THE EXPOSURE OF MAINTENANCE WORKERS TO HEAT STRESS WITHIN ESKOM

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Thesis submitted to the Department of Physiology

at the

University of Potchefstroom in partial fulfillment

of the

Requirements for the degree

Magister Scientiae.

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Potchefstroom

2000

Preface

Generally the perception of workers was that heat exposure in the industrial arena has always been a non-contributor (low-contributor) to occupational injuries /incidents and fatalities.

The contributions, which follow, are largely based on individual research projects conducted on the exposure of humans to heat and the effects thereof.

I thank everyone, who contributed to this study, and hope that his or her efforts may lead to a better appreciation of the problem of heat stress and to a reduction of its lethal potential in the industrial arena.

E C Julies

Acknowledgements

I firstly thank the Heavenly Father for His guidance and blessings on me to complete this study.

I thank all the personnel at the Department of Physiology of the University of Potchefstroom for their contributions, support and guidance. Special thanks to Mr. MN van Aarde for his support.

Special thanks to the electricity utility Eskom for their financial support and making their resources available for this study. Special thanks to Occusafe cc. for their value added input into the appendix.

Hypothesis

Maintenance workers in Eskom are exposed to hot environments above 30°C WBGT, during their normal job activities. These hot environments will put excessive strain on the body's thermo-regulatory system.

Abstract

This study was conducted to determine if maintenance workers were exposed to temperatures above 30°C WBGT and to determine the effect of this on their bodies. Maintenance workers were used as the target group due to their job tasks in hot environments.

Core body temperature was determined using a Questtemp II personal heat stress monitor. Measurements were taken before entering the hot environments and after exiting the hot environments.

Body weight, blood pressure and heart rate were also measured before the workers entered the heat stress area and after they exit the area. A normal t-test was done to determine if there was any significant difference between the readings taken before and after entering the hot environment.

All the measured parameters except for heart rate indicated a significant difference between readings taken before and after entering the hot environment with a P-value less than 0,05.

Environmental temperature was measured over a period of time in 3 different heat stress areas, by using the appropriate ISO 7243 method.

The significant difference on the parameters, weight, core temperature and blood pressure confirmed that workers are exposed to hot environments.

Although workers spend limited time in hot environments, precautions still needs to be taken to prevent any incidents resulting from exposure to hot environments. Appendix A, which is a Heat Stress management guideline, was developed to assist with the prevention of heat stress on Eskom maintenance workers. This guideline will assist by addressing factors such as weight loss and cardiovascular conditions of employees exposed to hot environments.

Opsomming

Die studie is gedoen om te bepaal of instandhouding werkers by Eskom blootgestel word aan hoë temperature, dit is temperature bo 30°C WBGT in hul daaglikse take. Hierdie studie is ook gedoen om die effek van hoë temperature op hierdie werkers te bepaal. Liggaams temperatuur, bloeddruk, gewig en polsslag is as hitte stress indikasie faktore gebruik. Hierdie faktore is bepaal voordat die werker die hitte omgewing binne gegaan het en nadat hulle uit die omgewing gekom het. Liggaams temperatuur was bepaal deur gebruik te maak van 'n Questtemp II persoonlike hitte stress monitor. Omgewings temperatuur was bepaal deur gebruik te maak van die ISO 7243 metode en Questtemp hitte stress monitor. T-toetse is gedoen om die statistiese waarde van die lesings te bepaal en om betekenisvolle verskille aan te dui.

Betekenisvolle verskille in liggaams temperatuur, gewig en bloeddruk was verkry deur die studie, dit wil sê, P-waardes kleiner as 0.05.

Instandhouding werkers is blootgestel aan hitte stress in hul daaglikse take. Om te verseker dat hierdie werkers se risiko om hitte stress siektes soos hittesteek te voorkom word 'n Hitte Stress Bestuurs program voorgestel soos saamgevat in bylaag A. Hierdie program inkorpereer ander faktore soos ouderdom, geslag en mediese geskiedenis wat ook 'n effek het op hitte stress.

THE DETERMINATION OF HEAT STRESS TO MAINTENANCE WORKERS WITHIN ESKOM.

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Appendix A

I. INTRODUCTION

Operations involving high air temperatures, radiant heat sources, high humidity, direct physical contact with hot objects, or strenuous physical activities have a high potential for inducing heat stress in employees engaged in such operations. Such places include iron and steel foundries, nonferrous foundries, brick-firing and ceramic plants, glass products facilities, rubber products factories, electrical utilities (particularly boiler rooms), bakeries, confectioneries, commercial kitchens, laundries, food canneries, chemical plants, mining sites, foundries, and steam tunnels.

Outdoor operations conducted in hot weather, such as construction, refining, asbestos removal, and hazardous waste site activities, especially those that require workers to wear semi-permeable or impermeable protective clothing, are also likely to cause heat stress among exposed workers.

As homoeotherms, human beings are well equipped to live in a wide range of environmental conditions. In a sense, therefore, we are free, within reason, to determine our own activities, rather than have them determine for us by the environment. The price that has to be paid is that core-body temperature cannot be allowed to fluctuate beyond a relatively narrow range without risking serious consequences to normal functional efficiency.

The exposure to heat stress in the maintenance occupation will differ to the tasks that will be performed. This is only one factor and other factors that will contribute to severity of heat stress exposure will depend on the individuals' physical appearance as well as frequency of exposure.

<u>Other Factors:</u>

1. Age, weight, degree of physical fitness, degree of acclimatization, metabolism, use of alcohol or drugs, and a variety of medical conditions such as hypertension all affect a person's sensitivity to heat. However, even the type of clothing worn must be considered. Prior heat injury predisposes an individual to additional injury. (Schoeman JJ, 1994:7)

2. It is difficult to predict just who will be affected and when, because individual susceptibility varies. In addition, environmental factors include more than the ambient air temperature. Radiant heat, air movement, conduction, and relative humidity all affect an individual's response to heat. (Schoeman JJ, 1994:7)

Eskom is South Africa's largest power utility. It produces about 96% of South Africa's electricity as well as more than ½ of Africa's electricity.

Eskom is divide into a few major groups namely:

a. Generation – generation consist of various types of power stations, which are Base load (coal-fired), Nuclear (Koeberg) and Peaking (Hydro and gas) stations.
b. Transmission
c. Distribution
d. Eskom Enterprises as a subsidiary of Eskom

Within all these groups are a group of workers generally referred to as maintenance workers. The job tasks of these workers vary within the groups but consists of general repair work, overhaul of equipment, replacement of equipment and servicing of machinery as well as general cleaning.

