



Measuring heat stress in industry

Summary report 2009

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In this document, you'll find a summary of the independent study we commissioned from the Institute of Occupational Medicine: 'Reliable industrial measurement of body temperature'. The researchers would like to acknowledge the support of the British Glass Manufacturers' Confederation, which operates on behalf of the UK glass industry on a wide range of topics, including health and safety, environment, recycling and waste, technical information services and standards. British Glass also plays a major role in the UK and Europe by lobbying on behalf of the industry, its various sectors and our members.



What's the problem?

Heat stress occurs when the heat lost from the body is less than the heat gained. Unless steps are taken to redress the balance, the body temperature rises, causing symptoms such as heat rash, cramp, fainting, heat exhaustion or heat stroke, and swelling of the feet and ankles. Heat stress can also make other issues, like dermatitis and fungal infections, worse.

Heat stress can be a problem in many industries, including glassmaking, metal refining, baking and commercial catering. There are thermal indices¹, such as Wet Bulb Globe Temperature (WBGT) and Predicted Heat Strain (PHS), that can be used to assess the risk but they can often overestimate it, restricting work unnecessarily. It's also difficult to know the impact of protective clothing and other forms of personal protective equipment when using these indices.

We can't assume that risk control measures such as work–rest schedules are effective. Therefore, taking physiological measurements, particularly body temperature, is often seen either as an 'add-on' to these indices or as an alternative.

For many years, rectal temperature was regarded as the 'gold standard' for measuring core body temperature. But in recent years, intragastric temperature, measured with a temperature-sensitive radio pill, has increasingly replaced rectal temperature as an indication of core body temperature. However, practical and cost issues mean that it can't be used as a routine monitoring method.

Technological advances have introduced new ways of measuring body temperature. For example, infrared sensors can be used to measure the temperature in the ear canal (sometimes incorrectly called 'tympanic' temperature) and may provide a simple solution for industrial monitoring. Scientific opinion so far has varied on the reliability of this approach, although there is enough positive evidence to suggest that it could provide an adequate monitoring measurement.

With the help of British Glass, we commissioned Dr Richard Graveling and his team at the Institute of Occupational Medicine (IOM) to explore this alternative approach further. We asked them to compare ear canal temperature measurements made using a simple infrared device against the temperature in the intestinal tract (intragastric temperature), and to assess whether the infrared unit could reliably be used to measure heat stress in industrial environments.

¹ A number of different factors contribute to the overall level of heat stress. One way of assessing these is for two or more to be combined, for example by means of a mathematical equation, to give a single 'thermal index'. WBGT (BS EN 27243) and PHS (BS EN ISO 7933) are examples of these.

The research had five main goals:

- to collect and collate paired data of body temperature measurements using intragastric (IG) and infrared (IR) measurements in the gut and ear canal respectively
- to find out how accurately and reliably IR temperature can be used as a predictor of IG temperature
- to look at the IG temperature data to determine the influence on any relationship of any temporal 'slip' between IR and IG temperatures
- to use environmental climate data to explore the potential change of any relationship as a result of circumstances such as localised radiant heating
- to prepare a procedure for the industrial measurement of IR temperature as a reliable indicator of IG (core) temperature – or to explain the reasons why it should not be used.

What did our researchers do?

The team at IOM recruited six companies representing the glass manufacturing and metal refractory sectors of industry, where working with red-hot molten materials meant that there was a potential for heat stress. There were 34 volunteers from the participating factories and they formed three groups:

- maintenance workers at a major manufacturer of float glass,² who were exposed to high temperatures during the primary glass production process and when manufacturing float glass
- production workers at two glass bottle manufacturers, who were exposed to heat from red-hot molten glass during the primary glass production process and when manufacturing glass bottles
- workers in three companies in the refractories sector, who were exposed to heat from molten ferrous or non-ferrous metals during casting processes.

The volunteer workers at each site were given temperature-sensitive pills to swallow and the radio signal from these pills was logged during normal working shifts. During the same shifts, measurements were taken of the temperature in the ear canal of these workers at certain times, using a proprietary hand-held infrared thermometer. The researchers also kept a record of the workers' level of physical activity and

² Float glass is sheet glass made by floating molten glass on a bed of molten metal, which gives the sheet uniform thickness and very flat surfaces

measured environmental parameters, such as dry bulb³ and radiant (globe)⁴ temperatures.

