or minimisation of heat hazards are outlined in Section 3 of this guideline.
Evaluate control measures	Use the same tools as for assessment of risk.

Table 2: The Hazard Identification Process as it Relates to Cold Environments

Hazard Identification Step	Cold Environment
Identify hazards	<p>The following situations may present risk of cold stress (at some time or most of the time):</p> <ul style="list-style-type: none"> • Any work situation where employees work outside in cold or wet weather; • Any situation where employees are required to work in, and spend some time in, an artificially cold environment such as a walk-in fridge, coolstore or freezer; • Any person doing occupational diving.
Assess hazards to determine if they are significant	<p>The main tools for evaluation and assessment of cold environments are measurement of temperature and windspeed, as well as observation of effects of cold on employees.</p>
Carry out control measures	<p>Some options for elimination, isolation or minimisation of heat hazards are outlined in Section 4 of this guideline.</p>
Evaluate control measures	<p>Use the same tools as for assessment of risk.</p>

2 The Human Response to Heat and Cold

HUMAN TEMPERATURE REGULATION

Although we are able to control our internal temperature, the human body does not maintain the same temperature throughout. The temperature of the body at the skin may be a few degrees different from the internal temperature. The body does, however, maintain a constant temperature at its centre, that is, in the interior of the brain, the heart and abdominal organs. This constant temperature is known as the core temperature, and fluctuates very slightly at around 37°C. Maintaining this core temperature is necessary for the normal function of important vital organs.

The body has a number of means to raise or lower the core temperature. The main ones are:

- Sweating to lower the core temperature. Loss of heat occurs from the evaporation of sweat on the skin.
- Shivering to raise the core temperature. Shivering is an involuntary muscle activity that increases metabolic heat production.
- Increasing or reducing the blood flow to the skin. In a hot thermal environment, a person's blood flow to the skin will increase, aiding heat transfer and loss. In a cold thermal environment, the blood flow to the skin is reduced. While this prevents heat loss and maintains the body's core temperature around the vital organs, it does make a person more susceptible to cold injuries such as frostbite.

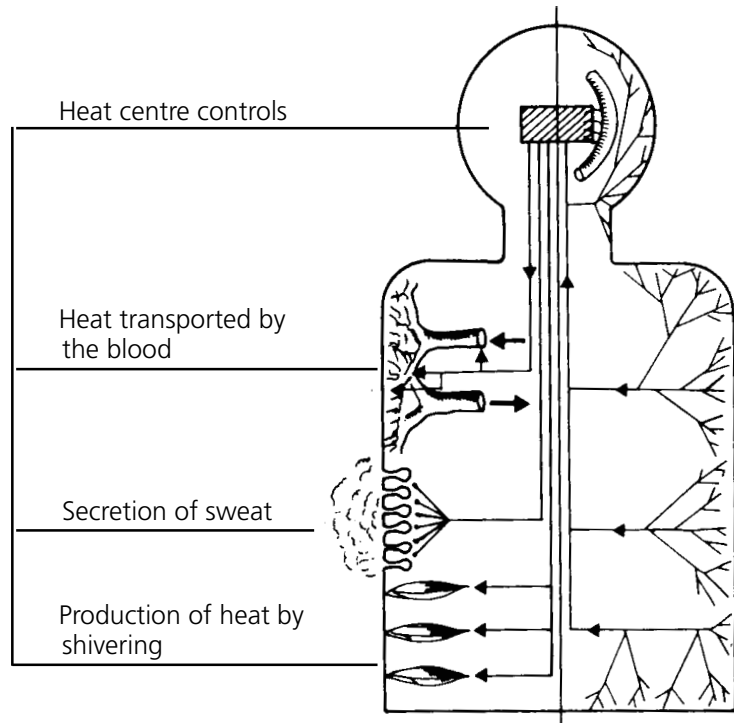


Figure 2: Schematic Diagram of the Human Temperature Regulation System (Grandjean 1986)

These control mechanisms are shown graphically in Figure 2 (above).

It is possible for the body's core temperature control mechanisms to fail. For example, if a person is working in an extreme hot environment, their core temperature may start to rise. They will start to sweat to cool down. If the fluid lost in sweat is not replaced, the person will eventually dehydrate and be unable to produce further sweat. The body has then lost the ability to control its core temperature. Serious heat problems may then occur.

FACTORS THAT
INFLUENCE
HOW WE FEEL
HOT AND COLD

There are six main factors that impact on a person to determine how they feel hot or cold. These are discussed below.

Air temperature is how hot or cold the air around us is. It is what we measure with a thermometer. It will have a direct warming or cooling effect on a person. In situations with a high radiant heat level, air temperature alone is not a good indicator of the thermal environment.

Humidity is the moisture content of the air. Relative humidity is the moisture content expressed as a percentage, with 100% being total saturation for that temperature. The warmer the air, the more moisture is able to be carried in the air. High humidity tends to make people feel hotter than low humidity. This is because although a person will sweat, sweat will not evaporate and cool the person if the air is already moisture saturated. Cold air has a lower moisture content, so humidity is not a factor in cold environments, except that mist, rain or wet clothing can cause a decrease in insulating characteristics.

Radiant heat is emitted from anything that is hot. Radiant heat will in time heat the air, but people will absorb heat far more quickly. Radiant heat will affect people anywhere there is direct sunlight, or where a person is close to a process that emits heat.

Air movement in most situations will cool a person. This will provide some relief to people in a hot situation, but extra chill to people in a cold situation. In hot environments increasing the air speed can be used as a control measure. In cold environments, a wind chill factor can make a person considerably colder than if there was no wind.

Physical activity will increase the generation of heat in the body. In a cold environment, physical activity can help to warm a person. In a warm or hot environment, physical activity can increase the load of heat on a person. A high level of physical activity on a hot day can place a worker at risk of heat strain, where the heat

of the day alone would not cause a problem.

Clothing aids or prevents heat transfer from our bodies to the surrounding environment. In a cold environment, a person should wear clothing that will prevent as much heat transfer as possible. Ideal clothing in a hot environment will allow a worker to freely dissipate heat.

Clothing can also be used to shield a person from factors such as radiant heat or a high wind speed.

In addition to these six factors that affect everyone, there are personal factors that affect individuals. These include:

- **Weight** Overweight people are more at risk of harm in both hot and cold environments. This is due to an imbalance in heat transfer.
- **Health** There are a number of medical conditions that increase the risk of harm to people working in an extreme hot or cold environment. These are listed in Appendix C.
- **Level of fitness** A physically fit person will acclimatise better and generally cope with heat or cold stress better than an unfit person.
- **Age** As a person reaches middle age (45+), lifestyle health issues can start to emerge. These can make people more susceptible to harm caused by extreme hot or cold environments.
- **Use of prescribed substances** Use of some prescribed medications will adversely affect people working in extreme hot or cold environments. A list of these is included as Appendix C.
- **Use of non-prescribed substances** Use of many non-prescribed substances such as alcohol or cannabis will adversely affect people working in extreme hot or cold environments. These substances also are listed in Appendix C.

THE INDIVIDUAL'S
RESPONSE TO
HEAT AND COLD

Once all the influences on an individual are taken into account, that individual will feel heat or cold in one of the following ways:

- **Thermal comfort** What an individual feels in an ideal thermal environment. They are not conscious of being either too hot or too cold.
- **Thermal discomfort** A person experiencing thermal discomfort feels either too hot or too cold. They can often be very uncomfortable, but the body's temperature control mechanisms are working adequately, and there is low risk of harm.
- **Heat or cold stress and strain** This is where harm or serious harm can occur to a person as a result of working in a temperature extreme situation.

In terms of the Health and Safety in Employment Act 1992, heat and cold stress is a "significant hazard", and heat and cold strain is "serious harm".

3 Heat Stress and Heat Strain

DEFINITIONS **Heat stress** is the *net heat load* on the body with contributions from both metabolic heat production, and external environmental factors including temperature, relative humidity, radiant heat transfer and air movement, as they are affected by clothing.

Heat strain refers to the acute (short-term) or chronic (long-term) consequences of exposure to environmental heat stress on a person's physical and mental states.

HEALTH EFFECTS FROM EXPOSURE TO HOT ENVIRONMENTS

Work in heat can result in both mental and physical effects on a person. These include:

Initial Mental Responses

- Increased irritation, anger, aggression, mood changes and depression.

Physical Responses

- Increased heart activity, sweating, an imbalance of water and salt levels in the body, and changes in the skin blood flow.

Combined Mental and Physical Responses

- A lack of efficiency in performing heavy tasks, people performing skilled tasks less well, accelerated onset of fatigue, and lack of concentration resulting in higher error rates.

Exposure to a hot environment can also result in acclimatisation.

Heat Strain Heat strain is the term used to describe the effects that occur in the body as a result of heat stress.

The physical effects of heat strain can vary from less serious disorders such as skin rashes and fainting, to serious life-threatening situations where sweating stops and heat stroke develops.

Symptoms of Heat Strain

Headaches are usually the earliest of all warning symptoms of heat strain, a warning sign that is often missed if the person has received no training in managing heat stress.

Other early warning signs and symptoms of heat strain are:

- Muscle cramps;
- Changes in breathing patterns and pulse rates;
- Weakness;
- Heavy perspiration;
- Prickly heat;
- Dizziness or faintness; and
- Reduced performance.

Later warning signs and symptoms (if the heat exposure continues) are:

- Increased disturbance of the breathing patterns;
- An initially strong rapid pulse, then changing to a weak rapid pulse;
- Severe headaches;

- Severe muscle cramps;
- Confusion;
- Cold clammy skin changing to hot dry skin; and
- Cessation of perspiration.

Any worker who stops sweating is at extreme risk of suffering serious harm. When sweating ceases, the body's core temperature will rise very rapidly. If the core temperature reaches 41°C or higher, the condition commonly known as "heat stroke" can occur.

Conditions Associated with Heat Strain

The following conditions are indications that heat strain is occurring.

Dehydration Sweat is one of the body's main means of controlling the core temperature. As a person works in a hot environment, the body produces sweat in an effort to cool itself, which occurs as the sweat evaporates. Dangerous levels of dehydration (greater than 10% of body weight) can occur rapidly when working in extremes of temperature. A moderate degree of dehydration, e.g. a 5% reduction in body weight, is usually accompanied by a sensation of thirst. Although thirst is not a reliable indicator of the degree of dehydration, it gets worse as dehydration progresses, and the person complains of fatigue, irritability, headaches, nausea, and giddiness. The main clinical signs of dehydration are:

- not passing urine; and
- changes to a person's mental state and personality.

It is therefore vital that any person replace water and salt that is lost through sweat. Water should be at room temperature and replaced often. A rate of 100 - 150 mls of water every 15 to 20 minutes is recommended. Salt should only be replaced through the diet or under medical supervision.

Heat syncope (fainting) may result from a drop in blood pressure during prolonged standing in heat, or be due to a sudden change from sitting to standing. The person quickly recovers if allowed to lie down. In some industrial situations, however, the faint may itself be dangerous if the person is held upright in a confined space and the fall in blood pressure is sustained.