In many cases these types of work require the worker to enter a heat stress area. These areas can differ from a boiler house up to the roofs of houses.(Julies E.C. 1999.)

Temperatures within these heat stress areas vary between 30°CWBGT and 50°C WBGT. In some cases this temperatures might be exceeded.

The amount of time being spent in these areas also differs from a few minutes up to a few hours. (Julies EC. 2000.)

Maintenance being an occupation that requires an immediate response to certain requests only increases the risk of exposure to heat stress. A boiler might need repairs as soon as possible and cannot be allowed to cool down to a below 30°C WBGT.

A geyser inside a roof of a house might need to be repaired during the hottest time of summer in an area where temperatures easily reach more than 35°C Dry bulb.

(Julies EC. 1999)

II. THE AIM OF THIS STUDY

The aim of this study is two fold.

- Firstly it is to determine the extend to which the Eskom employees are exposed to heat stress.

- Secondly it is to incorporate previous studies done on Heat stress with the current study and to produce a guideline to assist with the prevention of heat stress and heat related disorders within Eskom.

III. LITERATURE STUDY

Four factors were measured during the study namely:

- Blood pressure
- Pulse rate
- Weight
- Oral temperature
- Environmental temperature
- These factors were measured before the persons entered the heat stress area and as they exit the heat stress area.
- Environmental temperature was measured over the period of exposure.

The measurement of blood pressure

Both systolic and diastolic blood pressures are readily measured in human beings with the use of a sphygmomanometer.
(Vander et al.,1998)

Heart rate

In normal adults the average heart rate at rest is approximately 70 beats per minute, but it is significantly higher in children. During sleep the heart rate decreases with about 10 to 20 beats per minute, but during emotional excitement or muscular activity it may accelerate to rates considerably above 100 beats per minute. When well-trained athletes are at rest the heart rate is approximately 50 beats per minute. (Guyton & Hall, 1996)

Heart rate was measured taking the pulse of the person while seated. This was done by pressing the front fingers on the wrist of the person and counting the number of beats per minute. The beats were counted for the first 15 seconds and multiplied by 4 to determine the number of beats per minute and than to compare the readings to the standard beats per minute (O'Malley & O'Brien, 1991).

The measurement of Environmental temperature

Heat stress indices

There are four environmental factors which determine the degree of heat stress experienced by the body namely:

- **air temperature,**
- **radiation heat,**
- **air flow and**
- **humidity**

To incorporate all these factors into a temperature experienced by the body, a different number of indices can be used.

There are many types of indices. A few examples are the KATA index, effective and corrected temperature indices, the wed-bulb globe temperature index, Bots ball index, and heat stress index.

The effective temperature index gives an indication of comfort – in other words the sensation of ease or unease (ISO 7726, 1985).

It does not take metabolic heat into account and therefore does not indicate the heat stress at a medium or high workload. It is, however, often used with office workers. (Schoeman, 1994:7)

The corrected effective temperature index is used when radiant heat is present. Although no index could be found that correlates very well with heat stress, the WBGT index is one that is widely used and accepted. In the RSA, heat exposure is legislated by means of the WBGT index i.e. the Environmental Regulations for Workplaces (OHS Act Act 85 of 1993). A heat stress index is thus defined as a combination of several environmental factors in a single number. The number can be compared to a known standard.

The WBGT index

The wed-bulb globe temperature index (WBGT) incorporates the natural wet bulb temperature, the globe temperature and the dry bulb (air) temperature. (Schoeman, 1994:7)

Dry bulb temperature

Dry bulb temperature is the temperature of air as acquired by a thermal sensor, such as an ordinary mercury in-glass thermometer shielded from direct radiant heat sources. (Schoeman, 1994:7)

Wet – bulb temperature

Natural wet-bulb temperature is registered by a thermometer whose bulb is covered with a clean wet cotton which is effectively shielded from radiation, and exposure to a current of moving air.

The ventilated wet bulb temperature is determined by using a powered (aspirated) sling psychrometer / whirling hygrometer. The wet-bulb temperature is obtained by using a sensor such as a wet cotton over a mercury in –glass thermometer that is exposed to natural air movement, unshielded from radiation. The natural wet-bulb temperature is used in determining the WBGT index. A highly absorbent woven cotton wick should cover the thermometer bulb. The wick should be wet to top at all times with distilled water. The water and/or wick should be replaced when dirty.

If the air is saturated with water vapor, no cooling will take place and the wet-bulb temperatures will be identical to dry bulb. If the air is not saturated, the cooling will be in proportion to the rate of water evaporation at a constant speed of air movement. More rapid air speed causes excessive drying of the wick. (Schoeman, 1994:7)

Globe temperature [Black bulb temperature (for radiation)]

Radiation can contribute substantially to heat stress imposed on the worker. Globe thermometers are used to evaluate this factor.

The globe thermometer is a thin-wall, blackened (flat matt black) copper sphere, 15cm in diameter, with a temperature –sensing devise at its center. The temperature attained by the globe thermometer depends upon the transfer of radiant energy between it and the connective heat exchange with the ambient air speed and temperature. When using a globe thermometer, approximately 30 minutes must be allowed for it to stabilize before the temperature can be read. (Schoeman, 1994:7) (Hales & Richards, 1987).

The WBGT is calculated by using the following formula:

a.) In exterior environment with sunlight

$$WBGT = 0.7T_{wb} + 0.2T_g + 0.1T_{db}$$

b.) In interior or exterior environment without sunlight

$$WBGT = 0.7T_{wb} + 0.3T_g$$

Where:

Twb = wet bulb temperature (°C)

Tg = globe temperature (°C)

Tdb = dry-bulb temperature (°C)

The calculated WBGT value (WBGT °C) is evaluated against the exposure limit reflected in the Occupational Health and Safety Act (Act 85 of 1993).

It should be noted that the WBGT index only takes into account environmental factors, but when this value is evaluated against table I, workload and metabolic heat are also considered thus considering the two sources of heat to the body.
(Riedar et al., 1993) (Schoeman, 1994:7).