Statisticians then analysed the data to find out how reliably the infrared temperatures predicted the core body temperature as measured with the pills. They also looked at how factors such as physical workload or environmental working temperatures affected the prediction.

What did our researchers find out?

The researchers looked at a total of 272 pairs of temperature data taken across a total of 45 working shifts in the different sites.

They found that dry bulb temperatures ranged from around 23 °C to almost 50 °C, with a similar range for globe temperatures. This showed that despite what might be expected, the radiant heat contribution was relatively low. One explanation could be that the molten glass or metal was generally enclosed, so that the area of red-hot material to which workers were directly exposed was usually quite small.

When the team carried out statistical tests, they showed that IR temperatures did not give a very reliable prediction of core temperature in the industrial settings used. Their predictive ability was not improved by taking into account what work the workers were doing just before their temperatures were measured or what the environmental temperature was in the work area.

The researchers found that although some pairs of data were quite closely matched, others were considerably different (even allowing for the fact that the IR thermometer tended to give lower readings). Because the pill temperature isn't usually known, it's not possible to tell which are accurate and which are not. This makes it very difficult to get an accurate indication of the level of heat stress experienced.

The following table shows what core temperature would be predicted from a given IR temperature. So, for example, if the IR thermometer showed 37.0 °C, the predicted average core temperature would be 37.45 °C, but there is a 90 per cent chance of it being anywhere between 36.07 °C and 38.92 °C (the 'prediction interval').

³ The temperature of the air measured by a temperature sensor freely exposed to the air but shielded from radiation and moisture.

⁴ The temperature measured by a sensor placed in the centre of a matt black globe with standard characteristics.

IR temperature (°C)	Predicted IG temperature (°C)	IG 90% PI (°C)
36	35.64	(34.15, 37.09)
37	37.45	(36.07, 38.92)
38	39.25	(37.91, 40.84)
39	41.05	(39.65, 42.85)

Table 1

Predicted IG temperatures and prediction intervals given specific IR temperatures

What does the research mean?

At present, simple hand-held infrared thermometers that can be bought at pharmacies are not sufficiently accurate to be used as a safety measure in hot working conditions. On average, they tend to give lower measurements (by about 0.5 °C) but, more importantly, they cannot be relied on to give a reading which could be used confidently to control heat exposure among industrial workers.

However, it should be noted that the technique used to obtain IR measurements is important and that certain safeguards must be applied relating to how and where measurements are obtained. Related to this is the possibility that differences in technique between individuals may contribute to the overall accuracy (or inaccuracy) of the process. There is also evidence that the make of instrument used affects the temperatures recorded.⁵ At present, therefore, this conclusion is strictly only valid for the make of instrument used in this study.⁶

There are many different ways of measuring or estimating core body temperature,⁷ and they have varying degrees of accuracy and reliability. Unfortunately, those which tend to be most reliable tend to be more invasive or intrusive. Some may work better in certain environments than others. As a rough guide, those obtained on or close to the body surface will be less affected by the surrounding temperature if this is close to 'normal' body temperature of around 37 °C.

⁵ Jakobsson J, Nilsson A and Carlsson L. Core temperature measured in the auricular canal: comparison between four different tympanic thermometers. *Acta Anaesthesiologica Scandinavica* 1992; 36 (8): 819–824.

⁶ The make used in this study was the Braun Thermoscan Model 6022.

⁷ British Standards Institution. BS EN ISO 9886: Evaluation of thermal strain by physiological measurements. London: BSI, 2004.

Don't forget

Like most studies, this one had some limitations. Very few of the core (pill) temperatures measured reached a temperature that might give cause for concern. In one sense this is good, as it means that the risk of heat stress at the factories involved was well managed and that workers were good at controlling their own heat exposure. But it also means that there were fairly few body temperatures obtained at these higher levels on which to base the prediction. Most of the core temperatures obtained were between 37.0 °C and 38.5 °C, so the prediction is most reliable in this range. However, we would expect the prediction to become less reliable outside these values.