Heat rashes may appear on the body. The most common heat rash is prickly heat (miliaria rubra) which usually occurs in areas where clothing is restrictive, and gives rise to a prickling sensation especially when sweating. It can be aggravated when working in humid areas, or if protective clothing is worn and sweat cannot evaporate.

Another skin disorder (miliaria crystallina) appears with the onset of sweating in skin previously injured at the surface, commonly in sunburnt areas. As the sweat cannot escape, small to large watery blisters appear which will rapidly disappear once sweating stops.

Miliaria profunda occurs when the blockage of sweat glands occurs below the skin's surface. Discrete and pale elevations of the skin, resembling gooseflesh, appear.

All of the above skin disorders can be complicated if secondary infection occurs in the damaged skin.

Heat cramps are fairly common among individuals who work vigorously in the heat. Heat cramps are spasms in the voluntary muscles that occur following a reduction in the concentration of sodium chloride in the blood below a certain critical level. A negative salt balance in hot conditions usually arises in one of two ways:

- In the unacclimatised person with a naturally high salt content in sweat, when sweat salt losses are not replaced by additional dietary salt during the first few days of work in the heat; and
- In workers who drink water freely but do not replace salt.

Cramps often occur in the muscles principally used during work. They can occur either during work or after work has finished for the day. Cramps can be readily alleviated by rest, drinking water, and correction of the electrolyte imbalance in the body fluids.

Heat exhaustion is a more serious heat disorder which is linked to depletion of body fluids (dehydration) and electrolytes. The chief factors leading to heat exhaustion include:

- Increased dilation of the blood vessels with decreased capacity of blood circulation to meet the demands for heat loss to the environment, exercise and digestive activities.
- Decreased blood volume due to dehydration, pooling of fluid in the lower body, dilation of blood vessels or lack of salt (electrolyte imbalance).

Heat exhaustion usually responds readily to prompt treatment.

Heat stroke is the least common but most severe degree of heat strain. It has a high mortality rate, especially if effective treatment is not given immediately. It causes a major disruption of the central nervous system, and is characterised by the following symptoms:

- convulsions;
- mania or coma;
- dilated pupils;
- a core body temperatures of 41°C or above; and
- usually a hot dry skin.

Heat stroke may happen suddenly, or there may be warning signs such as irritability, dizziness or mental confusion.

A chart to aid workers in recognising the signs and symptoms of heat strain is included in Appendix D.

Acclimatisation Acclimatisation is best described as the processes (physiological changes) by which a person adapts themselves to be able to safely and comfortably work in a hot environment. Depending on the factors of fitness, age, physique, gender and race, the time needed to acclimatise can take 7-15 days.

The steps involved in acclimatisation are:

- (a) A gradual increase in perspiration, which means more and more heat loss.
- (b) The sweat becomes “less salty” as the sweat glands learn to conserve salts. This prevents a salt deficiency in the body which, if it did occur, could lead to muscular cramps.
- (c) There is a loss of weight which helps heat loss by reducing the amount of insulating fat and reduces energy consumption.
- (d) As the change proceeds, the worker drinks more to replace the fluid lost by sweating.

After a person becomes acclimatised, they feel thirst whenever their body needs more fluid, and will therefore drink more.

Acclimatisation should be carried out where it is known that the job will take a period of time.

Acclimatisation should be a managed process. People working in hot environments should not be allowed to suffer heat strain as part of the process.

Acclimatisation will gradually decline after exposure to a hot environment ceases. Unless a person moves from one hot job to another, it should never be assumed they are acclimatised.

ASSESSMENT
OF HOT
ENVIRONMENTS
AND PEOPLE
WORKING IN
THEM

There are two ways to find out how heat at work is affecting, or may affect, a person. These are to assess the environment being worked in (that is, to measure heat stress), or to assess the direct effects of heat on a person (that is, to measure heat strain). Means of carrying out these assessments are shown in Table 3 below.

The measurement techniques can be used as tools for hazard assessment, monitoring the health of the worker as part of hazard minimisation, and evaluating the effectiveness of controls. As heat is such a complex problem, it is desirable to measure both the heat in the environment and its effect on a person to gain a complete picture.

Table 3: Methods of Assessing Heat Stress and Heat Strain, and the Competencies Required to Do Them

Assessing heat stress	Assessing heat strain
Wet Bulb Globe Temperature Index Required sweat rate index	Observation of employee Medical assessment Core body temperature monitoring Heart rate monitoring
NOTE: These assessments should be carried out by a person who has a thorough knowledge of: <ul style="list-style-type: none"> • heat as a hazard; • the instruments required for measurements; and • the interpretation of the results. This could include an occupational hygienist or other suitably trained person.	NOTE: All people who supervise work, or work in hot environments should be trained to assess all visual symptoms of heat strain. All other assessments should be carried out by a person who has a thorough knowledge of: <ul style="list-style-type: none"> • heat as a hazard; • the instruments required for measurements; and • interpretation of the results. This could include a physician, registered nurse or other suitably trained person.

A Word of Caution on Using Thermal Models and Standards

Thermal models were developed using people in good health and fit for the work they perform. They do not predict how an individual worker will respond to heat. It is important to bear this in mind, as workplaces have staff at different levels of health and fitness. *Where thermal stress is very high, direct and individual observation of the exposed workers is essential.*

MEASURING HEAT STRESS The Wet Bulb Globe Temperature (WBGT) Index

The Wet Bulb Globe Temperature (WBGT) Index is a model for assessing the heat stress on a person in a hot environment. It takes into account the main factors that influence how people feel heat, by directly reading air temperature and radiant heat, and indirectly measuring humidity and air speed. Factors such as the level of physical activity and the clothing being worn are also considered. It assumes that the workers are healthy and physically fit for the work being done.

WBGT readings are taken using a globe thermometer, a natural wet bulb thermometer, and a dry bulb thermometer. All of these can be combined on an “area heat stress monitor”.

The documentation on the WBGT Index from the *New Zealand Workplace Exposure Standards* booklet is reproduced in Appendix G of this guideline.

Using the WBGT Index

The WBGT Index can be used in the following ways:

- As a preliminary or detailed assessment of hot environments;
- To determine if a hot environment is a “significant hazard”;
- To provide a benchmark for control of hot environments;

- To provide information on when administrative control measures such as work/rest regimes can be used.

Disadvantages of the WBGT Index

There are a few critical areas where WBGT readings will not predict the likely effect of heat on employees. These include:

- Where the WBGT temperature measured is hotter than the index allows for, and where it is not possible to eliminate or significantly reduce the heat the worker is exposed to;
- Where workers are exposed to extremely hot temperatures for short periods of time;
- Where protective clothing is required to be worn and it cannot be determined what effect the clothing is having on a person;
- Where a cooling device such as an air vest is being worn, and it cannot be determined what effect it is having on a person.

In these situations other means of measurement, such as core temperature or heart rate, are necessary.

Required Sweat
Rate (ISO
Standard
7933)

This standard was designed to be used where the measured Wet Bulb Globe Temperature exceeded the WBGT Index. The advantage of using this standard is that it can give guidance in managing work in exceedingly high temperatures. The disadvantages are that it is very complex, requires a computer to calculate the worker's recommended exposure times, and is not applicable for exposure times less than 30 minutes.

More information can be found in ISO Standard 7933 (1989) *Hot environments: Analytical determination and interpretation of thermal stress using calculation of required sweat rate.*

ASSESSING HEAT STRAIN

Observation of Employees

The onset of heat strain can be quite rapid and direct observation of the worker may be necessary to allow early intervention.

All employees who work, or supervise work, in hot environments should be trained to recognise the symptoms and effects of heat strain. They should be able to readily identify heat strain in themselves or others when it occurs.

Measurement of Core Body Temperature

When WBGT readings are taken, many assumptions are made to predict how the thermal conditions measured will affect a person. These assumptions may not be true in every situation. However, if you are able to measure a person's core body temperature, you are measuring the direct effect of heat on the body.

Core temperature can be measured by standard methods during work breaks. If a person has a high core temperature, they should not return to the work environment until it has returned to normal.

Instruments are available that will allow a person's core temperature to be measured while they are working in a hot environment. This is the preferred way of taking core temperature readings. The more recent of these instruments measure the aural or ear temperature. They will data-log the core temperature over the work time, allowing the readings to be downloaded into a computer or printer for recording or analysis. An alarm can be set to sound when the core temperature reaches or exceeds a predetermined level. This is usually set at 38°C.

This type of measurement is very useful where:

- The WBGT index is unable to predict how a hot environment will affect a person. Some of these are listed in the section on the WBGT index.

- To assess if a control regime determined by the WBGT index is in fact adequately protecting a person working in a hot environment.
- As an extra safeguard for people working in a hot environment.

While the results of this type of measurement can be very useful, they should be supervised or taken only by a suitably trained or competent person. People wearing devices of this nature should be given training on what the instrument is measuring, and what to do if an alarm sounds.

Work should be discontinued if a person's core temperature exceeds 38°C.

More information can be obtained in ISO 9886:1992 *Evaluation of thermal strain by physiological measurements*.

Heart Rate Monitoring

Heart rate is another relatively easy way to constantly monitor the effect that the working environment is having on a person. A heart rate monitor measures a person's heart rate in beats per minute, providing a general idea of the stress on the body. Changes in a person's heart rate can be caused by activity, heat stress, static exertion and psychological responses. Changes in heart rate can reflect core body temperature.

Heart rate, like core temperature, can be measured during breaks, but it is more desirable to do so during work by using a portable device like the Sports Tester. This consists of an electrode strapped around the chest which sends radio signals to a watch worn on the wrist. The monitors can be pre-set with an alarm that will sound if the heart rate exceeds the safe level for that worker, alerting them to the need to withdraw from the area until it returns to a satisfactory level.

Some models of heart rate monitors will log data, allowing downloading to a computer for recording or later analysis. They allow recording at a preprogramming rate, for the duration of the task (up to 24 hours). Comparisons can be made at a later time with activity logs and WBGT measurements to see what effect these have had on heart rate levels.

Safe alarm levels for heart rate should be determined for each individual by a medical practitioner. The best time to do this is at a pre-employment or pre-task health assessment. These are discussed in the section “Medical Support for People Working in Hot Environments”.

Appendix I is a chart on which the results from the monitor can be recorded.

More information can be obtained in ISO 9886:1992 *Evaluation of thermal strain by physiological measurements*.