HOW THE BODY HANDLES HEAT

GENERAL CONSIDERATIONS

Man is a warm blooded being. This means that he can maintain a fairly constant internal temperature (± 37°C), even though he is being exposed to varying environmental temperatures, within a specified range. To maintain this temperature within safe limits, the body must get rid of excess heat, primarily through varying the rate and amount of blood circulation through the skin and the release of fluid onto the skin by the sweat glands. (Curtis, 1997)

The body maintains temperature using the following principle:
Heat production = Heat loss, which can be explained as follows:
When the rate of heat production in the body is greater than the rate at which heat is being lost, heat obviously builds up in the body and the body temperature rises. Conversely, when heat loss is greater, both body heat and body temperature decrease. (Kielblock & Schutte, 1998)

THE BALANCE BETWEEN HEAT PRODUCTION AND HEAT LOSS

As the metabolic rate increases, heat production increases. Blood plays an important role in carrying heat from the core of the body, which is at a higher temperature, to the skin, which is at a lower temperature, where the heat is dissipated at a rate equal to it's generation.
As the temperature of the human body should be maintained at ±37°C, a good balance must be maintained between heat production and heat loss. Therefore a worker in a hot environment will perspire heavily in order to cool down as a result of heat evaporation, while a worker in a cold environment will dress warmly to prevent heat loss.
(Guyton & Hall, 1996)(Ramsey et al., 1983)

The following factors determine the extent of heat gain in the body:

- metabolic rate (rate of work);
- flow of warm air;
- heat conduction;
- radiation absorption;
- ambient temperature;
- humidity;
- clothing;
- personal factors; (Curtis, 1997)

Heat production as a result of metabolism can be described as follows:

(1) basal rate of metabolism of all cells of the body; (2) extra rate of metabolism caused by muscle activity, including muscle contractions caused by shivering; (3) extra metabolism caused by the effect of thyroxin on the cells; (4) extra metabolism caused by the effect of epinephrine, norepinephrine, and sympathatic stimulation on the cells; and (5) extra metabolism caused by increased temperatures of body cells themselves. (Guyton & Hall, 1996)

The following factors determine the extend of heat loss from the body:

- heat radiation from the body;
- movement of air;
- sweat evaporation;
- heat conduction through cold equipment,
- air temperature;
- humidity (Curtis, 1997)

Most of the heat produced in the body is generated in the deep organs, especially in the liver, the brain, the heart, and the skeletal muscles – especially so during exercise. Then this heat is transferred from the deeper organs and tissues to the skin, where it is lost to the air and other surroundings. Therefore, the rate at which heat is lost is determined almost entirely by two factors: (1) how rapidly heat can be conducted from the core to the skin, and (2) how rapidly heat can be transferred from the skin to the surroundings. (Tortora & Anagnostakos, 1996)

THE MECHANISMS OF HEAT LOSS

There are four major methods of heat loss namely:

1. **Radiation.** Loss of heat by radiation means loss in the form of infrared heat rays, a type of electromagnetic wave. The human body radiates heat rays in all directions. However, heat rays are also radiated from the walls and other objects toward the body. When the temperature of the body is higher than that of the environment, radiation heat is emitted, but when the temperature of the body is lower than that of the environment, radiation heat is absorbed.
2. **Conduction.** Only minute quantities of heat are normally lost from the body by direct conduction from the surface of the body to other objects, such as a chair or a bed. On the other hand, loss of heat by conduction to air does represent a sizable proportion of the body's heat loss even under normal conditions.
3. **Convection.** The removal of heat from the body by convection air currents is commonly called heat loss by convection. Actually, the heat must first be conducted to the air and then carried away by the convection currents. A small amount of heat loss through convection occurs even when a person is seated, because of the tendency for the air adjacent to the skin to rise as it becomes heated.
4. **Evaporation.** When water evaporate from the skin in the form of sweat, heat is lost from the body. Even when a person is sitting down heat is still lost via the skin and the lungs. Regulating the rate of sweating can control the loss of heat by evaporation of sweat. (Beshir, 1994) (Gonzalez-Alonso, 2000.)

The following equation can be used to determine evaporation from the skin:

$E = 14V_a^{0.6} (p_{sk} - p_a)$

E = Evaporation heat loss kcal/h

V_a = air speed, m/s

p_{sk} = vapor pressure of water on skin assumed to be 42mmHg at a 35°C skin temperature

p_a = water vapor pressure of ambient air, mmHg. (NIOSH, Occupational exposure to hot environments, 1986.)

BIOLOGICAL EFFECTS OF HEAT

PHYSIOLOGICAL RESPONSES TO HEAT

The body experiences various conditions relating to heat stress. These conditions can vary from simple heat disorders to extensive reactions from the central nervous system, and can even cause death.

These conditions are summarized below:

A. Heat disorders and health effects.

1. <u>**HEAT STROKE**</u> occurs when the body's system of temperature regulation fails and body temperature rises to critical levels. This condition is caused by a combination of highly variable factors, and its occurrence is difficult to predict. Heat stroke is a medical emergency. The primary signs and symptoms of heat stroke are confusion; irrational behavior; loss of consciousness; convulsions; a lack of sweating (usually); hot, dry skin; and an abnormally high body temperature, e.g., a rectal temperature of 41°C (105.8°F). If body temperature is too high, it causes death. The elevated metabolic temperatures caused by a combination of workload and environmental heat load, both of which contribute to heat stroke, are also highly variable and difficult to predict.

   If a worker shows signs of possible heat stroke, professional medical treatment should be obtained immediately. The worker should be placed in a shady area and the outer clothing should be removed. The worker's skin should be wetted and air movement around the worker should be increased to improve evaporative cooling until professional methods of cooling are initiated and the seriousness of the condition can be assessed. Fluids should be replaced as soon as possible. The medical outcome of an episode of heat stroke depends on the victim's physical fitness and the timing and effectiveness of first aid treatment.

   Regardless of the worker's protests, no employee suspected of being ill from heat stroke should be sent home or left unattended unless a physician has specifically approved such an order. (Barrow & Clark, 1998)

2. **HEAT EXHAUSTION**. The signs and symptoms of heat exhaustion are headache, nausea, vertigo, weakness, thirst, and giddiness. Fortunately, this condition responds readily to prompt treatment. Heat exhaustion should not be dismissed lightly, however, for several reasons. One is that the fainting associated with heat exhaustion can be dangerous because the victim may be operating machinery or controlling an operation that should not be left unattended; moreover, the victim may be injured when he or she faints. Also, the signs and symptoms seen in heat exhaustion are similar to those of heat stroke, a medical emergency.