On some occasions, where workers were exposed to higher temperatures while carrying out particular jobs, it was not possible to get close to them safely, and so these measurements could not be captured. Therefore, excluding the body temperature data from these workers did not improve the reliability of prediction.

It's also worth noting that when a worker is wearing highly insulative clothing they are actually exposed to the microclimate within the clothing rather than the measured climate.

Apart from any inaccuracies in the measurement method, 'core' body temperature differs at different parts of the body. So as the temperature pill moves through the gut, the reading it gives will change even if the 'core' body temperature doesn't.

What's next?

Further research is underway to explore some of the reasons for the apparent inaccuracy of this technique. These include:

- We know that the 'ear-tug' to alter the shape of the ear canal before inserting the instrument (familiar to those using ear plugs for hearing protection) is important but are there other issues about exactly how the temperature is taken?
- Is the shape of the ear canal and the ability of the sensor to 'see' the ear drum, even with an ear-tug, important?
- Does heating or cooling the side of the head produce localised temperature distortion?
- The temperature pill moves through the body during the day, which will change the 'core' temperature reading it gives. Is this an important source of error?

Good practice in action: managing the risk of heat stress in the workplace

When managing the risks associated with working in hot conditions, you need to take account of the Management of Health and Safety at Work Regulations 1999 and the associated Approved Code of Practice. These lay down a hierarchy of preventive and protective measures to be taken following the risk assessment:

- if possible, avoid a risk altogether
- combat risks at source
- wherever possible, adapt work to the individual
- take advantage of technological and technical progress
- take measures as part of a coherent policy and approach
- give priority to these measures which protect the whole workplace and all those who work there
- make sure workers understand what they need to do
- promote an active health and safety culture.

There's more guidance on this issue on the HSE's website at <http://www.hse.gov.uk/temperature/index.htm>.

Control measures before working in the heat

Pre-exposure screening

Pre-employment assessments should identify people with permanent or long-standing medical conditions that might mean that they're not suited for physically demanding work in hot conditions.

Health monitoring and self-assessment

Before work involving exposure to hot conditions, employees should be given some form of health check. This should include a self-completed checklist or questionnaire, agreed with the employer's occupational health adviser, which lists symptoms, illnesses or medication that may give rise to a temporarily increased susceptibility to the heat. For example, a stomach upset can disrupt the body's fluid balance and reduce tolerance to heat.

Information and training

Any system of self-assessment relies on accurate and honest reporting, unless the employee is visibly unwell. It's therefore important that employees receive adequate information and training, not just in recognising the symptoms of heat-related illness but in understanding what factors may cause their susceptibility to vary.

‘Pre-cooling’ measures

Some scientists have advocated artificially cooling workers before they start working in hot conditions. Although the benefits of this have yet to be demonstrated, it's a good idea to drink some water before such work. You should encourage your employees to drink a modest amount (about 250 ml) before starting hot work.

Dietary advice

High carbohydrate foods are preferable. Digesting high protein foods uses more water as some is lost in excreting the nitrogenous waste, while high fat foods take longer to digest, placing a heavier burden on the digestive tract.

Monitoring and control during work

Clothing

In hot conditions, the body uses the evaporation of sweat as a key method of keeping the body temperature down. Clothing can disrupt this process, particularly if it's non-breathable. Ideally, clothes should be lightweight and preferably made from an open weave fabric, allowing air and vapour to permeate easily. Air exchange can sometimes be improved by using two-piece (ie shirt and trousers) rather than one-piece clothing.

Where employees need to wear protective clothing (perhaps to protect against chemical exposure), you should ask for expert advice, as a lot of protective clothes can significantly increase the risk of heat-related illness.

Environmental monitoring and recording

Monitoring environmental heat exposure is essential for any work in hot conditions. It's unacceptable for employees to be exposed to heat levels that create a risk of injury if those responsible don't know the temperatures involved and therefore the extent of the risk.

You should keep records of heat exposure and match them against records from physiological monitoring (see below) to confirm that the measures you've taken to combat heat stress are effective. This will also help you modify working environments or tasks if necessary.