CONTROL MEASURES FOR HOT ENVIRONMENTS

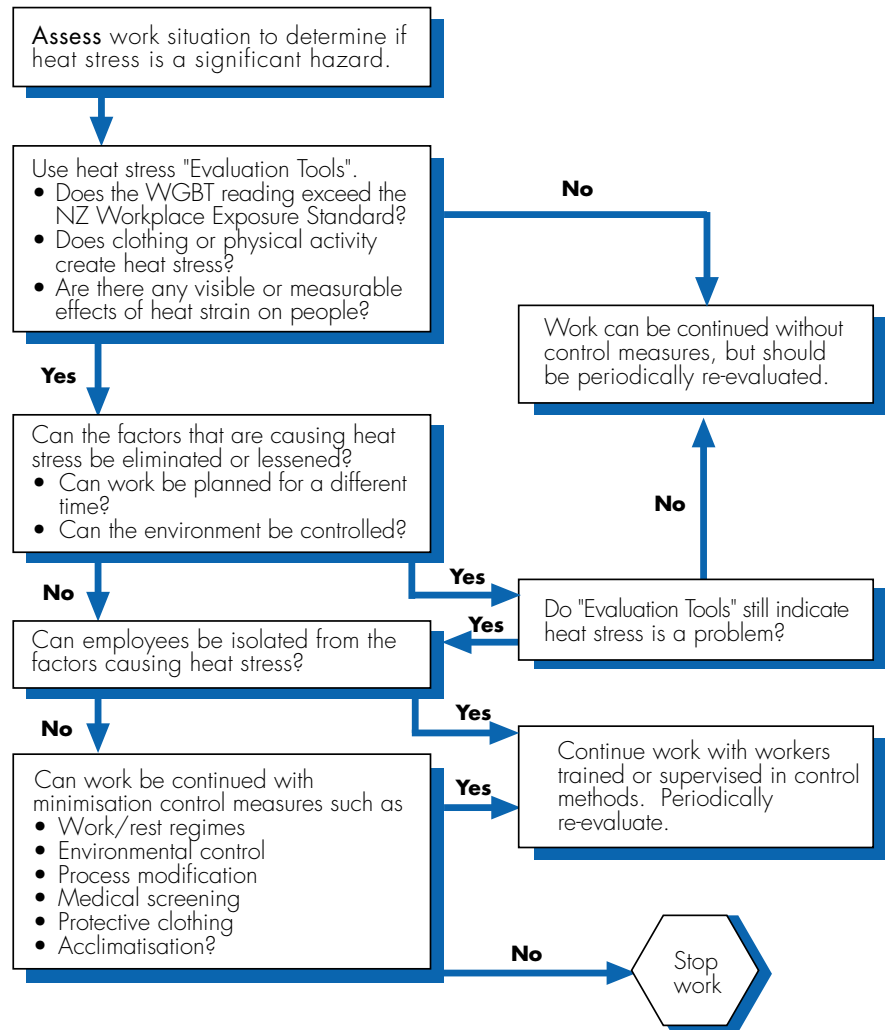
Elimination of Heat

The Health and Safety in Employment Act 1992 requires significant hazards to be controlled in order of preference, first by *elimination*, then *isolation*, then by *minimisation*. The following section lists some possible ways of achieving this.

The key questions are:

- Can another way be found to carry out the work required without having the source of heat that is causing heat problems in the workplace?
- Can the work be scheduled for a period of time when heat will not be an issue?

Figure 3: Flow Chart for Control of Work in Hot Environments



- Can the work and environment be altered so that heat is no longer a problem?

If you can answer “Yes” to these questions, you may be able to eliminate heat as a hazard. Means of elimination could include:

- Removing the source of heat from the workplace. This could be achieved by:
 - finding another way to do a process that does not require heat;
 - purchase a product that requires heat for its manufacture rather than manufacture it yourself.
- Doing work at times when heat is not a problem. This could be achieved by:
 - doing plant maintenance work during a specified shutdown period, so that emergency work in hot conditions is required less often;
 - doing work at a time of the day when the hot process is shut down;
 - scheduling jobs for a time of year when heat is not a problem.
- Altering the six main factors (as outlined on pages 14-15) so that heat is no longer a problem.

Isolation of Workers From Heat

The key questions are:

- Can a hot process be enclosed so that workers are protected from radiant heat?
- Can an enclosure or screen be provided for workers in a hot area so they are protected from radiant heat?

- Can a hot process be mechanised so that workers do not need to go near it, except for setup and maintenance?

If you can answer “Yes” to these questions, you may be able to isolate some or all workers from heat. Means of isolation could include:

- Placing an enclosure around a hot process so that heat from it does not escape into the general work area.
- Providing screens or an enclosure that workers can escape the heat inside or behind — especially relevant with a strong radiant heat source.
- A high level of mechanisation, so that workers do not need to go near the process except for setup and maintenance.

Minimisation of
Risk for those
Working in Hot
Environments

If employers are not able to eliminate or isolate workers from heat, they are required to minimise the hazard of working in heat.

Please Note

1. When minimising the effects of any hazard, the most effective controls are those that reduce the workers’ contact with the hazard, or soften the effect of the hazard. The least effective are those that shield the worker from the hazard, such as use of personal protective clothing.
2. A high level of physical fitness and regular intake of water are essential personal factors in preventing heat strain.

Controls for minimising the risk can include:

- Environment controls;
- Process modification;
- Administrative controls;

- Medical controls.

Environment Controls

- Provide ventilation, to give a significant air current. This will have the effect of both removing hot air away from the employee, and increasing the air velocity over the worker. An increased air velocity aids evaporation of sweat and cools the worker.
- Provide air conditioning, either by reducing humidity or providing cooling.
- Shield the work environment from any radiant heat sources such as sunlight, or insulating pipes or other hot objects.

Process Modification

- Modify the process so that less heat is needed to carry out the task required.
- Reduce the heat created in carrying out a process to the lowest possible level to still get the job done.

Administrative Controls

- Have only the workers necessary to do the work in any area where heat is a problem. Other workers who do not have to be exposed to heat as a part of their job should be situated elsewhere.
- Pre-plan jobs so workers have the right tools and only have to enter the hot environment once, minimising exposure to the heat and enabling the job to be completed quickly and efficiently.
- Do non-essential work at times when heat is lowest.

- Do all maintenance during a specified shutdown period, and do it well so breakdowns are minimised.
- Ensure workers are properly trained to work in a hot environment, so that they understand potential problems.
- Provide first aid training to those working in hot environments to enable them to recognise and treat any heat-related disorders. See Appendix D.
- Rotate jobs, or have more workers to do a job in a hot environment than would do a similar job in a normal environment. This means the activity level is lowered, and workers can get into a cycle of one working while the other rests. It also means that workers can observe each other for early signs of heat strain.
- Reduce the amount of physical work a person has to do in a hot situation, e.g. using a power tool instead of a hand tool will reduce the amount of heat produced from within the body. An indication of metabolic load that different tasks cause is outlined in the documentation from the Workplace Exposure Standards. See Appendix G.
- Provide clothing that will allow workers to sweat freely, and will not stick to the skin. See Section 3 “Clothing and Personal Protective Equipment” for more details.
- Provide protective clothing where necessary. See Section 3 “Clothing and Personal Protective Equipment” for more details.
- Introduce a work/rest regime for workers in hot environments. The WBGT Index schedules rests depending on the WBGT measured. In lower heat, the work rest ratio is more work than rest per hour. As heat in the environment increases, the ratio may be equal, or have more rest than work per hour.

Standards for heat stress assume the rest area is the same WBGT as the work area. Some adjustments can be made if the rest area is cooler, but these should not be made arbitrarily. Medical assistance is needed.

- Allow people to acclimatise to a hot environment. If possible, leave heavier tasks for fully acclimatised workers, or do them in a later stage of project work when acclimatisation has occurred.

Medical Controls As individuals can vary considerably in their ability to tolerate heat, a careful watch must be kept at all times, with comprehensive monitoring programmes in place.

- **Regular rehydration** People working in hot environments should drink 100-150 mls every 15-20 minutes as a minimum guideline. Fluids must be freely available at the work site. Plain water or a mixture of 50/50 water/fruit juice are adequate. These are best at room temperature. These fluids are in addition to routine cups of tea and coffee.

It is best to over-hydrate (drink plenty) before commencing work in a hot environment. As a guideline, people should drink enough fluids so that they need to urinate slightly more often than usual. *Employers must ensure that fluids are available, and that the workers drink them.*

- **Maintain fitness** during and between periods of work in hot environments.
- **Eat healthily** Fatty food intake should be reduced. Most people do not need to add extra salt to their diet. The normal intake of salt in their food is usually sufficient. Additional salt is only justified for unacclimatised workers, and

is best taken in the form of a salty liquid such as beef soup or similar. It is not necessary for short exposure times. Salt tablets are not recommended, as it is possible to over-compensate for lost salt.

If a person is on a salt-reduced or salt-free diet, they will need to either add salt to their food for the period of hot work, or have some other means to replace lost salt. If this situation arises, you should seek medical advice.

- **Pre-employment medical examinations** must be done to ensure that all who are going to be on the job are sufficiently fit, and have no precluding medical conditions. (See later in this section.)
- **Regular medical assessments** of workers who spend a lot of time in hot environments should be undertaken.
- **Personal hygiene** is most important, especially to reduce the risk of prickly heat. A shower and fresh clothing is advisable as soon as work has finished in the hot environment, and in some situations at the midday break as well.

MEDICAL
SUPPORT FOR
PEOPLE
WORKING IN
HOT
ENVIRONMENTS

Few hazards interfere with the normal working of a person's body to the same extent as exposure to extreme hot or cold environments. For this reason, it's important not only to have some medical input into health and safety plans, but to ensure that people selected to work in these environments have no pre-existing medical conditions that would place them at greater risk of harm.

All tasks outlined in this section should be carried out by a registered nurse or physician. However, employers and supervisors of people at work in hot environments should be aware of this information so they can include it in plans for work in heat.

Medical support is recommended at three separate stages. These are:

- Pre-employment health screening, or health screening of existing employees whose duties will change to include work in heat;
- Pre-task health screening, or assessing a person’s health and fitness directly before a specific job or period of work in heat;
- Monitoring of a person’s health during and after a job in a hot environment.

Pre-Employment
Health
Assessments

Before employing a person, or hiring a contractor to work in a hot environment, details of what the job includes, and the hazards associated with it should be fully explained. It is also useful to ask for information on the candidate’s previous exposures to hot environments.

It is recommended that you do not employ or hire a person for work in a hot environment unless they can pass a medical examination carried out as part of the employment procedure, or can provide a medical certificate stating their fitness for such work.

Medical assessment can be carried out by means of a questionnaire and basic medical examination, or a more detailed medical examination.

Table 4 details situations where a questionnaire or a full examination should be used.

Health Questionnaire

A recommended format for a health questionnaire is given in Appendix E. Where any question is answered “Yes”, the person should be referred to a physician for a full examination. When the

questionnaire is used, the following details should also be recorded:

- Blood pressure;
- Pulse;
- Weight;
- Height;
- Temperature.

Table 4: Situations Where Questionnaire or Clinical Examination is Required to Assess People for Work in Extreme Hot Environments

	The questionnaire should be used when:	Clinical examination should also be carried out when:
The worker:	<ul style="list-style-type: none"> • is less than 45 years of age • has prior satisfactory heat exposure • is acclimatised 	<ul style="list-style-type: none"> • is over 45 years of age • has no prior heat exposure • is unacclimatised
The work:	<ul style="list-style-type: none"> • has a moderate level of physical activity 	<ul style="list-style-type: none"> • has a high level of physical activity • requires protective clothing to be worn
The workplace:	<ul style="list-style-type: none"> • the WBGT reading is lower than the WBGT index as determined by the WES documentation 	<ul style="list-style-type: none"> • the WBGT reading is higher than the WBGT index as determined by the WES documentation • is a confined space • has any unusual environmental or physical stressors present

Clinical Examination

The clinical examination should be comprehensive and concentrate on the following adverse factors:

- Obesity.
- Lack of physical fitness.
- Pre-existing disease of the:
 - cardiovascular system, e.g. hypertension, valvular disease cardiac enlargement;
 - respiratory system, assessed clinically and by spirometry e.g. obstructive or restrictive airways disease;
 - thermoregulatory system e.g. thyroid disease, other endocrine disease, prescription (home) medication.

