Effects of Heat and the impact on production rates – Written by Johannes Holtzhausen

1 HEAT AND THE IMPACT OF HEAT ON PRODUCTION RATES

1.1 HEAT ENERGY

What is heat, this may sound like a simple question which all of us should know the answer too. Heat is not that simple and not that easy to deal with. The following are a few definitions or descriptions of heat:

- The degree of hotness or coldness of a body or environment.
- A measure of the warmth or coldness of an object or substance with reference to some standard value.
- A measure or the average kinetic energy of the particles in a sample of matter, expressed in terms of units or degrees designated on a standard scale.
- A measure of the ability of a substance, or more generally of any physical system, to transfer heat energy to another physical system.
- Any of various standardized numerical measures of this ability, such as the Kelvin, Fahrenheit, and Celsius scale.

The important message to take away from these definitions or descriptions of heat would be that it is energy. What makes the fact that heat is energy so important? Energy cannot be destroyed and something has to be done with it for it to go away or change degree/state. Heat flows/transfer from warm to cold and the bigger the difference in temperature the faster the heat transfer takes place. Should you not introduce a method of treating the heat present in a working it will not go away. There are a couple of ways to reduce heat in an underground working:

- Dilution through ventilation. Ventilating air may be used to carry the heat (energy) out of the mine and reject it on surface into the general atmosphere. Due to the effects of auto compression this becomes a challenge in deep level mines and many factors have to be taken into account.
- Changing state. Use the heat to do work (Steam engines, combustion engines)
- Improve efficiencies of electrical and diesel plant in the underground environment.
- Insulation. Care must be taken with insulation as it could result in heat being rejected in concentrated areas and may also effect the performance and longevity of plant if not correctly applied.
- Wetting & cooling where heat is removed from the air or an object and captured within a coolant (Water, Ammonia, R134a and the list goes on) to be carried away and be rejected within a controlled environment or on surface (These systems may become extremely complex and costly).
- Change practices and mining methods.
- Substitution of chemicals and explosives for more efficient lower heat generating alternatives.
- Equipment management programs reducing the introduction of additional heat which may build up within a ventilation circuit.
- Reduced watering down or controlled watering down of surfaces and roadways higher up in the ventilation circuit.

There are many more ways and approaches to the reduction of heat but controlling it at the source are the most effective. In an underground mine this is not always possible to do at the source but with the use of effective engineering solutions most conditions can be improved to within a safe range. Administrative controls (procedures and work schedules) and PPE should be left as a last and final resort.

1.2 EFFECTS OF HEAT ON SAFETY & HEALTH

Heat stress or the exposure to temperatures above 27˚C Wet Bulb dramatically increase the likelihood of workers to experience heat related illnesses or the effects there of. It is important to note that some individuals who are prone to heat related illnesses may be affected even when working in temperatures below 27˚C Wet Bulb. Heat tolerance testing is a good way to identify such individuals within a controlled environment without exposing them to adverse health effects. Employees affected by heat stress may suffer from various conditions that can range from simple rashes to **fatal** heat stroke. Heat stress has also been proven to affect mental and physical performance impacting on:

- Motor skills
- Communication
- Decision making ability, mental clarity

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- Aggression
- Physiological effects (Cramps and reduced efficiency)
- Failure to process safety signs and signals
- Failure to carry our instructions
- Incapacitated

These effects of heat on the human body and mind may indirectly or directly relate to safety performance in the workplace. For these effects to take place a person may not necessarily have to be exposed to a warm environment for an extended period of time and caution must be exercised when introducing new employees to a new working environment. To avoid these negative impacts, employers or companies should create a plan or a set of guidelines that will enable their workers to avoid heat stress. This may include appropriate education for workers, workplace improvement, heat management plan, environmental monitoring and a hydration program. Some of the heat related diseases are:

- **Heat Exhaustion** is a condition where a worker is unable to continue working due to an elevated core body temperature. Common signs of heat exhaustion are profuse sweating, nausea, fatigue, pale skin, head ache, hyperventilation, urge to defecate and light headedness.
- **Heat Stroke** occurs when the core body temperature reaches and exceeds 41˚C and the body is unable to reject the heat to cool itself. Symptoms include seizures, emotional instability, disorientation, impaired judgement, aggression, vomiting, elevated heart rate and may lead to permanent loss of body function and even death.
- **Heat Syncope** is a fainting (syncope) episode or dizziness that occurs with prolonged standing or sudden rising from a sitting or lying position. Some of the symptoms are light-headedness, dizziness and fainting.
- **Heat Cramps** usually affect workers who sweat profusely during strenuous activity in warm environments. The sweating depletes the body's sault levels and moisture levels which lead to painful cramps. Symptoms would be muscle pain or spasms usually in the abdomen, arms or legs.
- **Heat Rash** is a skin irritation caused by excessive sweating during hot humid weather. Heat rash looks like a red cluster of pimples or small blisters. Heat rash is more likely to occur on the neck and upper chest, in the groin area, under the breasts and in elbow creases.

