Health and Safety Executive

Prevention of heat illness in mines

photo: Martyn Pitt

This guidance represents what is considered to be good practice by members of the Mining Industry Committee, and was prepared by their Occupational Health in Mines sub-committee.

Members of the Occupational Health in Mines committee:

Mr G Gilmour	Chairman, HM Inspectorate of Mines, HSE
Mr A Allsop	Union of Democratic Mineworkers
Mr D Flack	Federation of Independent Mines
Mr S Hunneyball	TES Bretby
Mr S Jobling	UK Coal Ltd
Mr J R Leeming	HM Inspectorate of Mines, HSE
Mr D Mark	Health and Safety Laboratory
Dr R M Quinlan	Business Healthcare Ltd
Mr G Robinson	Cleveland Potash Ltd
Dr A Scott	Senior Medical Inspector, HSE
Mr T Spurry	UK Coal Ltd
Mr R H G Young	BACM/TEAM
Mr R Shepherd	Secretary, HM Inspectorate of Mines, HSE

Foreword

This guidance provides useful and important information for mine management and mineworkers in deep hot mines that will help them avoid heat illness. I welcome and fully support the advice given and recommend it to all in the industry.

Dan Mitchell
HM Chief Inspector of Mines
Chairman, Mining Industry Committee

Introduction

The Mining Industry Committee (MIC) is aware of studies that point to the possibility that some mineworkers can be subjected to such high levels of heat (and humidity) that they may suffer from heat illness.

This guidance has been prepared to help employers and employees understand where this may occur in a mine, to recognise the symptoms and to ensure that any necessary control measures are understood and implemented.

Employers in mines should use this guidance to assess whether such effects could occur, and take the recommended remedial action. Employees should follow the best practice advice in the guidance to minimise their risk of heat illness.

This guidance is intended to raise awareness and promote improvements between employers in mines and their employees and safety representatives. The MIC will continue to review the situation.

Both management and the workforce must recognise that most workers in an adverse environment in a mine cannot take easy refuge from the conditions by opening a door and going outside, as in most other industries. The effects of heat illness must not be taken lightly, and steps must be taken to minimise the impact of the work environment, and to promote safe working practices within it.

Relevant legislation

- The Health and Safety at Work etc Act 1974
- The Mines and Quarries Act 1954
- The Management and Administration of Safety and Health at Mines Regulations 1993
- The Management of Health and Safety at Work Regulations 1999
- The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995
- The Workplace (Health, Safety and Welfare) Regulations 1992
- The Health and Safety (First Aid) Regulations 1981

Heat illness – the hazard

Working in high temperatures may not only cause heat illness and even death, but also loss of concentration leading to lowered productivity, and mistakes which can lead to accidents. Where humidity is relatively high, the hazard is increased. More heat strain is placed on a person as the Wet Bulb (WB) and Dry Bulb (DB) temperatures get closer. The absolute values of the temperatures are of less importance than the difference between them, as it is the relative humidity that causes the problem by inhibiting body cooling by the evaporation of sweat. For example, 28 ^{o}C WB/45 ^{o}C DB causes less heat strain than 32 ^{o}C WB/36 ^{o}C DB.

If the WB temperature rises above 32 ^{o}C, however, then substantial extra control measures should be implemented. The figure of 32 ^{o}C is derived from guidance published by the Institute of Occupational Medicine which recommends additional control measures above an effective temperature (explained later in this document) of 30 ^{o}C.

Signs and symptoms of heat illness

During work in hot conditions, the human thermo-regulatory system tries to maintain the body core temperature at 37 ^{o}C. It does this by increasing blood flow to the skin to carry heat away from the core, and by causing sweating, the evaporation of which cools the skin and hence the blood.

If this control is lost and the core temperature begins to rise, various physiological effects progressively result.

Initial symptoms

These are:

- loss of interest in the task;
- difficulty in remaining alert; and
- the desire to seek more comfortable surroundings. Suppression of this desire may result in irritability.

These initial symptoms progress to a loss of co-ordination and dexterity, presenting significant safety and productivity implications.