Further investigations (X-ray, ECG, etc.) can be ordered at the physician's discretion.

Pre-Task Health Assessments

Pre-task health assessments should be carried out prior to a specific task, or block of work, in a hot environment. For people regularly working in hot areas, the frequency of assessments should be decided by the physician.

On-Job Medical Surveillance

The onset of heat strain can be quite rapid and direct observation of the worker is necessary to allow early intervention.

Good practice would dictate that the following parameters are measured during these breaks and individuals would not return to

work until these measurements have returned to normal:

- heart rate;
- blood pressure;
- core body temperature.

This is the time that fluid replacement must occur and generally requires encouragement from supervision. Inexperienced workers find it quite difficult to replace their fluid losses, which can easily reach 5-6 litres per 8-hour shift.

A form that can be used when assessing an individual's ability to tolerate heat is included in Appendix H. It is helpful to put the worker's baseline recordings at the top before starting the monitoring.

Other factors that need consideration include:

- Acclimatisation; and
- Temporary unfitness. This is a situation which is often overlooked. Conditions such as current infection with or without fever, dehydration or loss of sleep may render a previously fit worker at risk from heat stress. Claims of feeling unwell should be taken seriously and investigated by the physician.

Emergency Medical Support

Early intervention is the key to successful treatment of severe heat strain. If treatment is not given immediately, there is a reasonable chance the person suffering will die before outside medical assistance can be called in, or the person is transported to a medical facility.

It is therefore essential to have at least one trained first aider, with additional training in heat stress, as part of a "hot environments"

team. As tasks increase in severity, having a nurse or doctor on site should be considered.

It is outside the scope of these guidelines to detail the treatment required for heat strain.

CLOTHING AND PERSONAL PROTECTIVE EQUIPMENT

Clothing is one of the six main factors that determine how we feel temperature. It can assume one of two main functions in a hot environment:

- It can maximise heat exchange, i.e. allow a person to sweat freely and lose heat to the environment.
- It can protect a person from a hot environment. It can do this either by:
 - Shielding a person from the hot environment, such as a very high radiant heat source; and/or
 - Providing cooling to a person, usually by means of air or water flow, or by ice melting.

It is very important to note that the best form of body temperature control is for a person to sweat freely, and frequently replace lost fluids. When a person puts on clothing that protects or shields them from the hot environment, the free evaporation of sweat is stopped. This shuts off the body's most effective heat reduction system.

It is very important to weigh up carefully the need for and provision of protective clothing in hot environments. All other forms of control should be considered before opting for protective clothing. In the section of the WES documentation on heat stress entitled "Effects of Clothing on Heat Exchange" you will note that the WBGT index value should be altered once heavier clothing is worn.

The situations where protective clothing cannot be avoided are those where the disadvantages of not wearing protective clothing equal or outweigh the disadvantages in wearing it. These include:

- Where people are working in front of a very high radiant heat source, and need to be protected from the “blast” of the heat;
- Where the environment is very hot and most control measures are not possible;
- Where a person may come into contact with objects or plant that will burn them.

Clothing that Maximises Heat Exchange

The WBGT Index is based on a person wearing a “summer uniform”, that is, a light shirt and trousers. Even clothing items such as overalls will reduce heat exchange.

In order to maximise heat exchange, a garment should be able to transmit moisture. Moisture can be transmitted through the fabric or through garment openings (neck, waist, ankle, arms).

Light colours reflect radiant heat but must be kept clean.

Protective Clothing that Shields Against Hot Environments

Clothing can be a mobile line of defence. Workers may wear heat-reflective or insulating clothing, including gloves and face shields. Clothing may also be required to withstand molten metal splashes.

An examples of such clothing is the “Nomex” suit, a reflective garment that gives protection from radiant heat and is worn by fire service personnel. Although it is ready for instant wear, the disadvantage is that the suit does not allow evaporation of sweat, so

is a trade-off between the protection it gives and the lack of cooling effect. The suit needs to be removed as soon as a person leaves the hot work area. It is possible to use a Nomex hood with an air vest or other garment.

Heavy wool garments may be worn where there is risk of molten metal splashes.

Protective
Clothing that
Provides
Cooling in Hot
Environments

This type of garment can be used on its own, or can be worn under a “shielding” garment. Items that need to be considered when selecting cooling garments include:

- How accessible is the place the people will be working in?
- What time span is involved?
- How many people (and cooling garments) are going to be needed?
- What back-up facilities are required for the various types of cooling equipment, e.g. air supplies or freezing facilities?

The advantages and disadvantages of various types are discussed below:

Air Vest

This is a jacket worn over clothing and consists of two layers of fabric through which air is blown, coming out at two vents which project up onto the face. The effect of air blowing over the face has the advantage of a considerable cooling effect. The air must be of a quality that is safe for respiratory use. Air vests are quick and easy to put on and can be ready for use quickly.

Disadvantages are the need to be attached to an air line. Care has to

be taken not to get the line in too hot a spot, or get it tangled up in something.

AIR VEST ALERT

An air supply source used for normal reticulation to air tools should not be used with an air vest as it often contains oil or lubricants. Air supplied by a compressor should be used in conjunction with an approved filter for breathing air.

Air from a compressor can be “conditioned” by devices such as a “kool tube”. This is a small unit placed in the air line that spins air at a high speed and fractionates warm and cool molecules, cooling the air supply significantly.

Cool Vest

This is a vest that has an insert of frozen liquid placed between fabric and is worn on the upper trunk. An advantage of this vest is the freedom it gives to move around, since it has no attached lines. Disadvantages include getting the liner refrozen, and the need to have a second liner available if any task is going to take longer than 30 minutes. Time is required to freeze the liner before any task can start, so the vest is not available for immediate use unless liners are permanently frozen.

Heat Transfer Suits

These garments are worn next to the skin and consist of three pieces: pants, shirt and hood. Resembling thermal underwear, they contain tiny tubes which circulate ice-cooled water over most of the body. Only the face, feet and hands are not covered by the garment. Advantages include a constant and steady cooling effect to the whole body.

Disadvantages are the need to change the ice bottle every 20-30 minutes in very high temperatures. The tubes can block up and the pump can prove temperamental. Using ice blocks in the bottle rather than freezing it solid has helped with these problems. Because of the pump the suit can be clumsy in confined spaces, and the plastic tubing between the pump and the suit is vulnerable to snagging.

Hygiene is important as the suits need to be washed after each use. Washing must be hand done as the suits cannot be dry-cleaned.

Which type of protection you choose will depend on factors like access to the task, backup services and the individual preferences of staff.

Evaporation of sweat is a very effective cooling technique. If sweat drips off, it does not cool and is wasted. An example of this is sweating that occurs under non-permeable garments. The Nomex suits come under this category.

4 Cold Stress and Cold Strain

INTRODUCTION The dictionary defines a *stress* as a form of applied pressure upon a body, and the effect of that pressure on the body as *strain*.

Cold stress is the existence of an environment capable of causing cold strain. In the case of cold stress, the stress factors are mainly environmental, e.g. low temperature, wetness and air movement, and cold strain is exhibited in a variety of adverse medical symptoms. If the degree of cold stress is slight, the resulting effects will probably be minor, but greater cold stresses can result in serious harm, or even death to those exposed to them.

In any workplace where workers may be exposed to cold working environments, employers must ensure that the appropriate protective and control measures are taken.

The most likely situations where cold stress could develop are where employees are working:

- Outside in winter, or at altitude;
- In wet conditions; or
- Inside walk-in freezers.

These guidelines provide information on the causes and results of cold stress, and the measures that should be taken, if most workers are to be protected from harm.

THE HEALTH EFFECTS OF COLD STRESS

The colder the environment, the more adverse the health effects observed. Cold stress, like heat stress, impairs the ability to carry out both manual and mental tasks. As the temperature drops, the sensitivity and dexterity of fingers lessen. At lower temperatures still, deeper muscles are affected, reducing muscle strength and stiffening joints. Cold-related discomfort also affects mental alertness. For these reasons, accidents are more likely to occur under cold working conditions.

The health effects of cold can be divided into two categories:

- Those affecting the body's extremities; and
- Those that affect the body's core.

Cold Injuries to the Extremities

Cold injuries occur because the body reduces blood supply to the extremities, in an effort to conserve heat around the vital organs. The main cold injuries are frostnip, frostbite, immersion foot and trench foot, which affect localised areas of the body.

- **Frostnip** is the mildest form of cold injury. It affects the toes, fingers, cheeks, nose, and earlobes, causing the skin to turn white. It can be prevented by wearing adequate warm clothing, and is treated by simple rewarming.
- **Frostbite** is a common injury caused by exposure to extreme cold, or contact with cold objects. It happens when tissue temperatures fall below freezing point. Blood circulation may cease in the affected areas, and blood vessels can be ruptured and irreparably damaged. In milder cases, the symptoms include a patchy inflammation of the skin, accompanied by slight pain. In more severe cases, there is often tissue damage without pain, or there could be blistering accompanied by a burning or prickling sensation. Frostbitten skin is susceptible to infection and gangrene.

In treating frostbite, it is important that the body is warmed slowly back to normal. Frostbitten limbs should first be immersed in cold water (10 -15°C), and the temperature increased by 5°C every 5 minutes to a maximum of 40°C. Recovery may take several days. Residual effects, such as pain, numbness, abnormal skin colour and cold feet, may continue for several more days.

- **Immersion foot or trenchfoot** occurs in individuals whose feet have been wet and cold for extended periods of time (days or weeks), but not frozen. Injury occurs to nerve and muscle tissue. The symptoms are numbness, swelling, and in some cases superficial gangrene. Medical treatment of the affected areas is required.

The Effects of Cold on the Body's Core

In moderately cold environments, the body's core temperature does not usually fall by more than 1°C below its normal level of about 37°C. However, in extremely cold environments, without proper protective clothing, the body's normal thermal regulatory mechanisms are not able to maintain this core temperature. A worker's core temperature should never be allowed to fall below 36°C (rectal), or 35.5°C (oral).

Often the first signs of this are a sensation of cold, followed by pain in exposed parts of the body. Because water is a much better conductor of heat than air, both to and from the body, the most dangerous situations occur when the body is immersed in cold water.

As the exposure time increases, or the temperature continues to drop, increasing numbness develops, and the sense of pain decreases. The next symptoms to develop are weakness and drowsiness, which usually occur when the core temperature drops

below 33°C. This condition is called “hypothermia”. Additional symptoms of hypothermia include a cessation of shivering, diminished consciousness and dilated pupils. When the temperature reaches approximately 26-27°C, unconsciousness occurs.