As soon as a person show signs of heat induced illness they must be treated immediately to ensure it does not progress into a more severe or even fatal event. First aid training plays an important role in the identification, preparation and treatment of heat induced illness.

A paper was written by Dr A Michael Donoghue, Senior research fellow, J Sinclair and Graham P Bates on heat exhaustion in a deep underground metalliferous mine. This paper and research were undertaken in Australia and it is well worth reading the full research document available on http://oem.bmj.com/content/57/3/165.full . Reference is also made to multiple research papers that have been written around heat and the effects thereof.

Cumulative percentage of heat exhaustion in relation to psychrometric wet bulb temperature (n=74).

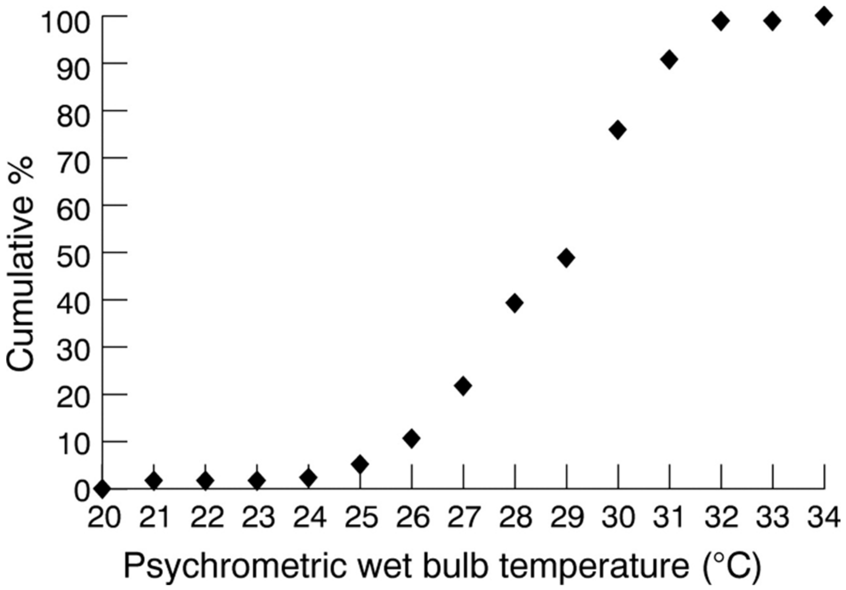

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Figure 1

Figure 1 shows the relation between wet bulb temperature and heat exhaustion occurring in the underground work environment. When the temperature reaches 32˚C 100% of the research group was effective irrespective of their age and gender.

Cumulative percentage of heat exhaustion in relation to dry bulb temperature (n=74).