Heat rash

Also known as prickly heat, heat rash is caused by unrelieved periods of constant perspiration, producing inflammation and blockage of the sweat ducts. This can result in areas of tiny red blisters, causing irritation and soreness. Heat rash can cause secondary problems with infections of the skin and is an indication of adverse conditions that may potentially cause heat stroke.

Heat syncope (fainting)

Heat syncope occurs when blood pools in the lower parts of the body, causing a temporary reduction in blood supply to the brain and hence a short-term loss of consciousness.

Heat exhaustion

Heat exhaustion results from the failure of the blood flow to adequately remove heat. A decrease in blood volume may result from dehydration caused by an inadequate intake of fluids. Alternatively, if a combination of environmental heat stress and work rate causes an excessively fast heartbeat, then the time interval between successive contractions of the heart muscles may be insufficient to maintain an adequate supply to the heart and, as a consequence, the rate of blood flow will drop. Core body temperature may rise to 39 ^{o}C.

The symptoms of heat exhaustion are:

- tiredness, thirstiness, dizziness;
- numbness or tingling in fingers and toes;
- breathlessness, palpitations, low blood pressure;
- blurred vision, headache, nausea and fainting;
- clammy skin that may be either pale or flushed.

Heat stroke

This is the most serious of all heat-related illnesses and may occur when the body core temperature exceeds 41 ^{o}C (it may reach 45 ^{o}C), and the co-ordination of the involuntary nervous system including thermal regulation is affected. Irreversible injury to the kidneys, liver and brain may occur. Heat stroke carries a high risk of fatality from cardiac or respiratory arrest, and must be treated as a medical emergency.

Some symptoms of heat stroke are similar to those of less serious heat illnesses, ie headaches, dizziness, nausea, fatigue, thirst, breathlessness and palpitations, but the onset of illness may be sudden and dramatic, and pre-existing heat exhaustion is not necessary.

Additional symptoms of heat stroke can include:

- cessation of perspiration, the skin remains hot but is dry and may adopt a blotchy and red colouration, and the lips may take on a bluish tinge;
- disorientation, which may become severe, including dilated pupils, a glassy stare and irrational aggressive behaviour;
- shivering and other uncontrolled muscular contractions;
- loss of consciousness and convulsions.

Risk assessment

Some work activities carry an increased risk of heat illness, and should be avoided if possible. There are times, however, when there is no alternative to working in hot conditions and these circumstances require special consideration. Risk assessments should be made, safe systems of work designed and appropriate control measures introduced to control the duration and extent of exposure. Measures should follow the hierarchy of control defined in Schedule 1 of the Management of Health and Safety at Work Regulations 1999, ie:

- avoiding risks;
- combating the risk at source;
- adapting working practices;
- giving collective protective measures priority over PPE;
- giving appropriate instructions and training.

Particular attention must be paid to the organisation of more physical work. Examples of such activities include:

- setting supports;
- pulling cables;
- building conveyor structure;
- manual handling tasks.

Non-acclimatised persons, eg contractors, service engineers etc working in the mine, may be at greater risk from heat illness. Management must ensure that employers other than the mine-owning company understand the hazard, and that they and the mine management have assessed the risk and identified appropriate precautions. The employers of these categories of persons should ensure that their employees are fit for all the environments that they are likely to be exposed to in the course of their particular employment. Visitors should not normally be taken into areas where they would be exposed to high heat strain.

Assessing the heat risk

Several factors can influence the heat load on the body. These include:

- air temperature (WB and DB);
- radiant heat;
- humidity;
- air movement;
- the level of physical work; and
- the amount and type of clothing being worn.

Thick, multiple-layered or impervious clothing particularly impede heat loss, and can cause additional risk especially during physically demanding tasks. Using PPE such as respiratory protection may also affect a person's tolerance to hot environments.

It is not possible to estimate the strain placed on the body by examining any one of these factors in isolation. Instead a number of heat stress indices have been developed which integrate these variables and give a single value that represents the amount of heat risk in a given situation. In the mining situation, where radiant heat is not a major factor, it has been found that the best index is the Effective Temperature (ET), because it takes air velocity into account.