Table 5 (over page) illustrates the symptoms associated with exposure to cold.

Factors
Affecting
Sensitivity to
Cold

It has been found, that apart from the normal variability found between individuals, there are other factors that affect the response to cold stress:

Sex The rate of cooling of the torso is slower in women, but that of the extremities is faster. In general, women have less capacity for metabolic heat production, by either exercise or shivering. Therefore, women should be regarded as being at a greater risk of cold injury.

Other factors A number of other factors have been found to worsen the risk of cold injury. These include:

- Increasing age;
- Circulatory diseases;
- Fatigue;
- Certain drugs;
- Alcohol;
- Smoking;
- Raynaud’s disease;

Table 5: Progressive Clinical Presentation of Hypothermia

Core Temperature (°C)	Clinical Symptom
37.5	Normal core (rectal) temperature.
37	Normal oral temperature.
36	Metabolic rate increases in an attempt to compensate for heat loss.
35	Maximum shivering.
34	Victim conscious and responsive, with normal blood pressure.
33	Severe hypothermia below this temperature.
31-32	Consciousness clouded, blood pressure becomes difficult to obtain, pupils dilated.
30-29	Progressive loss of consciousness, muscular rigidity increases, pulse and blood pressure difficult to obtain, respiratory rate decreases.
28	Ventricular fibrillation possible with myocardial irritability.
27	Voluntary motion ceases, pupils non-reactive to light, deep tendon and superficial reflexes absent.
26	Victim seldom conscious.
25	Ventricular fibrillation may occur spontaneously.
24	Pulmonary oedema.
22-21	Maximum risk of ventricular fibrillation.
20	Cardiac standstill.
18	Lowest accidental hypothermia victim to recover.
17	Isoelectric electroencephalogram.
9	Lowest artificially cooled hypothermia patient to recover

Source: *American Family Physician*, January 1982

- Previous cold injury;
- Exposure to other workplace hazards.

Acclimatisation to Cold

The human body does not acclimatise well to cold conditions, though frequently exposed body parts can develop a degree of tolerance. For example, blood flow to the hands can be maintained in conditions that would otherwise result in a significant reduction in blood flow, extreme discomfort, and loss of dexterity in unacclimatised workers.

ASSESSMENT OF COLD ENVIRONMENTS

The three key factors affecting cold stress are:

- Temperature;
- Air movement;
- Physical activity.

Workplace Conditions Influencing Cold Stress

Air temperature is measured by an ordinary thermometer calibrated in °C.

Air movement is measured using an anemometer, either hot wire or vane, calibrated in m/sec. Wind speed is normally quoted in km/h (5 mph = 8 km/h).

Physical activity produces body heat from the metabolic process. This is expressed in kilocalories per hour (kcal/h). However, this is difficult to measure, although metabolic activity tables can be found in some text books.

Wind-Chill Temperature

At any temperature, a person will feel colder as air movement increases. The combined effect of air movement and temperature is called the “equivalent chill temperature” (ECT), or the “wind-chill temperature” (see Table 6).

The ECT is the air temperature that would produce the same cooling effect on exposed flesh as the given combination of air temperature and air movement. It is useful in determining the clothing requirements and potential health effects of cold. Table 7 indicates the level of hazard from different air temperatures and air speeds.

CONTROL OF WORK ENVIRONMENTS CAUSING COLD STRESS

There are a number of New Zealand working environments with the potential to produce cold stress — for example, work in refrigerated plant in the food processing industry, diving, or outdoor work in winter.

Control measures for cold stress are a reflection of those that can be used for heat stress. For example, planning work for times of the year or day when cold is not a problem, and looking at how to carry out tasks efficiently so that time in a cold environment is minimised.

Elimination of Cold

The key questions are:

- Can another way be found to carry out the work required without having the source of cold that is causing problems in the workplace?
- Can the work be scheduled for a period of time when cold will not be an issue?
- Can the work and environment be altered so that cold is no longer a problem?

Table 6: The Cooling Power of Air Movement on Exposed Flesh as Equivalent Temperature (Under Calm Conditions)

Ambient Air Temperature (°C)								
4	-1	-7	-12	-18	-23	-29	-34	-40

Wind Speed km/h	Equivalent Temperature in Still Air °C)								
0	4	-1	-7	-12	-18	-23	-29	-30	-40
8	3	-3	-9	-14	-21	-26	-32	-38	-44
16	-2	-9	-16	-23	-30	-35	-43	-50	-57
24	-6	-13	-20	-28	-36	-43	-50	-58	-65
32	-8	-16	-23	-32	-39	-47	-55	-63	-71
40	-9	-18	-26	-34	-42	-51	-59	-67	-76
48	-10	-19	-27	-36	-44	-53	-62	-70	-78
56	-11	-20	-29	-37	-46	-55	-63	-72	-81
64	-12	-21	-29	-38	-47	-56	-65	-73	-82
(Wind speeds greater than 64 km/h have little additional effect)	LITTLE DANGER In <1 hr with dry skin. Maximum danger of false sense of security.			INCREASING DANGER Danger from freezing of exposed flesh within 1 minute			GREAT DANGER		
	Ensure dry clothing worn			Continuous work not permitted					

Table 7: Work/Warm-up Schedule for a 4-hour Shift and Moderate to Heavy Work Activity

Air Temperature (°C) - Sunny Sky	No noticeable wind		8 km/h wind (1.6 m/sec)		16 km/h wind (3.2 m/sec)		24 km/h wind (4.8 m/sec)		32 km/h wind (6.4 m/sec)		
	Max. Work Period (mins)	No of Breaks	Max. Work Period (mins)	No of Breaks	Max. Work Period (mins)	No of Breaks	Max. Work Period (mins)	No of Breaks	Max. Work Period (mins)	No of Breaks	
-26 to -28	Normal	1	Normal	1	75	2	55	3	40	4	
-29 to -31	Normal	1	75	2	55	3	40	4	30	5	
-32 to -34	75	2	55	3	40	4	30	5	emergency work only		
-35 to -37	55	3	40	4	30	5	emergency work only				
-38 to -39	40	4	30	5	emergency work only						
-40 to -42	30	5	emergency work only								
-43 and below	emergency work only										

NOTES This schedule applies to any 4-hour work period with moderate to heavy work activity, and with warm-up breaks of 10 minutes and an extended lunch break, all in a warm location. For light to moderate work (little physical movement), apply the schedule one step lower. For example, if the recommended maximum work period is 40 minutes on the above chart, for light work

If no means of measuring air movement is available, in an outside location the approximate air speed can be determined from the following:

Light flag movement	8 km/h
Flag fully extended	16 km/h
Raises sheets of newspaper	24 km/h
Blows drifting snow	32 km/h

Isolation of
Workers from
Cold

The key questions are:

- Can a cold process be enclosed so that workers are protected?
- Can an enclosure or screen be provided for workers in a cold area so they are protected?
- Can a cold process be mechanised so that workers do not need to go near it except for setup and maintenance?

Minimisation of
Risk for those
Working in Cold
Environments

Outdoor Workers in Cold Environments

The New Zealand Mountain Safety Council Incorporated has published a booklet called *Hypothermia* (Mountain Safety Manual No.24). This booklet is of particular use to people who work for extended periods outdoors in cold conditions, in remote areas, for example in adventure tourism, forestry, farming, hunting, trapping or pest destruction.

Prevention of Adverse Health Effects

For continuous work in temperatures $0^{\circ}\text{C}_{\text{ECT}}$, heated warming shelters, such as cabins and rest rooms, should be provided. The level of activity should not be great enough to produce excessive sweating. If excessive sweating is likely to occur, or it involves working in the wet, facilities should be available for changing, or for drying clothes and footwear.

The risk of cold injury can be minimised by the provision of properly designed work environment, equipment, protective clothing, and safe work practices.

Work environment The cooling effects of air movement should be reduced by the provision of effective shielding in the work area.

Equipment design In cold working environments, metal handles and bars should be covered with thermal insulating materials. In addition, tools and equipment should be designed so that they can be operated without having to remove gloves.

Clothing Protective clothing should be worn in all environments where work takes place at temperatures below $4^{\circ}\text{C}_{\text{ECT}}$. Clothing must be selected to suit the temperature, nature of the work carried out, and the level of activity. Clothing with multiple layers is better than a single thick layer, as air trapped between the layers forms a good insulating barrier. In wet conditions, the outer layers of clothing should be water repellent. In working conditions that cannot be shielded from windy conditions, clothing should be designed to prevent wind penetration.

Clothing should always be kept clean to prevent air spaces, which increase insulation, from becoming clogged.

Hand protection If fine work needs to be performed with bare hands for greater than 10-20 minutes at temperatures below 16°C , special precautions need to be taken to keep hands warm, for example, providing warm air blowers, and insulated handles on tools.

If fine manual dexterity is not required, gloves should be worn for:

- Sedentary work $< +10^{\circ}\text{C}$
- Light work $< +4^{\circ}\text{C}$
- Moderate work $< -7^{\circ}\text{C}$

Where the temperature is below -17°C , mittens should be worn.

Footwear Felt-lined, rubber-bottomed, leather-topped boots with removable thermal insoles are best suited for work in cold environments.

Head covering A head covering, such as a woollen cap or a hard hat with a thermal liner, should be worn in cold environments, as over 50% of heat loss is through the head.

Safe Work Practices

- Do not allow bare skin to come into contact with cold surfaces below -7°C , especially surfaces made of materials that are good conductors of heat, e.g. metals.
- Do not allow bare skin to come into contact with evaporative liquids, e.g. petrol, cleaning fluids, alcohol.
- Do not remain stationary for prolonged periods of time.
- Do not consume alcohol.
- For warming purposes, supply hot non-alcoholic drink. Caffeine consumption should be limited as it increases urine production and blood circulation, both increasing the loss of heat from the body.
- Tobacco consumption should also be restricted.
- Consume adequate amounts of food and eat frequently.
- Drink plenty of water to prevent dehydration.
- In refrigerated rooms, keep the air speed below 1 m/sec where possible.
- All work in cold conditions should be under constant observation (through a buddy system or supervision).
- New employees and workers should not be required to work full-time in the cold until they have become accustomed to the working conditions and the personal protective clothing they need to wear.

- Apply lip balm and moisturising lotions to prevent lesions.
- Maintain a high level of physical fitness.

If a worker cannot be adequately protected from the effects of cold, then work must be suspended, or work regimes modified, to remove the risk of harm.

Monitoring

- A suitable thermometer should be in use in every workplace where the atmospheric temperature may drop below 16°C, to monitor any further temperature changes.
- In workplaces where the temperature is below freezing (0°C_{ECT}), and/or the speed of air movement is greater than 2 m/sec, the temperature should be monitored at least every 4 hours.

Emergency Procedures

In every workplace where workers are likely to be exposed to cold working conditions, the emergency procedures must include provisions for dealing with cold-related emergencies. For example, procedures should exist that ensure that an adequate first aid response is available within the workplace.

Pre-employment Screening

Subject to Human Rights and Privacy Act provisions, all workers likely to be routinely exposed to cold working conditions should be medically examined to confirm their ability to carry out such work without risk of harm.