   Workers suffering from heat exhaustion should be removed from the hot environment and given fluid replacement. They should also be encouraged to get adequate rest. (OSHA, 2000)

3. **HEAT CRAMPS** are usually caused by performing hard physical labor in a hot environment. These cramps have been attributed to an electrolyte imbalance caused by sweating. It is important to understand that cramps can be caused by both too much and too little salt. Cramps appear to be caused by the lack of water replenishment. Because sweat is a hypotonic solution (±0.3% NaCl), excess salt can build up in the body if the water lost through sweating is not replaced. Thirst cannot be relied on as a guide to the need for water; instead, water must be taken every 15 to 20 minutes in hot environments.

   Under extreme conditions, such as working for 6 to 8 hours in heavy protective gear, a loss of sodium may occur. Recent studies have shown that drinking commercially available carbohydrate-electrolyte replacement liquids is effective in minimizing physiological disturbances during recovery. (OSHA, 2000)

4. **HEAT COLLAPSE** ("Fainting"). In heat collapse, the brain does not receive enough oxygen because blood pools in the extremities. As a result, the exposed individual may lose consciousness. This reaction is similar to that of heat exhaustion and does not affect the body's heat balance. However, the onset of heat collapse is rapid and

unpredictable. To prevent heat collapse, the worker should gradually become acclimatized to the hot environment. (OSHA, 2000)

5. **HEAT RASHES** are the most common problem in hot work environments. Prickly heat is manifested as red papules and usually appears in areas where the clothing is restrictive. As sweating increases, these papules give rise to a prickling sensation. Prickly heat occurs in skin that is persistently wetted by unevaporated sweat, and heat rash papules may become infected if they are not treated. In most cases, heat rashes will disappear when the affected individual returns to a cool environment. (OSHA, 2000)

6. **HEAT FATIGUE**. A factor that predisposes an individual to heat fatigue is lack of acclimatization. The use of a program of acclimatization and training for work in hot environments is advisable. The signs and symptoms of heat fatigue include impaired performance of skilled sensorimotor, mental, or vigilance jobs. There is no treatment for heat fatigue except to remove the heat stress before a more serious heat-related condition develops. (OSHA, 2000) (Barrow & Clark, 1998)

B. The central nervous system

The central nervous system control many body mechanisms of which the thermo-regulatory system is only one. The temperature of the body is regulated almost entirely by nervous feedback mechanisms and almost all of these operate through temperature regulating centers located in the hypothalamus. However, for these feedback mechanisms to operate there must also exist temperature detectors, to determine when the body temperature becomes too hot or too cold.

The central nervous system is responsible for the integrated organizational of thermo-regulation. The hypothalamus of the brain is considered to be the central nervous system structure, which acts as the primary seat of control. In general terms, the anterior hypothalamus operates as an integrator and "thermostat" while the posterior hypothalamus provides a "set point" of core or deep-body temperature and initiates the appropriate physiologic responses to keep the body temperature at the "set point" if the core temperature changes. (University of Western Cape, Science department.)

The anterior hypothalamus is the area, which receives the information from receptors sensitive to changes in temperature in the skin, muscle, stomach, other central nervous system tissues, and elsewhere. (Berne & Levy, 1998) (Rappaport et al., 1999)

IV. METHODOLOGY

Instruments used to obtain readings for the WBGT index may vary from basic mercury-in-glass thermometers, to solid state sensors that integrate the three variables and provide a single digital reading.

However, the basic principle of operation is the same and may be demonstrated by using three mercury-in-glass thermometers.

The thermal-sensing instrumentation should be located at the workstation so that the actual conditions of heat exposure are measured. A person's body is a shield and therefore measurements would have to be made at the position of a worker but with the worker not there. Where measurements must be made at an occupied workstation, an effort should be made to evaluate the shielding effect of the body on thermal radiation and on air movement as that effect relates to the measurements.

All instruments are calibrated internally and externally.

- Internal calibration is performed by the operator before and after measurements as per manufacturers' instructions.
- External calibration is done on an annual basis by an approved laboratory such as the SABS or CSIR.
- Sensors were placed at the mean height of the worker on a tripod.
- The instrument is placed at a distance away from radiation sources.
- Sufficient time is allowed for stabilization after setting up the instruments but before obtaining readings. This time varies from 15-30min.
- Information on environmental conditions e.g. cloud cover, is recorded.
- Measurements were taken between 10:00am and 15:00pm, for a time period of between 1-2hours, depending on the time the instrument took to stabilize.

The standard method for determining heat stress (i.e. WBGT index for heat stress monitoring) is the ISO 7243 Standard Procedure.

The electronic equipment used:

Quest Temp°15 Area heat stress monitor. Serial number: KL7010029. Calibration certificate number HM/HS-0092.

The instrument basically contains three sensors and provides for solar and no solar load conditions.

The WBGT is directly read of the instrument. An added advantage is that only sensors and not the whole instrument is exposed to the hot conditions.

Multiple sensors can be used with this instrument. All these instruments can be connected to a PC or printer and the individual values obtained by the instrument can be downloaded.

The employee is continuously exposed to a hot environment, thus the temperature taken over a period of between 1-2hours.

The calculated TWA WBGT index were measured over a period not less than 60minutes, can now be compared with:

- OHS Act Environmental Regulations, regulation 2. TWA WBGT not more than 30,
- TLV Values – ACGIH,
- ISO 7243 standards see annexure, table 2 for standard.

The measurement of core body temperature:

Body temperature is reflected by:

- Core temperature with an average of 37°C (constant during rest within 1°C);
- Oral temperature with an average of 36,8°C (readily influenced by ambient temperature and when liquids are taken);
- Skin or shell temperature with an average of 32-33°C (strongly influenced by ambient temperature).

By using a normal thermometer placing it under the person's tongue for two minutes an oral temperature was obtained, this was done before entering the area and immediately after exiting the heat stress area.

Core temperature was obtained using a Quest Temp° II personal heat stress monitor. Serial number: JU8030003. Factory calibrated. A thermometer was inserted into the ear and isolated from external environmental sources.

This instrument is factory calibrated once a year. A stabilization time of 5-10minutes is allowed when the instrument is inserted.

Data were recorded over a period of 1-2 hours depending on sampling time and electronically downloaded on a PC.

The measurement of body weight

An athlete can lose as much as 2.3-4.5kg in weight, in a period of 1 hour during endurance athletic events under hot and humid conditions. Essentially all of this weight loss results from loss of sweat (Guyton et al., 1996).