The ET is an accepted, straightforward and easy to use index. For example, it can be determined without the need to use electronic instruments, which may be difficult to introduce into a coal mine for example. The ET takes into account the WB and DB temperatures and the air velocity. It is important to consider all these factors – eg a good air movement over the body has a cooling effect, whereas high relative humidity will reduce the body's ability to lose heat by sweating. Although ET can be calculated, it is more easily derived by use of a chart, reproduced in the Appendix.

The temperatures shown in Table 1 are indicative of the kind of environments that can be anticipated in deep mines. Individual mines may have potential for hotter or cooler environments. As mine workings get further from the shafts and the source of cool air, and heat sources in the form of diesel engines and electrical equipment increase in number and power, then the trend will be upwards.

Location	WB °C	DB °C	ET °C
Main intake	22.0	28.0	18.0
Main return	28.0	32.0	25.5
District intake	28.0	35.0	28.0
District return	33.0	37.0	32.0
District intake	28.0	33.0	27.0
District return	35.0	37.0	34.0
District intake	27.0	31.0	26.5
District return	31.0	33.0	29.0
Face	29.5	43.0	32.8
Face	30.7	44.3	33.6
Face	28.3	34.9	29.9
Face	27.5	34.8	29.8

Table 1 Typical ETs found in deep mines

Mines need to carry out heat surveys to determine the areas of the mine that could give rise to potential problems, so remedial measures can be properly targeted.

Reducing the risk – improving the environment

The first line of defence must be to reduce the impact of the environment, ie reducing effective temperature by engineering controls. Mines should construct a heat plan of the mine, highlighting in different colours regions of the mine that exhibit different effective temperatures. Mines must plan for heat, and take steps in the planning stages of a new district to minimise as far as possible the effective temperature that will be experienced. There are a number of influencing factors.

Provision of good quality air

Careful attention should be paid to the position and timing of ventilation connections, and the minimising of leakages between intake and return outbye, to maximise the quantity of air reaching the inbye workings. Working areas of the mine should be provided with an adequate supply of clean air that has not already ventilated another working place, so series ventilation is avoided.

One of the most significant factors influencing the temperature of air reaching the inbye workings is the effect of the heat given off by mineral in transit on the conveyors. Deep mines experience relatively high virgin strata temperature. The large quantities of mineral produced, and the fact that it may be conveyed damp for dust suppression purposes, contribute significantly to heat and humidity being given off into the air passing over the conveyor.

As a heat control technique, homotropal (where the conveyors are in return air) ventilation is very effective as any heat given off the mineral in transit goes into the return airstream, and does not pass to the working area. The use of whole mine homotropal ventilation helps to make the air reaching the outbye end of the production district considerably cooler, and ventilating air arriving at development headings would also be improved in quality.

The efficiency of auxiliary ventilating systems should be maximised by minimising resistances on the ventilation duct. Mines should pursue the use of low resistance types of ducting. Simple attention to housekeeping will ensure the minimum number of joints, an absence of kinks and restrictions, and a smooth internal face by ensuring the duct is stretched. The duct should be protected from impact and abrasion and any leaks sealed.

Siting of equipment that generates heat

Static equipment that generates heat should be kept out of the main intakes as much as possible, and sited either in the return airstream or in cross cuts so that any heat generated is passed to the return and does not contaminate the intake air. Such equipment includes conveyors, as detailed above, compressors, pumps, and electrical switchgear, particularly transformers.

Use of equipment

A common source of excess heat is equipment that has been left running when not required. Examples include diesel engines left idling when the vehicle is not being used, and dust extraction systems kept running when no mineral is being cut. Optimising the running time of such equipment will give obvious financial savings. Equipment should also be selected for the duty to be performed, for example a 56 kW fan should be used in preference to a 90 kW unit if the former is capable of performing the duty required. The selection of fire-resistant hydraulic fluids can also have an effect on machine running temperature.