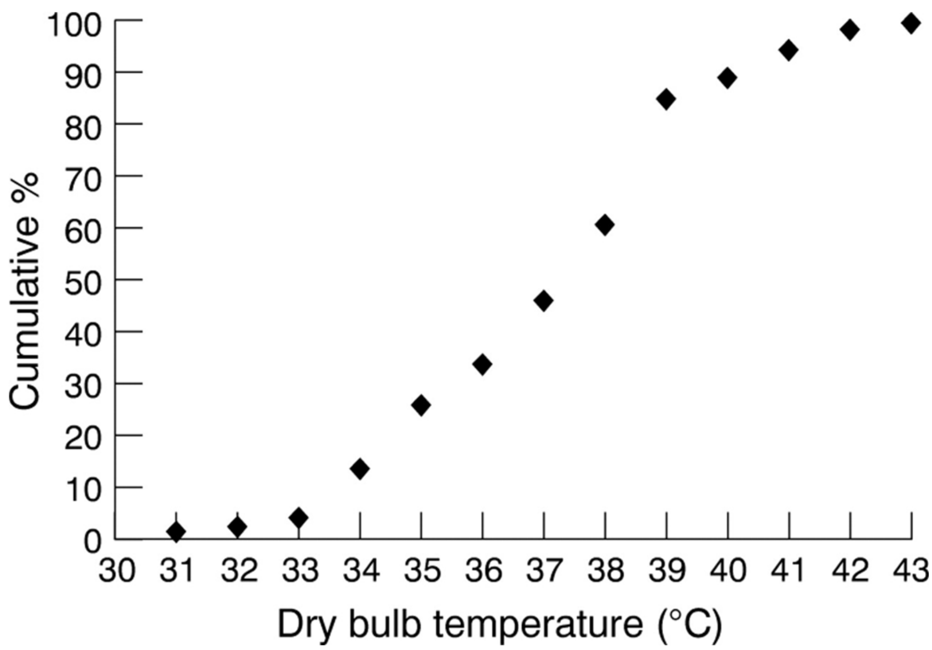

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Figure 2

Figure 2 indicates that when temperatures exceed 43˚C dry bulb 100% of the research group suffered from heat exhaustion, it should be noted that the chances of suffering heat exhaustion dramatically occurs and increases with a dry bulb temperature from 37˚C and above.

Cumulative percentage of heat exhaustion in relation to air velocity (n=74).

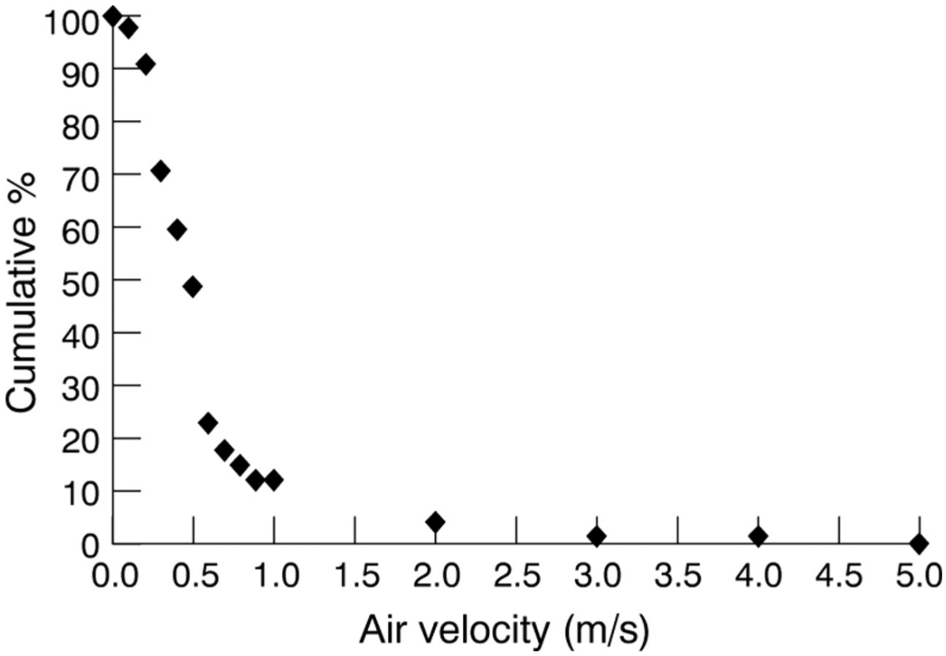

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Figure 3

Figure 3 indicates that with an air velocity of less than 0.5m/s the occurrence of heat exhaustion dramatically increases.
Unfortunately thermal data from underground areas where heat exhaustion did not occur were not recorded, so it is not possible to measure the risk of heat exhaustion for given levels of psychrometric wet bulb temperature, dry bulb temperature, air velocity, air cooling power, or psychrometric wet bulb globe temperature. However, it is clear that few cases of heat exhaustion (<5%) occurred at psychrometric wet bulb temperature <25.0°C, dry bulb temperature <33.8°C, air velocity >1.56 m/s, air cooling power >248 W/m2, or psychrometric wet bulb globe temperature <28.5°C. It seems likely, therefore, that heat exhaustion would be practically eliminated if ventilation and refrigeration systems achieved air cooling power >250 W/m2at all underground work sites. In failing to do so the risk of heat induces illnesses and impact on production would be elevated and the risk must be controlled (Practical effective working in heat procedure).

Mine productivity (tonnes/month) has been reported to fall at air cooling powers <300 W/m^2. Declining productivity therefore occurs at air cooling powers above those associated with heat exhaustion. This is not surprising, as physiologically it would be expected fatigue would occur before heat exhaustion which highlights the importance to ensure heat is controlled at all times in the underground environment.

2 ACKNOWLEDGEMENTS AND REFERENCES

Material referenced during the writing of this paper:

- Thermal physics Lesson 1
- Better health channel
- Medical journals of Australia and South Africa
- NIOSH position papers
- Paper on the "Heat exhaustion in a deep underground metalliferous mine" by Dr A Michael Donoghue, Murray J Sinclaire and Graham P Bates