The same principle will apply to workers, doing strenuous work under hot conditions.

Loss of enough sweat to decrease body weight can influence a person's performance. If enough body weight is loss via sweat it could lead to muscle cramps, nausea and other effects. (Barrow & Clark, 1998)

Body weight was measured with an electronic scale before and after entrance into the hot environment. This was done with the person not having eaten before measurement and with only his underpants on.

General comments

Clothes:

All the test subjects wore two piece overalls. These overalls were all long sleeved.

RESULTS:

The results are summarized in the tables below:

Table 1: Detailed results of all measured factors.

Person	Weight Before	Weight After	B/P Before	B/P After	Pulse before	Pulse after	Core temp before	Core temp after	Age
1	91.3	91.2	130/86	148/96	84	88	36.7	38	38
2	71.4	71.4	122/74	130/80	104	92	36.9	37.9	20
3	78.9	78.7	134/90	141/94	58	60	36.1	39	29
4	72.3	72.1	114/70	120/75	88	90	37.1	38	24
5	80.5	80.4	126/74	128/75	77	80	35.9	37	32
6	82.6	82.3	138/80	142/81	87	92	36.4	38.4	36
7	67.8	67.7	109/65	120/67	78	78	37	37.8	51
8	59.9	59.7	148/80	158/89	81	84	36.9	37.1	45
9	84.6	84.4	117/76	120/76	65	69	36.4	37.6	37
10	94.9	94.6	140/90	151/96	79	83	37.1	38.6	48
11	90.2	90.3	131/70	137/75	84	86	37	37.2	38
12	70.6	69.9	107/68	112/70	87	94	36.9	38	41
13	77.8	77.8	111/69	115/74	69	77	37.4	37.6	30
14	84.8	84.6	124/78	135/82	68	70	37	37.1	42
15	67.5	67.5	113/64	120/66	66	68	36.7	38.4	49
16	72.3	72.1	110/70	119/76	91	86	37.5	39.7	21

The data was statistically tested using the t-test for paired data. The significance of the measurements was tested.

Table 2: Environmental temperature measured in WBGT

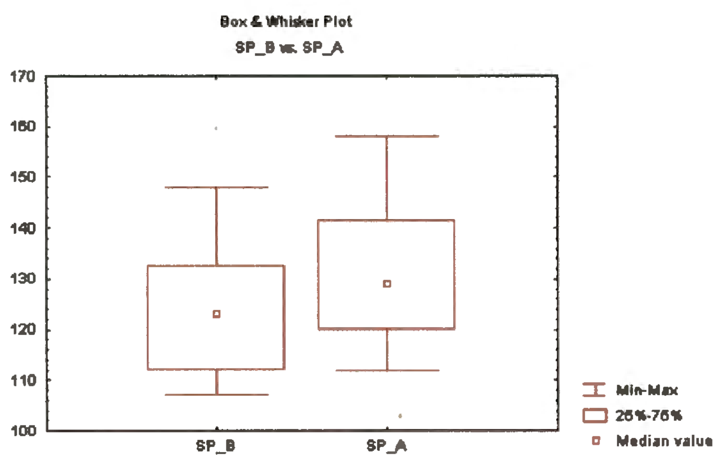
Time (min)	Study 1 (°C)	Study 2 (°C)	Study 3 (°C)
0	26	23	28
15	29	26	30
30	30	29	33
45	31	31	35
60	31	33	36
75	32	31	36
90	32	29	35
105	31	29	36
120	31	28	37
135	30	30	36
150	30	30	36

Study 1, 2 &3 are average temperatures representing 112 feet level of boilers 3, 4 & 5 taken over 150min.

Table 3: T-test for Systolic blood pressure in mmHg

{PRIVATE}	MEAN	STD_DV_	N	DIFF_	STD.DV.	T	DF	P
Systolic bp Before	123.3750	12.55322						
Systolic bp After	131.0000	14.01428	16	-7.62500	4.014557	-7.59735	15	**0.000002**

P<0.05, therefore there is a significant difference between systolic blood pressure before and after exposure to heat stress.

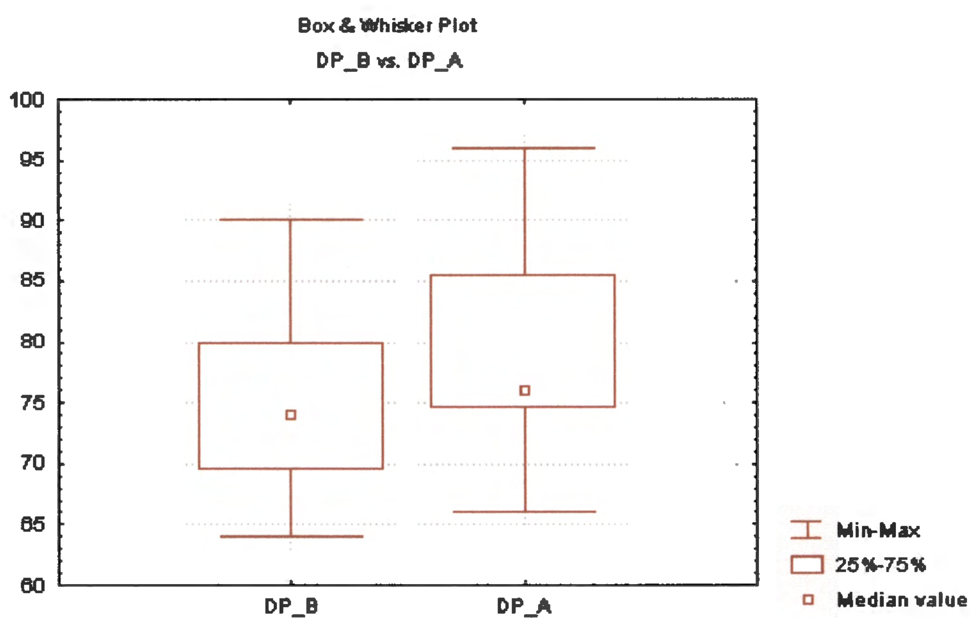


Graph 1. Difference between diastolic blood pressure before and after entering hot environment.

Table 4: T-test for Diastolic blood pressure in mmHg.

{PRIVATE}	MEAN	STD_DV_	N	DIFF_	STD.DV.	T	DF	P
Diastolic bp Before	75.25000	8.217867						
Diastolic bp After	79.50000	9.654015	16	-4.25000	2.840188	-5.98552	15	**0.000025**

P<0.05, therefore there is a significant difference between diastolic blood pressure before and after exposure to heat stress.