Control of water to minimise humidity

This can be achieved by eliminating standing water and by minimising the amount of water that is introduced underground. Obvious water sources include leaks, spillages, flushing pipes during extensions/retractions, excessive sprays, machine cooling water, and natural strata water. Allowing water to accumulate into puddles will also increase the humidity of the passing air, so that should also be avoided. Any spillage should be collected and removed through pipes. Suitable pump ranges should be maintained, at least to strategic locations where they can be accessed if and when required. Allowing water to merely soak away or dry up is not acceptable.

If operations are planned that will generate spilled water eg washing down mobile plant, the planning of the work should also address water management.

Artificial cooling

Refrigeration has been rarely used in the UK. Air coolers remove heat from the passing air, but then dump that heat elsewhere. The plant is an additional heat source, but its use must be considered as part of the control measures. Chilling the water supply underground is also worth considering. In both these applications, it is important that all pipework, including joints, is properly insulated to achieve maximum benefit.

Local artificial body cooling, using dry-ice vests or similar, is an option. The systems have their limitations, particularly when they have to be transported over long distances. These systems are reactive and, as they do not have any impact on the actual environment, may instil a false sense of security. For routine working, they are not recommended.

Reducing the risk – safe systems of work

Selection

Even after the application of engineering controls, in areas of high effective temperatures, risk assessments will highlight the need for carefully defined safe systems of work. Personnel deployed to work in these areas must be physically capable of coping with the conditions, and will need to be selected on grounds of physical and medical fitness. More detail is given in the *Medical selection and health surveillance* section. Following selection of personnel, various other precautions must be put in place to minimise the risk, as follows.

Acclimatisation

Employees who will be exposed to high effective temperatures throughout the course of the shift need to be acclimatised to the conditions. Most workers become acclimatised over about one week, however acclimatisation decays quickly, tolerance decreases even over two days and disappears completely over about two weeks. Someone who has been absent for more than a week cannot be expected to work in a hot environment at the same pace on return without being at increased risk of suffering heat illness, so work/rest pacing would need to be modified to take this into account. This has implications for planning of shift patterns.

Acclimatisation is not likely to be necessary for those who experience occasional, intermittent, short-term heat exposure, although the precautions and behaviours detailed elsewhere in this guidance are still appropriate.

Work planning

Adequate supervision must be deployed to ensure that employees are complying with the recommended behaviours, as detailed in the *Reducing the risk – safe behaviours during work* section.

Manual effort in a hot environment needs to be minimised at the planning stage. Manriding as a proportion of total travelling needs to be maximised, and close attention should be given to manual handling operations.

If work of a physical nature is to be carried out in hot conditions, adequate manpower must be deployed to permit work sharing and the taking of regular breaks. This is a management function. Breaks should be taken at intervals appropriate to the conditions and nature of the work. Supervisors should ensure that appropriate breaks are being taken, and should pay particular attention for the signs of any heat illness becoming apparent.

To limit exposures within a set team size, job rotation is likely to be necessary and consideration should be given to additional training requirements to allow 'multi-skilling'. Systems of work should be devised which anticipate all likely tasks giving rise to risk. Such systems will necessarily become more restrictive as WB temperature rises.

Employers should also give strong consideration to the provision of a cooler environment near to the working area where employees can seek some refuge. This area must not be cold, just cooler than its surroundings.

Training and education

Of prime importance is the training and education of the workforce, including management and supervisors. Training must cover the precautions to be taken, the behaviours to adopt, and the recognition of the signs, symptoms and treatment of heat illness. The recognition of symptoms is of particular importance for lone workers, who will usually have to self-diagnose. For that reason, lone working is discouraged and should be avoided if possible. If lone working is necessary, a system of welfare checks over and above normal supervision should be put in place.

Hydration

Drinking 250 ml every 15 minutes requires each worker to have access to 10-12 litres of water on each shift. This is an excessive amount to carry when food, equipment and tools may also need to be carried. In these conditions, the employer should arrange for a supply of chilled drinking water to be available underground so individuals can replenish their personal containers.

Ice-making facilities of sufficient capacity to meet peak demand at main shift start times should be provided at a suitable location on the surface.

Water/fluids should not be drunk ice cold. Although it could be assumed that this would cool the body faster, the stomach is not part of the body core and the cold has the effect of constricting the stomach. As a result, flow to the intestines from where the fluid is absorbed is reduced and rehydration delayed.