The questionnaire in Appendix E can be adapted by a medical practitioner for people working in cold. Medical examination will be similar to that outlined for heat in Section 3 of this guideline.

5 Training and Supervision

CONTENT OF TRAINING

People who work in hot or cold environments, or who supervise that work, should be adequately trained to avoid heat or cold strain and associated conditions.

Training should include information about:

- The hazards they are exposed to;
- Recognition of the symptoms of heat or cold strain or injury in both themselves and others;
- Any systems or control measures put in place by the employer;
- What they as individuals need to do to protect themselves from the hazard;
- Measurement of environmental conditions;
- The correct type of personal protection to be worn;
- Physical fitness and other personal factors;
- Emergency procedures that must be followed.

Employees and contractors who have not been fully trained must be supervised by someone who has been trained.

6 Planning for Hot and Cold Environments

AREAS TO CONSIDER Entry into extremely hot or cold environments should be planned for. This is especially necessary if entry occurs infrequently.

Planning for this type of work will need to address four main areas. These are:

- The environment people are required to work in;
- The people who will do the work;
- Special equipment or protective equipment required; and
- Support systems.

The Environment

- Has the thermal environment been measured to determine its impact on people?
- Is there a plan to modify the environment so that work can be carried out with less thermal stress?
- Are there other hazards to consider in addition to thermal stress?
- Are there adequate lockout procedures where necessary?

The People

- Are the people employed to do the work physically fit?
- Are they adequately trained both in the hazard and its effects on themselves and others?
- Are they trained for any other hazards in the work?

Equipment and Consumables

- Is monitoring equipment required?
- Is it still working?
- Is it within current calibration?
- Is special equipment necessary for altering the environment?
- What protective clothing and equipment is required?
- Is previously used equipment in good condition?
- Have drinks or food been catered for?

Support

- What first aid and medical staff are required?
- Are adequate emergency medical procedures in place?

7 Hot and Cold Environments and Other Hazardous Operations

OTHER HAZARDOUS SITUATIONS

The thermal environment may be only one of the hazards a person will be exposed to. Options for control of thermal hazards may need to be different for situations where other hazards exist. Examples include:

- Entry into confined spaces;
- Exposure to chemical contaminants;
- Occupational diving.

CONFINED SPACE ENTRY

The primary confined space hazards include:

- An oxygen-deficient atmosphere;
- Restricted access and escape;
- Limited movement;
- Close proximity to hot or cold surfaces; and
- The increased potential for a buildup of atmospheric contaminants from welding or other processes.

These may mean that protective clothing options need to be considered sooner than would normally be the case.

For more information on confined space entry, refer to AS 2865 1995: *Safe working in a confined space*.

EXPOSURE TO
CHEMICAL
CONTAMINANTS

Often the work required in hot or cold areas will create atmospheric contaminants such as welding fumes, or solvent vapours. Points to watch out for include:

- Whether exposure to substances will amplify the effects of heat or cold stress;
- Whether protective clothing such as respirators will cause added fatigue to a person;
- Whether a health and safety control measure will interfere with a work process, e.g. increased ventilation to control heat stress may not be feasible because it blows away welding shielding gases.

OCCUPATIONAL
DIVING

Diving in cold water, or where surface conditions are cold, will increase the risk of harm from both cold stress and decompression sickness.

For more information, refer to the OSH Guidelines on Diving (in preparation).

Appendix A: Summary of the Health and Safety in Employment Act 1992

OBJECT OF THE ACT

The principal object of the Health and Safety in Employment Act 1992 is to prevent harm to employees at work. To do this, it imposes duties on employers, employees, principals and others, and promotes excellent health and safety management by employers. It also provides for the making of regulations and codes of practice.

EMPLOYERS' DUTIES

Employers have the most duties to perform to ensure the health and safety of employees at work. Employers have a general duty to take all practicable steps to ensure the safety of employees. In particular, they are required to take all practicable steps to:

- Provide and maintain a safe working environment;
- Provide and maintain facilities for the safety and health of employees at work;
- Ensure that machinery and equipment is safe for employees;
- Ensure that working arrangements are not hazardous to employees; and
- Provide procedures to deal with emergencies that may arise while employees are at work.

Taking “all practicable steps” means what is reasonably able to be done to achieve the result in the circumstances, taking into account:

- The severity of any injury or harm to health that may occur;
- The degree of risk or probability of that injury or harm occurring;
- How much is known about the hazard and the ways of eliminating, reducing or controlling it; and
- The availability, effectiveness and cost of the possible safeguards.

HAZARD MANAGEMENT

Employers must have an effective method to identify and regularly review hazards in the place of work (existing, new and potential). They must determine whether the identified hazards are *significant* hazards and require further action.

If an accident or harm occurs that requires particulars to be recorded, employers are required to investigate it to determine if it was caused by, or arose from, a significant hazard.

“Significant hazard” means a hazard that is an actual or potential cause or source of:

- Serious harm; or
- Harm (being more than trivial) where the severity of effects on a person depends (entirely or among other things) on the extent or frequency of the person’s exposure to the hazard; or
- Harm that does not usually occur, or usually is not easily detectable, until a significant time after exposure to the hazard.

Where the hazard is significant, the HSE Act sets out the steps employers must take:

- Where practicable, the hazard must be eliminated.
- If elimination is not practicable, the hazard must be isolated.
- If it is impracticable to eliminate or isolate the hazard, the employer must minimise the likelihood that employees will be harmed by the hazard.

Where the hazard has not been eliminated or isolated, employers must:

- Ensure that protective equipment is provided, accessible and used;
- Monitor employees' exposure to the hazard;
- Seek the consent of employees to monitor their health; and
- With their informed consent, monitor employees' health.

INFORMATION FOR EMPLOYEES

Before employees begin work, they must be informed by their employer of:

- Hazards employees may be exposed to while at work;
- Hazards employees may create which could harm people;
- How to minimise the likelihood of these hazards becoming a source of harm to themselves and others;
- The location of safety equipment; and
- Emergency procedures.

Employees should be provided with the results of any health and safety monitoring. In doing so, the privacy of individual employees must be protected.

EMPLOYERS TO INVOLVE EMPLOYEES

Employers need to ensure that all employees have the opportunity to be fully involved in the development of procedures for the purpose of identifying and controlling significant hazards, or dealing with or reacting to emergencies and imminent dangers.

TRAINING OF EMPLOYEES

Employers must ensure employees are either sufficiently experienced to do their work safely or are supervised by an experienced person. In addition, employees must be adequately trained in the safe use of all plant, substances and protective clothing and protective equipment that the employee may be required to use or handle.

SAFETY OF PEOPLE WHO ARE NOT EMPLOYEES

Employers also have a general duty towards persons who are not employees.

Employers must take all practicable steps to ensure that employees do not harm any other person while at work, including members of the public or visitors to the place of work.

EMPLOYEES' AND SELF-EMPLOYED PERSONS' DUTIES

Employees and self-employed persons have a responsibility for their own health and safety while at work. They must also ensure that their own actions do not harm anyone else.

However, these responsibilities do not detract from the employer's responsibilities.

ACCIDENTS
AND SERIOUS
HARM
(RECORDING
AND
NOTIFICATION)

The HSE Act requires employers to keep a register of work-related accidents and serious harm. This includes every accident that harmed (or might have harmed):

- Any employee at work;
- Any person in a place of work under the employer's control.

Employers are also required to investigate all accidents and near-misses to determine whether they were caused by or arose from a significant hazard. Employers are required to notify serious harm that occurs to employees while at work to the Secretary of Labour (in practice, the nearest OSH office), as soon as possible. In addition, the circumstances of the accident must also be notified in the form prescribed within 7 days. (Suitable forms for notification are available from OSH offices and selected stationers.)

If a person suffers serious harm, the scene of the accident must not be disturbed unless to:

- Save life or prevent suffering;
- Maintain public access for essential services, e.g. electricity, gas;
- Prevent serious damage or loss of property.

The OSH office will advise whether it wishes to investigate the accident and what action may be taken in the meantime.

Appendix B: Glossary of Terms Used

Acclimatisation is best described as the processes (physiological changes) by which a person adapts themselves to be able to safely and comfortably work in an environment of temperature extremes.

Cold strain refers to the short- or long-term consequences of exposure to cold stress on a person's mind and body.

Cold stress is the sum of environmental cold and metabolic heat and the effects this can have on a person. It can lead to an imbalance between an individual's heat gain and heat loss.

Core body temperature is the temperature found in the brain, the heart and the abdominal organs. It changes very little from 37°C, and is vital for the normal functioning of these organs.

Fatigue refers to general fatigue rather than muscular fatigue. It is easiest described as a state of extreme tiredness. There is increased discomfort and decreased efficiency, with a loss of power or capacity to respond to stimulation. There is a decreased desire for physical or mental effort.

Heat strain refers to the short- or long-term consequences of exposure to environmental heat stress on a person's mind and body.

Heat stress is the *net heat load* on the body with contributions from both metabolic heat production, and external environmental factors including temperature, relative humidity, radiant heat transfer, and air movement, as they are affected by clothing.

Heat Stress and Cold Stress Indices are methods of combining physical measurements into a table (index), in most cases producing one figure, which can then be compared to a standard, to give an estimation of the potential for heat or cold strain to occur.

Heat stroke is an extreme state of heat strain and occurs when the core body temperature reaches very high levels of 41°C or above. This can very quickly be fatal if immediate and appropriate treatment is not given.

Hypothermia is an extreme state of cold stress. It is a condition of low core temperature and is clinically defined as a deep body temperature below 35°C.

Metabolic heat is the heat created within the body. It is formed when food is converted, by chemical reaction, into mechanical energy (muscle contraction) and heat.

Prickly heat is a skin rash, occurring in skin saturated with sweat. Secondary infection can occur if prompt action is not taken.

Thermal comfort is achieved when a person is not conscious of being either too hot or too cold, and is very subjective.

Thermal discomfort is a state where a person is very conscious of being either too hot or too cold, but where no harm is suffered from the thermal environment. It is very subjective.

WBGT Index: Wet Bulb Globe Temperature is the most widely accepted index used and forms the basis of many standards. This can be explained as a temperature reading that takes into account the parameters of air temperature, humidity, radiant heat and air speed.