Graph 2. Difference between diastolic blood pressure before and after entering hot environment.

Table 5: T-test for Weight in kg.

{PRIVATE}	MEAN	STD_DV_	N	DIFF_	STD.DV.	T	DF	P
WEIGHT Before	77.96250	9.779494						
WEIGHT After	77.79375	9.797038	16	0.168750	0.181544	3.718101	15	**0.002061**

P <0.05. Therefore there is a significant difference between the readings.

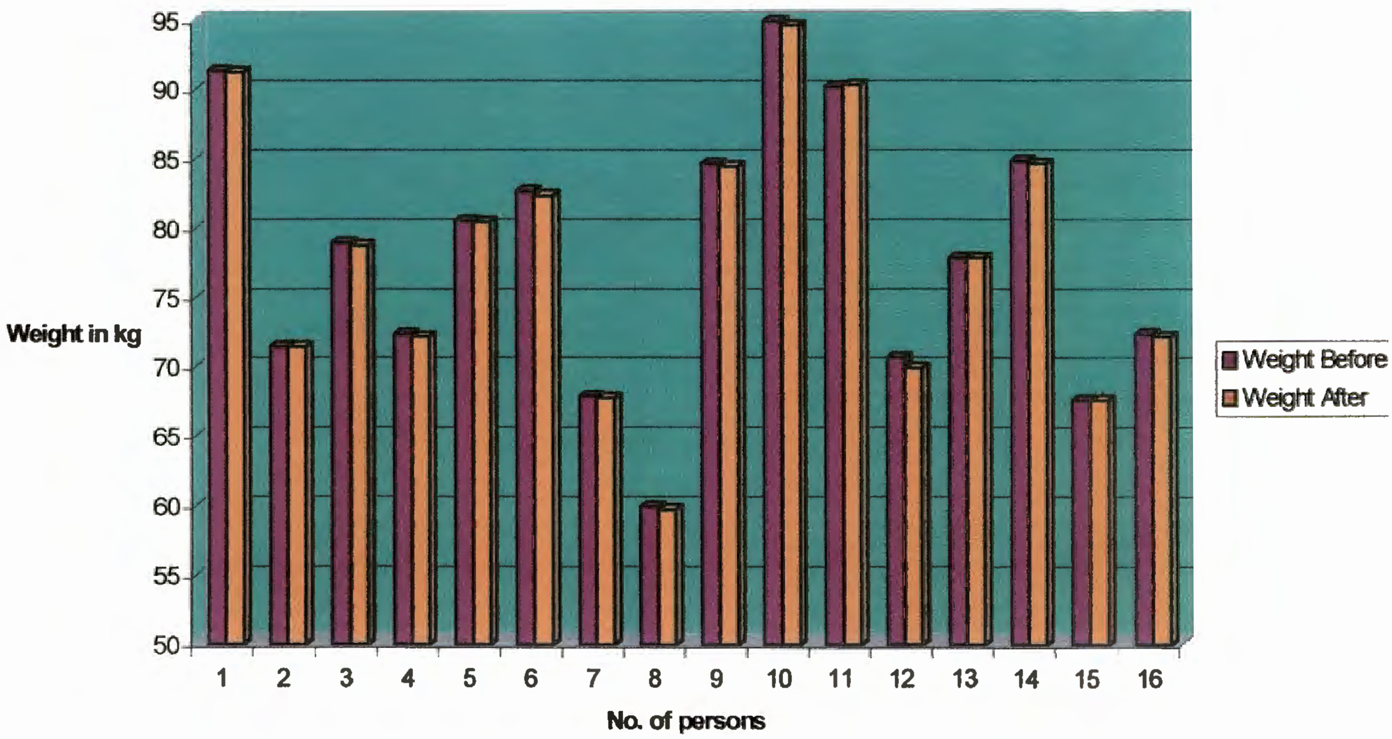


Figure 1. Weight before and after entering heat stress area

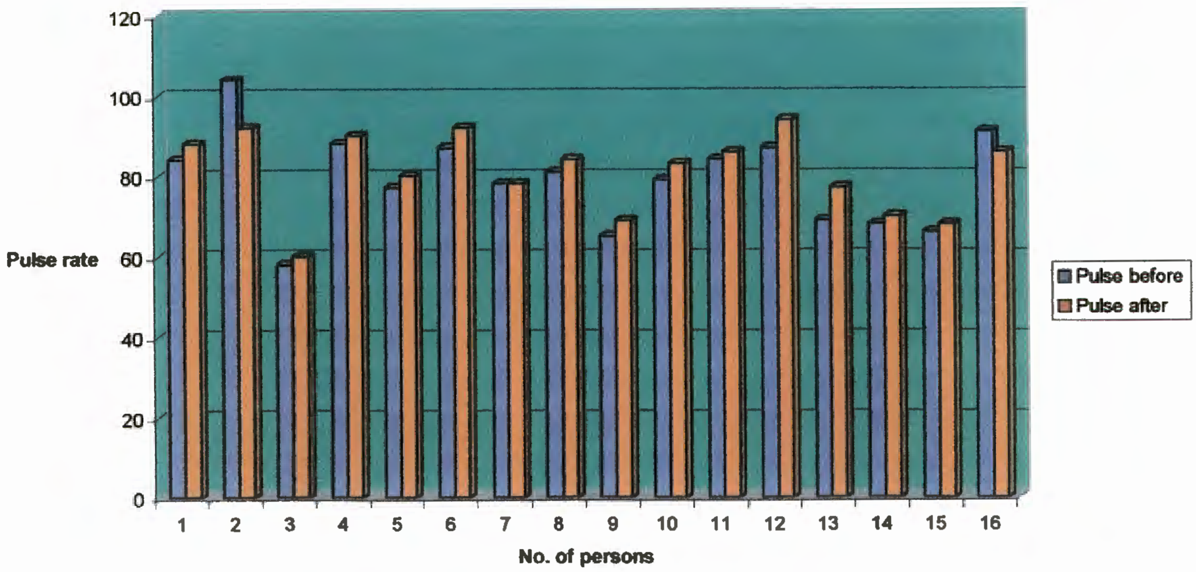


Figure 2. Pulse rate before and after entering heat stress area

Table 6: T-test for Pulse rate per minute.