Some means of keeping food cool, eg an insulated box, should be provided.

First aid and rescue

In addition to the primary aim of preventing heat illness, arrangements must be made for first aid, with specific training being required for the recognition and treatment of heat illness.

The employer must decide on criteria that will result in immediate removal from the mine in case of apparent heat illness, before collapse occurs. These criteria will be site specific, and should be taken on medical advice. The main criterion considered is likely to be the time or distance to a cool refuge.

Rescue and retrieval of an individual who has collapsed will be arduous if any manual handling of a stretcher is required, and arrangements should be made to minimise this effort, for example by the provision of adapted vehicles, or even trolleys.

Reducing the risk – safe behaviours prior to work

To minimise the effects of heat, employees need to present themselves for work in good condition. This includes:

- maintaining a healthy diet and optimum weight;
- ensuring a good quality rest period prior to attending work;
- eating prior to attending work, as this aids hydration. Bread, cereal bars, bananas, yoghurts, beans and fruitcake are all recommended;
- keeping alcohol intake within national guidelines and avoiding drinking alcohol 8-12 hours before the start of the shift;
- avoiding taking strenuous exercise immediately before or after the shift;
- avoiding taking caffeine before the shift ie coffee, tea and cola;
- increasing fluid intake prior to the start of the shift by drinking non-caffeine based drinks ie water, milk and squash to ensure proper hydration. It should be noted that the lighter the colour of the urine, the better the level of hydration;
- informing the on-site occupational health department if on regular medication or if suffering from a medical condition.

Some medication can have side effects relevant to heat whether taken before or during the shift. For example:

Medication	Effect
Antihistamine (hay fever tablets)	Inhibits perspiration
Beta blockers (blood pressure tablets or heart medicine)	May inhibit exercise tolerance
Diuretics (water tablets)	May cause dehydration
Angina treatments (GTN spray, tablets, patches)	May cause a drop in blood pressure
Tranquillisers, sedatives (anti-depressants or sleeping tablets) or muscle relaxants	Implicated in lowered heat tolerance, and may cause a drop in blood pressure
Anti-inflammatories (Brufen/Ibuprofen) and analgesics (painkillers – Voltarol, Paracetamol)	May interfere with body temperature regulation

Table 2 Effects of common medication on thermo-regulation

Reducing the risk – safe behaviours during work

Critical behaviours to adopt during the shift to minimise risk are:

- Wearing clothes that allow sweat to evaporate.
- Pacing work. It has been found that frequent, short breaks give more benefit than occasional, long breaks from manual effort.
- Job rotation. In addition to pacing work, if the more arduous tasks can be shared, no one member of the team is put at additional risk.
- Regular drinking to maintain an adequate hydration level. A potential sweat loss of one litre per hour has to be replaced, and it is recommended that regular, small drinks are taken rather than fewer, large drinks, which can cause cramps. An intake of 250 ml every 15 minutes is recommended. Salt should NOT be added to the water, as this is likely to interfere with the kidneys' normal physiological control mechanisms. Water can be made more palatable by the addition of fruit flavourings.
- Avoiding drinks containing caffeine, such as tea, coffee, colas and some 'anti-sleepiness' drinks during the shift. Caffeine is a diuretic and encourages fluid loss. Similarly, energy drinks should be taken in moderation, as excessive consumption can result in a salt, particularly potassium, imbalance.
- Monitoring hydration levels. This can be simply accomplished by observing the colour of the urine stream: the darker the colour, the less hydrated the individual. If this is noted, then immediate remedial action in the form of taking on extra fluids can be initiated. Urine colour charts for objective comparison are available and their use is encouraged.
- Regular food intake. Like water intake, small meals should be taken at regular intervals throughout the shift, rather than waiting until mid shift to start eating.

Bread, cereal bars, bananas, yoghurts, beans and fruitcake are all recommended. Meat, cheese or other protein rich foods are not recommended, as these do not encourage fluid absorption. All food should ideally be kept at or below 10 °C to avoid deterioration.