Appendix C: Medical Conditions and Substances that Increase the Individual's Susceptibility to Heat or Cold Strain

Medical Conditions that Increase Susceptibility to Heat or Cold Strain

Medical conditions that can make individuals more susceptible to heat strain	Medical conditions that can make individuals more susceptible to cold strain
Cardiac disease High blood pressure Respiratory disease Diabetes Skin diseases and rashes	Cardiac disease High blood pressure Respiratory disease Diabetes Raynaud's disease

Substances that Increase Susceptibility to Heat or Cold Strain

Substances that can make individuals more susceptible to heat strain	Substances that can make individuals more susceptible to cold strain
Alcohol Antidepressants (e.g. tricyclics) Hypnotics (e.g. barbiturates) Psychotropics (e.g. phenothiazines) Cannabis Morphine Amphetamines Anaesthetics Cocaine Anticholinergics (e.g. atropine)	Alcohol Antidepressants Tranquilisers (e.g. benzodiazepines) Hypnotics Psychotropics (e.g. phenothiazines) Cannabis Morphine Anaesthetics Hypoglycaemics (e.g. biguanides) Antithyroids (e.g. carbimazole) Sympathetic and ganglion-blocking agents (e.g. reserpine) Organophosphates Insulin

Appendix D: Symptoms of Heat Strain

	Early Symptoms	Mild Heat Strain	Severe Heat Strain
Muscle cramps	Yes, can be severe, usually in legs and abdomen	Yes, can be severe usually in legs and abdomen	Yes (maybe with convulsions or muscular twitching)
Breathing	Varies	Rapid	Deep breathing initially but progressing to shallow breathing
Pulse	Varies	Shallow	Rapid weak pulse
Weakness	Yes	Can be total body	Yes (severe)
Skin	Moist warm or no change Prickly heat	Cold to hot clammy	Dry and hot
Perspiration	Heavy	Heavy	Little or none
Level of consciousness	Reduced performance Sometimes dizziness or faintness	Headaches Dizziness leading to fainting	Confusion Loss of strength Unconsciousness, dilated pupils, possible coma and death

This table is included as a training tool for employers. Any person who supervises work in a hot environment, or works in a hot environment, should be able to recognise the symptoms of heat strain both in themselves and others.

Please note that heat strain does not occur in the neat and tidy fashion as is portrayed in this table. It is possible to display symptoms of mild heat strain in one area, while displaying symptoms of severe heat strain in another.

Appendix E: Screening Questionnaire Prior to Heat Exposure

To be completed by a Physician or Occupational Health Nurse Only

IN CONFIDENCE

1 Name:

Date of birth:

Sex: Male / Female

Present occupation:

For how long?

Years

2 (a) Have you ever been affected by hot conditions, making you think that you have a low tolerance to heat?

Yes No

(b) If "Yes", please state what happened and describe the circumstances and treatment (if any):

(c) Has this or anything similar ever happened before or since?

Yes No

3 Have you ever experienced attacks of loss of consciousness, fits or faints?

Yes No

4 Do you suffer from diabetes or any other medical condition which you think may be affected by the heat?

Yes No

5 Do you suffer from heart disease or high blood pressure?

Yes No

6 Do you suffer from any chest disease, e.g. asthma, emphysema?
If yes, please specify:

Yes No

7 Do you suffer from any skin disease, e.g. eczema, dermatitis?
If yes, please specify:

Yes No

- 8 Have you had any treatment which reduces your ability to sweat, e.g. scarring from burns? Yes No
- 9 Are you on any medication, either prescribed by your doctor or bought over the counter at a pharmacy? (Some medications affect tolerance to heat)
If yes, please specify: Yes No
- 10 In this last week have you had any of the following? If yes, please tick:
Infection Fever Diarrhoea Vomiting Immunisation Yes No
- 11 Are you on a salt-free or salt-reduced diet? Yes No
- 12 Do you get little or no physical exercise? Yes No
- 13 Do you drink alcohol?
If yes, please specify how many units per week: Units
(1 unit = 0.5 litre beer, single spirit, glass of wine) Yes No
- 14 Do you smoke tobacco? Yes No

If the answer to any of these questions is in the left hand (shaded) of the "Yes/No" columns, refer to a physician for advice.

RECORDINGS:	
Date:	Time:
Blood pressure:	Weight:
Pulse:	Height:
Temperature:	

Appendix F: WBGT Surveillance Form

Name:

Date:

Task:

Time	Dry Bulb	Wet Bulb	Globe Bulb	WBGT Indoor	WBGT Outdoor	Comments/Activity

Appendix G: Documentation of New Zealand Workplace Exposure Standards for Hot Environments

NOTE This is the documentation from the 1994 *Workplace Exposure Standards for New Zealand* (WES) booklet, published by the Occupational Safety and Health Service of the Department of Labour. This is based on ISO 7234. Modifications to ISO 7234 that appeared in the 1994 WES booklet are given in italics. More recent information is commented on at the end.

INTRODUCTION This workplace exposure standard covers the measurement of heat stress, and the management of hot environments to which workers may be exposed. Compliance with this standard should prevent heat stress and provide for conditions under which, it is believed, that nearly all workers may be repeatedly exposed without adverse health effects.

The term heat stress refers to the adverse effects on the human body that occur when it is not able to dissipate sufficient heat — heat that originates either as a result of exposure to sources of heat in the external environment, or is generated internally by metabolic activity. The result of this inability to lose sufficient heat causes the body's core temperature, normally at 37-38°C, to begin to rise. Such a rise in core temperature can result in serious harm, and may even be fatal.

Workers should not be permitted to continue their work where their core body temperature exceeds 38°C.

These standards are based on the assumption that nearly all acclimatised, fully clothed workers (e.g. wearing lightweight shirt and trousers [= 0.6 Clo]), with adequate water intake, should be able to function effectively under a given working condition without exceeding the normal core body temperature of between 37-38°C.

HEAT STRESS MEASUREMENT

As in most cases, it is not practical to measure core body temperature directly as an indication of workers' heat balance. The method described here is a predictive, empirical index based on the measurement of environmental factors, i.e. wet bulb globe temperature (WBGT). This index is easy to determine and well-suited to the occupational environment. The specific method followed is that described in International Standard ISO 7243 *Hot Environments: Estimation of the heat stress on working man, based on the WBGT index*. This standard has been endorsed by Standards New Zealand for use in this country, and is the method adopted, with minor modifications (indicated by italics), in this workplace exposure standard.

This workplace exposure standard requires the estimation of work effort, the insulatory effects of clothing and the measurement of WBGT, with corrections where required for variability in:

- (a) heat loading to different parts of the body;
- (b) exposure time to hot environments;
- (c) working in various locations with different thermal environments.

The WBGT index is derived from the measurement of three environmental factors: wet bulb temperature, globe temperature, and if measurement is taking place outside in direct sunlight, then also the natural dry bulb temperature.

The two equations shown below are those used to calculate the WBGT from these three parameters.

$$\text{WBGT} = 0.7t_{\text{nw}} + 0.3t_{\text{g}}$$

$$\text{or WBGT} = 0.7t_{\text{nw}} + 0.2t_{\text{g}} + 0.1t_{\text{a}} \quad (\text{in direct sunlight})^1$$

where t_{nw} = natural wet bulb temperature^{°C},

t_{g} = standard globe temperature^{°C},

t_{a} = dry bulb air temperature^{°C}.

Each of the three environmental temperatures measured requires the use of a separate measurement device: a black bulb globe thermometer, a natural (static) wet bulb thermometer, and a dry bulb thermometer. Detailed specifications for the construction and operational parameters of each are given in ISO 7243. In brief, the specifications of the three devices should be as follows:

Wet bulb temperature: measuring range 5 - 40^{°C} with an accuracy of $\pm 0.5^{\circ}\text{C}$.

This is the natural wet bulb temperature and is different from the thermodynamic temperature determined with a sling psychrometer.

Globe temperature: measuring range 20 -120^{°C} with an accuracy of $\pm 0.5^{\circ}\text{C}$

This should be a 150 mm sphere with the temperature sensor placed at the globe centre. For the purposes of this standard, a smaller 50 mm globe will be accepted.

Dry bulb temperature: measuring range 10 - 60^{°C} with an accuracy of $\pm 1.0^{\circ}\text{C}$.

The sensor must be protected from radiant heat sources.

¹See notes on update to heat stress standards at the end of this section.

The temperature sensors can be of traditional construction utilising glass thermometers, or, as is now more usual, electronic sensors that automatically integrate the separate readings to produce a WBGT result automatically.

CORRECTING
OF WBGT FOR
VARIATIONS IN
HEAT LOADING
TO PARTS OF
THE BODY

Where heat loading is fairly consistent over the whole body, then only one set of WBGT measurements need to be taken, and this should be at the level of the abdomen, which will vary according to the posture of the worker. In industry, the source of heat that a worker may be exposed to frequently originates from a particular point and affects just a portion of the body, rather than the load being evenly spread over the whole body. ISO 7243 recommends that under such circumstances, three transducers should be used concurrently to measure the WBGT-index. *However, for the purposes of this workplace exposure standard, and as most WBGT arrays consist of a single set of transducers, consecutive readings at each of the following positions are also acceptable, as long as exposure is reasonably constant.* Measurements should be obtained at the level of the head, abdomen and ankle. The recommended height above floor level for the siting of the transducers is given in the following table:

Recommended Heights of Transducer Above Ground

	<i>Standing Person</i>	<i>Seated Person</i>
Ankle level	0.1m	0.1m
Abdomen level	1.1m	0.6m
Head level	1.7m	1.1m

The three individual WBGTs produced for each height are then combined to produce a weighted index for whole body exposure from the following equation:

$$\text{WBGT}_{(\text{whole body weighted})} = \frac{\text{WBGT}_{(\text{head})} + 2\text{WBGT}_{(\text{abdomen})} + \text{WBGT}_{(\text{feet})}}{4}$$

When positioning the transducers, it is important that their exposure to heat should be the same as that experienced by the worker. Care should therefore be taken to ensure that:

- (a) The transducers are as close as possible to the work station under investigation.
- (b) The transducers are not placed so as to screen them from radiant heat sources.
- (c) The sample period is representative of normal working conditions.

To ensure compliance with point (c), the ISO recommends that the WBGT should always be given as a time-weighted average, with a minimum sampling period of 1 hour. This applies whether readings are obtained from one or more transducer sets.

CORRECTION OF
WBGT FOR
VARIATIONS IN
EXPOSURE TIME
AND LOCATION

When a worker's exposure to heat is spasmodic, occurs at a number of locations, or consists of exposure to variable heat loading, it is necessary to measure the WBGT level and exposure time for each. The separate measurements are then combined using the following equation:

$$\text{WBGT}_{(\text{time/location weighted})} = \frac{(t_1 \times \text{WBGT}_1) + (t_2 \times \text{WBGT}_2) \dots (t_n \times \text{WBGT}_n)}{t_1 + t_2 + \dots t_n}$$

where $WBG T_n$ = WBG T determined for situation n
 t_n = time in minutes at situation n = 1 hour

The WBG T(time/location-weighted) averages the WBG T for variations in work duration and location. Taken with any corrections required for variations in body loading, an overall corrected measurement of WBG T is calculated. To enable an interpretation of the WBG T value to be made, the figures need to be interpreted to predict the likelihood of heat strain occurring.

To assess the probability of such an occurrence, we also need to know the amount of physical effort the worker puts into that particular job. The more physically demanding the job, then the greater the amount of internally generated metabolic heat there will be, and the lower the WBG T (the measure of external heat loading) at which heat stress could possibly occur. ISO 7243 adopts a simple method that breaks down work type into four categories, one of which needs to be selected that corresponds to the type of work under investigation (see table next page).