	MEAN	STD_DV_	N	DIFF_	STD.DV.	T	DF	P
PULSE Before	79.12500	11.72959						
PULSE After	81.06250	10.01644	16	-1.93750	4.711245	-1.64500	15	**0.120758**

P >0.05. Therefore there was no significant difference between before and after entering heat area.

The study sample was to small to indicate a significant difference in pulse before and after entering heat area.

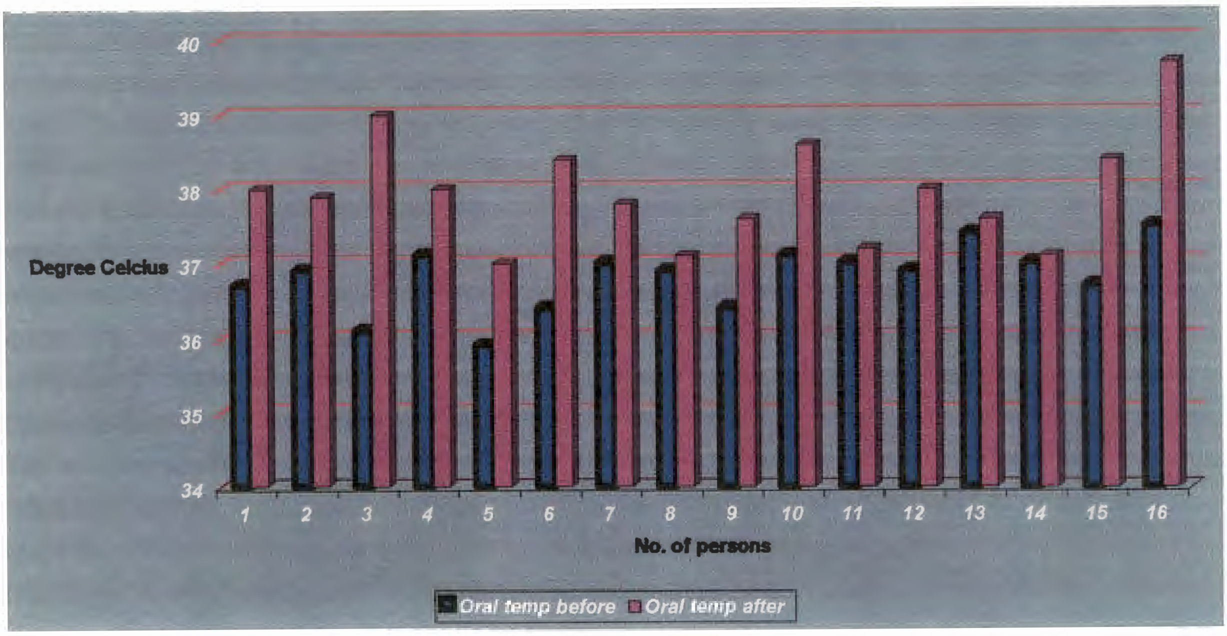


Figure 3. Core temp before and after entering heat stress area

T-test for Dependent Samples (Table7)

	MEAN	STD_DV_	N	DIFF_	STD.DV.	T	DF	P
Temp Before	36.81250	0.433397						
Temp After	37.96250	0.738354	16	-1.15000	0.789937	-5.82325	15	**0.000034**

$P<0.05$. Therefore there is a significant difference between readings taken before and after entering heat stress area.

VI. DISCUSSION OF RESULTS

Below is a normal blood pressure distribution curve indicated the different stages of hypertension.

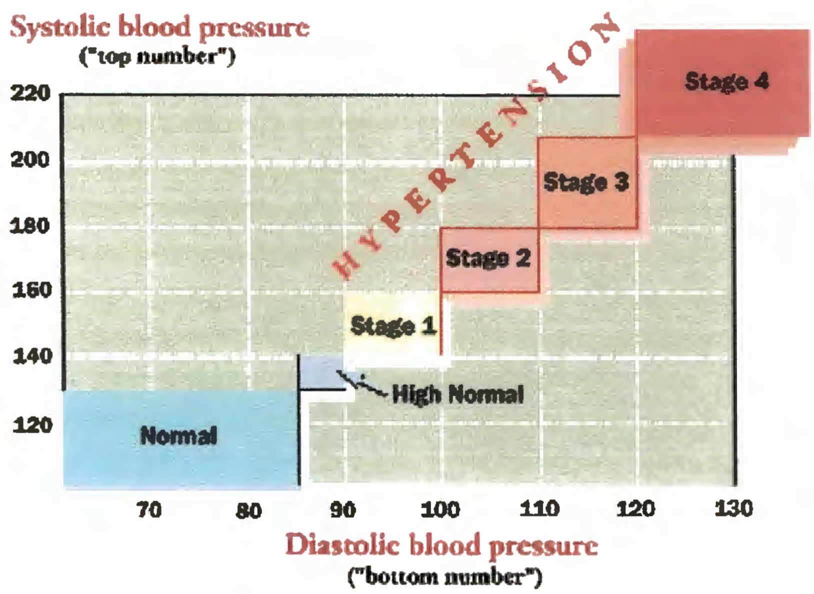


Figure 4: Blood pressure distribution curve

(Barrow &Clark, 1998)

As indicated in the results most of the blood pressure the entire test subjects indicated a difference in readings before and after entering the heat stress area.

Some of the test subjects indicated a higher increase in diastolic blood pressure then others. This could be due to their physical build. One of the contributing factors could be obesity.

Blood pressure is influenced by high noise levels as well as others factors. The employees were exposed to high noise levels in the hot environments thus blood pressure cannot be used in isolation as the only indication that exposure to hot environments increases blood pressure (Viljoen, 1996).

As indicated in the study all three test groups showed an increase in blood pressure, core temperature, pulse rate as well as a reduction in body weight due to the effects of exposure to heat.

Heart rate

As temperature increases as indicated in table 2 the heart rate of the various test subjects increased as well (Table 6). This indicates that prolonged exposure to hot environments raises pulse rate. This is especially prominent in unacclimatized and unfit persons.

The P value was however larger than 0.1, which indicates that the sample number was too small to get a significant difference between measurements before and after entering heat area.

Weight loss

Almost all the workers indicated a reduction in weight with exposure to hot environments. This weight loss could be attributed to the fact that the sweat rate increased as exposure to heat stress increased. Water contributes more than 60% of the body weight for humans. An un-acclimatized person can loose between 700ml – 2L of water every hour as well as 15 to 30 grams of salt each day, when exposed to hot environments. (Guyton & Hall, 1996)

It could be said that an increased exposure to heat stress could cause an increased in body fluid loss, which in turn will cause an increase in weight loss.