- On-shift surveillance. This should be three-tier, ie self, team, supervisor. Compliance with recommended behaviours should be checked and verified. The team must also check that the supervisor is complying, for example by taking sufficient fluids, and must monitor the supervisor for signs and symptoms of heat illness.

Medical selection and health surveillance

In some circumstances individual mines will need to seek competent medical advice to help develop their own procedures (including health surveillance if appropriate) and systems of work. This will be based on the anticipated exposures identified from heat survey work, the work rates for various tasks, the duration and frequency of the tasks, and individual capabilities.

New employees intended for deployment to hot areas of the mine should be selected with particular care and be assessed by a competent medical practitioner to ensure that they are physically fit.

It is essential that a medical assessment programme is put in place to monitor established employees' continued suitability for high temperature work. This assessment should take place under the supervision of a competent medical practitioner, but may be carried out by an occupational health nurse. The practitioner should be provided with details of the individual's duties, the potential exposure to hot/humid environments and details of any PPE required.

Factors to be considered include:

- pre-existing medical conditions eg diabetes;
- use of prescription or non-prescription drugs which affect thermo-regulation;
- physical fitness;
- obesity (overweight people have less tolerance to heat);
- age (tolerance to heat decreases with age);
- previous heat illness, demonstrating an individual's susceptibility;
- chronic skin disorders, which can impair temperature regulation;
- habitual alcohol abuse, with increased risk of dehydration.

At the initial assessment, and at subsequent refresher training, staff should be given enough information to recognise their own symptoms. It should be made clear to them that any such symptoms should be immediately reported and that work should not be resumed until they are cleared by the occupational health practitioner. Such reports should be fed back into the risk assessment and trigger a review of the assessment.

Persons appearing to suffer from a heat illness, or who are off work for a length of time because of illness or injury, should be reassessed before being reassigned to work in hot/humid areas. Any absence as a result of heat illness must always trigger medical reassessment.

Competence of the occupational health practitioner

The medical advice and assessment arrangements must be carried out by, or under the direct supervision of, a doctor competent in occupational health and with minimum Associateship of the Faculty of Occupational Medicine (AFOM).

The practitioner should have had enough experience in evaluation of fitness to work in high temperatures and also have first-hand knowledge and experience of the conditions under which the workers operate. It is not necessary for the practitioner to carry out the detailed medical examination (which may be carried out by another practitioner or nurse), but it is necessary for that person to have established the assessment regime and be responsible for decisions on individual cases on fitness for work.