Physiological monitoring

Monitoring individual workers' body temperature during work and rest would offer protection against their body temperature rising too high. Data from several experimental studies have suggested that the core temperature should not exceed 39 °C, although measured values will vary with the site and method of measurement. When you're deciding an acceptable working limit, you must always consider the accuracy of the measurement system you're using, the risks associated with a worker becoming incapacitated in the workplace, and the time you're likely to need to evacuate a casualty to a cooler location, as well as other factors.

At present, few monitoring systems provide accurate measurements in use with sufficient reliability to be used, other than established techniques such as rectal temperature or use of the gastro-intestinal pill.

Supervising, buddy systems and self-monitoring

Everyone working in hot conditions should be aware of the symptoms of heat stress so that they can recognise them in themselves or their colleagues. Typical symptoms include vagueness, impaired memory or reasoning and lightheadedness or dizziness, although any abnormal behaviour should be regarded with suspicion.

Limiting workplace temperatures and the length of time workers are exposed to heat, together with other control measures, should be enough to control the risks.

Nevertheless, you should always make it clear to your staff that they can voluntarily withdraw from work in a hot area if they feel unwell, and that no-one will think any the worse of them if they do.

Control measures after working in the heat

Accelerated cooling

After a period of heat exposure, workers will retain a significant amount of heat in their body and clothing. Their clothing will help to keep the heat in, preventing it dissipating. Simply unfastening overalls can help to speed up the cooling process. Without this, in some circumstances body temperature can continue to rise inside highly insulating clothing, as heat from working muscles continues to be distributed around the body.

Where natural air movement is low, fans can help to evaporate sweat and dissipate heat, but take care that workers don't become chilled. Some studies have shown that immersing your hands and wrists in cool water can help to lower your body temperature.⁸

Rehydration

Many of the problems of heat exposure stem from dehydration. Fluid replacement is an important part of restoring workers' thermal and physiological equilibrium. Flavoured drinks are acceptable if preferred, but avoid carbonated and alcoholic drinks. Discourage staff from drinking too much too quickly, as this can cause excessive dilution of salts in the blood, which can have ill effects.

It's not usually necessary to provide saline drinks or salt tablets. The salt concentration of sweat is less than that of blood and, although the salts lost through sweating must ultimately be replaced, a normal diet generally provides enough for

⁸ Giesbrecht G G, Jamieson C and Cahill F. Cooling hyperthermic firefighters by immersing forearms and hands in 10 °C and 20 °C water. *Aviation, Space, and Environmental Medicine* 2007; 78: 561–567.

this purpose. This may not be true of people on a salt-controlled diet, but these individuals should already have been identified.

Emergency procedures

You should have a procedure for removing affected workers from the hot area to a suitable cool location where prompt first aid can be given. There may be problems with evacuating an unconscious casualty from the working area, in which case you should have a plan of action that can be deployed quickly. If necessary, you should set up an emergency refuge nearby with cooling fans and other items easily available.

There should be facilities in place to help people with minor symptoms (concentrating on rehydration and cooling) and those in a state of collapse, to whom the usual first aid priorities of airway, breathing and circulation apply. Cooling the casualty is also important, as clinical experience has shown that complications don't occur if casualties are treated within 15 minutes of collapse and if their temperature is below 38 °C within one hour of starting treatment. A prompt response is clearly vital.

For the conscious casualty who can be cooled (by removing protective clothing and then wetting and fanning the body) and who is able to drink water, hospitalisation is not generally necessary, as long as there's no loss of consciousness, no evidence of complications, and their core temperature has fallen below 38 °C within one hour of the start of treatment. Be aware that evaporation is the most efficient means of removing heat, so wetting and fanning is likely to be a more effective approach than immersing the casualty in water or using ice packs. Casualties who may have suffered circulatory collapse should be sent to hospital.

Information and training

You should give your workers information and training on what to do after exposure to heat. They need to be aware of the importance of cooling and rehydration, and if they're experiencing dizziness they should be advised against driving until they feel better. It will help to reassure them if you can monitor their body temperature until it returns to normal. Urine colour can also provide an informal check – small quantities of dark urine suggests dehydration.

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Our summary gives you the major findings of the independent project report by the Institute of Occupational Medicine. If you want to read about the study in more depth, you can download the full report at [iosh.com/research](https://www.iosh.com/research).

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