Few workers are exposed to the same level of heat throughout the working day. Most workers are involved in a variety of tasks, only some of which involve heat exposure. Using ISO 7243 it is therefore necessary to calculate the metabolic rate in Wm^2 from the above table for each of the tasks the worker carries out, and to find the time-weighted average for the period using the formula:

$$MR_{(time-weighted)} = \frac{(t_1 \times MR_1) + (t_2 \times MR_2) \dots (t_n \times MR_n)}{t_1 + t_2 + \dots + t_n}$$

Classification of Levels of Metabolic Rate

Class	Metabolic Rate Range M		Value to be Used for Calculation of Mean Metabolic Rate		Examples
	Related to a Unit Skin Surface Area Wm ²	For A Mean Skin Surface Area of 1.8m ² W	Wm ²	W	
0 Resting	M < 65	M < 117	65	117	Resting
1 Low metabolic rate	65 < M < 130	117 < M < 234	100	180	Sitting at ease: light manual work (writing, drawing, sewing, book keeping, hand and arm and leg work (driving vehicle in normal conditions, operating foot switch or pedal). Standing: drill (small parts); milling machine (small parts; coil winding; small armature winding; machining with low-power tools; casual walking (speed up to 3.5 k/h).
2 Moderate metabolic rate	130 < M < 200	234 < M < 360	165	297	Sustained hand and arm work (hammering in nails, filing); arm and leg work (off-road operation of lorries, tractors or construction equipment); arm and trunk work (work with pneumatic hammer, tractor assembly; plastering, intermittent handling of moderately heavy material, weeding, hoeing, picking fruit or vegetables); pushing or pulling light-weight carts or wheel barrows; walking at a speed of 3.5 to 5.5 km/h; forging.
3 High metabolic rate	200 < M < 260	360 < M < 468	230	414	Intense arm and trunk work: carrying heavy material; shovelling, sledge hammer work; sawing, planing or chiselling hard wood; hand mowing; digging; walking at a speed of 5.5 to 7km/h. Pushing or pulling heavily loaded hand carts or wheel barrows; chipping castings; concrete block laying.
4 Very high metabolic rate	M > 260	M > 468	290	522	Very intense activity at fast to maximum pace ; working with an axe; intense digging or shovelling; climbing stairs, ramp or ladder; walking quickly with small steps; running or walking at a speed greater than 7km/h.

where MR_n = metabolic rate determined for situation n [W/m²]

t_n = time in minutes at situation n

From this time-weighted average, the corresponding classification 1-4 of work activity is then chosen. The following is an example of how this calculation of the time-weighted metabolic rate is worked out.

EXAMPLE A person acclimatised to heat works according to the following schedule:

<i>Time</i>	<i>Metabolic Rate</i>	<i>WBGT</i>
20 mins	230 W/m ²	28°C
30 mins	165 W/m ²	28°C
10 mins	65 W/m ²	28°C

The time-weighted average of the metabolic rate is then:

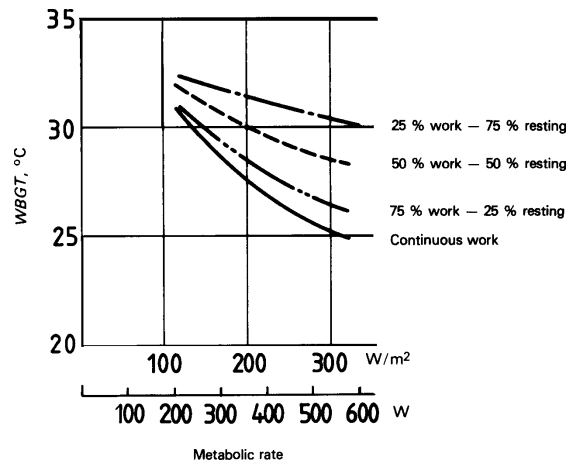
$$MR_{\text{(time weighted)}} = \frac{(20 \times 230) + (30 \times 165) + (10 \times 65)}{20 + 30 + 10} = 170 \text{ Wm}^2$$

From the previous table, 170 W/m² can be seen to correspond to a time weighted activity classification of 2 — moderate metabolic rate.

Having obtained WBGT readings adjusted for whole body exposure and work pattern, these figures can then be compared to the reference value sprinted in Annex A of ISO 7243 (see table below).

ISO 7243 Annex A: Reference Values of the WBGT Heat Stress Index

Metabolic Rate Class	Metabolic Rate M		Reference Value of WBGT			
	Related to a Unit Skin Surface Area	Total (for a Mean Skin Surface Area of 1.8m ²)	Person Acclimatised to Heat		Person Not Acclimatised to Heat	
	W/m	W	°C		°C	
0 (resting)	M < 65	M < 117	33		32	
1	65 < M < 130	117 < M < 234	30		29	
2	130 < M < 200	234 < M < 360	28		26	
3	200 < M < 260	360 < M < 468	No sensible air movement 25	Sensible air movement 26	No sensible air movement 22	Sensible air movement 23
4	M > 260	M > 468	23	25	18	20



ISO 7243, like many other heat stress standards, assumes that workers are healthy, physically fit for the level of activity being done, and wearing light clothing with an insulatory factor of 0.6 Clo. The reference levels described above are designed to give the maximum WBGT at which most such workers can safely work for prolonged periods, without giving rise to potentially dangerous increases of more than a 1°C in the core temperature.

It must be pointed out that the reference levels are not intended to ensure that all workers are protected, but that almost all are protected. Care must therefore be taken where conditions approach the reference level to ensure the suitability of staff expected to work under such conditions.

The standard does not take account of peak values of heat stress that might be experienced for short periods, either as a result of exposure to a particularly hot environment, or a sudden burst of activity.

Exceeding the reference limits does not necessarily indicate the inevitability of serious consequences, or that all work must immediately cease. It implies that precautions need to be taken when continuing the work. The easiest way to achieve this is to alter

the pattern of work/rest periods as described in Annex B of ISO 7243 (this does not form part of the official standard). (See figure above.)

These curves are included in the ISO for information only, to facilitate the reorganisation of work/rest cycles. Where the reference values previously described are exceeded, action should be taken wherever possible through engineering changes, or other means, to reduce the WBGT to which workers are exposed.

When heat exposure exceeds the limits of the described work/rest cycles then exposure to such environments must only take place where workers are under close medical supervision. Personal monitors that indicate changes are also available that can assist in such close medical supervision.

EFFECTS OF CLOTHING ON HEAT EXCHANGE

Clothing serves as a protective barrier between the environment and the human body. In many occupational settings, special clothing is worn to protect against hazardous chemical, physical or biological agents. Irrespective of whether heat is one of those agents that the clothing is designed to protect against, it will still alter the rate and amount of heat exchange between the skin and the external environment. In general, the thicker and/or the greater is the vapour impermeability of the garments worn, the greater is the interference with normal heat exchange. In any consideration of the potential likelihood of heat stress occurring, the type of clothing worn by workers must be included.

The overall insulatory effects of different types of clothing can be expressed as a thermal insulatory index, in units called Clo's (1 Clo = 0.155 m² WW). The reference values for WBGT given in ISO 7243 assume that clothing worn is of standard type (permeable to air and steam), having a thermal insulatory index value of 0.6 Clo. Where

the Clo value of the clothing worn differs from this standard, alterations must be made to the reference values adopted (see table below).

Suggested Correction Factors for Clothing (not part of ISO 7243)

<i>Clothing Type</i>	<i>Clo Value</i>	<i>WBGT Correction</i>
Summer work uniform	0.6	0
Cotton coveralls	1.0	-2
Winter work uniform	1.4	-4
Water barrier, permeable	1.2	-6

Changes to the use of WBGT Calculations by the American Conference of Government Industrial Hygienists (ACGIH) 1997

The 1997 update of the American Conference of Government Industrial Hygienists (ACGIH) changes the way in which the calculations for the WBGT are used. The “direct sunlight” calculation that includes a dry thermometer reading should be used wherever there is an infrared radiant heat source, such as direct sunlight or molten metal. The “indoor” calculation should be used when there is no radiant heat source. Therefore:

With an infrared radiant heat exposure (e.g. solar, molten metal, hot surfaces), the following calculation should be used:

$$\text{WBGT} = 0.7t_{\text{nw}} + 0.2t_{\text{g}} + 0.1 t_{\text{a}}$$

Without infrared radiant heat exposure, the other calculation should be used:

$$\text{WBGT} = 0.7t_{\text{nw}} + 0.3t_{\text{g}}$$

where

t_{nw} = natural wet bulb temperature^{°C},

t_{g} = standard globe temperature^{°C},

t_{a} = dry bulb air temperature^{°C}.

Appendix H: Personal Recordings

Name:

Task:

Date	Time	WBGT	Pulse	Temp (oral)	Weight Start	Weight Finish	Urinalysis cc	Urinalysis Sp.grav	Fluid Intake	Heart Rate	Protective Clothing	Activity

Appendix I: Heart Rate Result Sheet

Name:

Date:

Time	Rate	Time	Rate	Time	Rate

Appendix J: References

Part 1: International Standards Relating to Heat Stress and Heat Strain

<i>Number</i>	<i>Title</i>	<i>Purpose</i>
ISO 11399	<i>Ergonomics of the thermal environment: principles and application of relevant International Standards</i>	General presentation of the set of standards in terms of principles and application.
ISO/CD 13731	<i>Ergonomics of the thermal environment: Vocabulary</i>	Standardisation of quantities, symbols and units used in the standards.
ISO 7243	<i>Hot environments: Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature)</i>	Diagnostic method Thermal stress evaluation in hot environments
ISO 7933	<i>Hot environments: Analytical determination and interpretation of thermal stress using calculation of required sweat rate.</i>	Analytical method
ISO 7730	<i>Moderate thermal environments: Determination of the PMV and PPD indices and specification of the conditions for thermal comfort.</i>	Comfort evaluation
ISO/TR 11079 Technical Report	<i>Evaluation of cold environments: Determination of required clothing insulation (IREQ)</i>	Thermal stress evaluation in cold environments
ISO 8996	<i>Ergonomics: Determination of metabolic heat production</i>	Metabolic rate

<i>Number</i>	<i>Title</i>	<i>Purpose</i>
ISO 7726	<i>Thermal environments: Instruments and methods for measuring physical quantities</i>	Requirements for Data measuring instruments collection standards
ISO 9920	<i>Ergonomics of the thermal environment: Estimation of the thermal insulation and evaporation resistance of a clothing ensemble</i>	Clothing insulation
ISO 9886	<i>Evaluation of thermal strain by physiological measurements</i>	Evaluation of thermal strain using physiological measures
ISO 10551	<i>Assessment of the influence of the thermal environment using subjective judgement scales</i>	Subjective assessment of thermal comfort

Proposed International Standards (Not yet publicly available)

ISO/CD 12894	<i>Ergonomics of the thermal environment: Medical supervision of individuals exposed to extreme hot and cold environments</i>	Selection of an appropriate system of medical supervision for different types of thermal exposure.
ISO/NP 13732		Contact with hot, moderate and cold surfaces.
ISO/NP 14415		Comfort of the disabled
ISO/NP 14505		Vehicle environments
New work item agreed		Long-term assessment of environmental quality
New work item proposed		Design of work for cold environments

Part 2: Other Publications

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