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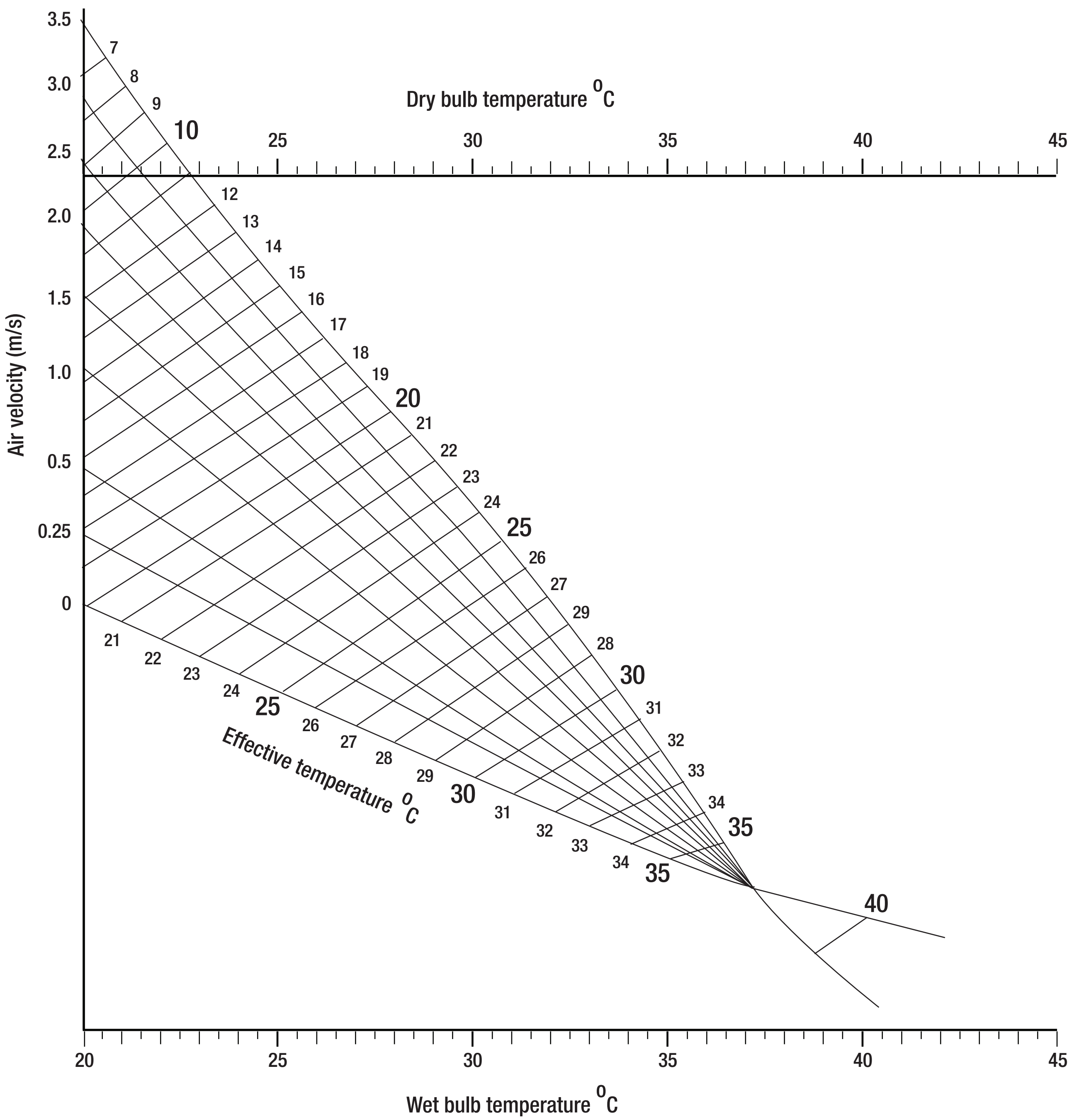
Appendix

How to determine Basic Effective Temperature

The standard index used in British mines for thermal comfort is the Basic Effective Temperature (BET, or commonly ET in the mining industry). This is the equivalent temperature in still, saturated air that appears to feel the same to an individual in the prevailing conditions. The BET is configured for nude subjects which, in hot and particularly humid mines, most closely reflects the level of clothing actually worn.



The ET can be found by reference to the chart reproduced here. This is essentially a nomogram giving a graphical representation of the relationship between the Wet

Bulb temperature (WB), the Dry Bulb temperature (DB), and the air velocity. To evaluate the ET in any given situation, the WB, DB and air velocity must be known.

The DB temperature is the temperature of the air, measured with a standard thermometer.

The WB temperature is measured using a thermometer, the mercury bulb of which is surrounded by a wetted gauze. The effect of the gauze is to saturate the atmosphere locally by evaporation, so the WB temperature is reduced in proportion to the dryness of the air.

The two temperatures are usually taken simultaneously using a whirling hygrometer. If required, the relative humidity can be calculated from the two temperatures.

The air velocity is usually measured using an anemometer and stopwatch. Air velocity produces a wind chill factor, which lowers the apparent temperature, giving a person the sensation of being exposed to a lower temperature than actually being experienced.

The chart is used by drawing a straight line between the points on the upper and lower scales corresponding to the measured DB and WB temperatures. From the point at which this drawn line intersects the curve corresponding to the measured air velocity, the effective temperature can be read off the ET scale. For example, the ET corresponding to 25 ^{o}C WB, 29 ^{o}C DB and an air velocity of 1.5 m/s, is 23 ^{o}C.

Further information

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This document contains notes on good practice which are not compulsory but which you may find helpful in considering what you need to do.

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