Core temperature

It should be remembered that core temperature was used as an indication of the effect of heat stress on the human body core temperature.

Core temperature increased in most test subjects with an increase in heat exposure. Body temperature will increase up to a certain level until the body's thermo-regulatory system kicks in and increases sweat rate. This will in turn reduce/retain the body's temperature.

To protect workers against the exposure to heat stress conditions it is advisable to implement a heat stress management program as laid out below.

The net heat exchange between a worker and the environment depends on various factors such as evaporation, radiant heat, metabolic heat and air-movement.

Metabolic heat and work load

Although workload was not considered during this study it can assumed that with an increase in workload, metabolic rate would increase, thus an increase in body temperature.

The tempo at which a person performs his task can also determine heat load on the body. The faster a task is done the higher the oxygen consumption and thus an increase in metabolic rate, which in turn will increase body temperature.

It can be assumed that a person who is acclimatized and physical more fit will have less heat strain on their bodies. This means that a acclimatized person will have a lower heart rate, a lower body temperature and a higher or better sweat rate, with more pure or dilute sweat. (National Safety Council).

VII. CONCLUSION

It can thus be concluded that maintenance workers exposed to hot environments can put extra strain on their body's temperature regulatory system. With an increase in exposure to hot environments the workers heart rate and core temperature will increase as well as their body weight that will decrease. Other factors such as work load and physical fitness and build of a person can also contribute to increase strain on the body's thermoregulatory system.

Sweat production and heat exchange becomes difficult when core temperature exceeds 39°C and it is generally accepted in the industry that core body temperature should not be permitted to rise above 39°C. (NIOSH)

While this reading seems very low, other factors also play a role in heat stress as experienced by the person. These factors include age, sex, inherent work capacity and fitness. Although the average heart rate was below 100beats/minute, it should be noted that the heart rate is related to work load and environmental temperature. The type of work conducted during the study was considered as light work and it can be expected that heart rate will increase with an increase in workload (see table 8 below).

Table 8. General relationship between work rate and oxygen consumption. (Zenz, 1988).

Category	Oxygen consumption (L/min)	Heart rate (beats/minute)
Light	0.5 – 1.0	75 – 100
Moderate	1.0 – 1.5	100 – 125
Heavy	1.5 – 2.0	125 – 150
Very heavy	2.0 – 2.5	150 – 175
Extremely heavy	>2.5	>175

The Occupational Health and Safety Act (Act 85 of 1993) sets 30°C WBGT as a maximum level of exposure to hot environments. Eskom maintenance workers were exposed to levels above 30°C WBGT whilst worker at the 112 feet level at boilers 3, 4, and 5 as indicated in table 2.

Appendix A, is a drafted guideline on Heat Stress Management, which incorporates factors such as medical history, fitness, age and most other factors that influences heat stress.

It is advisable that Eskom maintenance workers be subjected to this Heat Stress Management programme, to protect the worker from overexposure to heat stress.

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ESKOM **GUIDE**

(Draft 1)	REFERENCE	REV
	ESKAGAAO3	**0**
TITLE: **HEAT STRESS MANAGEMENT GUIDELINES**	DATE: **FEBRUARY 2000**	
	PAGE **1** OF **20**	
	REVISION DATE: **FEBRUARY 2002**	

COMPILED BY	FUNCTIONAL RESP.	AUTHORIZED BY
....	....	....
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	Risk Control Manager	**ED (Finance)**

Contents

1 Scope

This document sets out guidelines on occupational exposure to heat stress. The document gives guidelines to assist with the compilation of a Heat Stress Management Programme to meet the specific requirements of Eskom.

The guidelines provided are based on current best practices locally as well as internationally. The guidelines are directed solely towards personal protection, and assume that optimized environmental control practices and procedures are in place. It is a common philosophy amongst health and safety professionals to examine the use of engineering controls as the first choice.

2 References

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3 Abbreviations

3.1 EHSI: Emergency Heat Stress Index

3.2 GT: Globe temperature

3.3 HSM: Heat Stress Management

3.4 OHS Act: Occupational Health and Safety Act (Act 85 of 1993)

3.5 WB: Wet bulb temperature

3.6 WBGT: Wet bulb globe temperature (as an index)

4 Guide

I. 4.1 Heat stress management

Heat Stress Management can be defined as a multifaceted approach to promote worker health and safety through minimizing human heat stress and the incidence of heat disorders.

It is recommended that Eskom considers implementing a Heat Stress Management Programme consisting of the following elements:

a) the detection of medical and physical contra-indications for work in heat by means of appropriate screening procedures;

b) the natural progression of heat acclimatization on the basis of safe work practices; and

c) the implementation of special precautions when working in abnormally hot environments.

II. 4.2 Categorization of the thermal environment

Heat Stress Management should apply to all workers who work in hot environments and full understanding of the thermal environments is a prerequisite with respect to the allocation of employees to their respective areas of work.

The categorization in table 6 is recommended:

Table 1 – Categorization of the thermal environment

1	2	3	4
Categorization	**"Cool"**	**"Hot"**	**"Abnormally hot"**
Interpretation	**Risk of heat disorders negligible**	**Potentially conducive to heat disorders**	**Unacceptable risk of heat disorders**
Permissible Thermal Environment	WBGT ≤ 30,0°C WB < 27,5°C GT < 37,0°C	WBGT 30-35°C WB 27,5-32,5°C GT ≤ 37,0°C	WBGT > 35°C WB > 32,5°C GT > 37,0°C
Action	HSM not mandatory	HSM mandatory	No routine work. Special precautions

In defining any particular thermal environment, the precautions listed below should be heeded:

a) Care should be exercised to detect trends where the thermal environment changes, especially from "cool" to "hot" to "abnormally hot". Regular monitoring is clearly indicated, even if only on a random basis, and "cool" environments should not be excluded, especially when marginal. The specific protocol will be dictated by prevailing circumstances, and, therefore, cannot be stipulated or prescribed.

b) The thermal environment of any particular area of work should be defined in terms of the maximum, not average, prevailing temperatures recorded.

c) Seasonal drifts could be crucial and to rely on winter temperatures may lead to an underestimation of the risk. Environmental monitoring should take this into account.

III. 4.3 Overall fitness for work in hot environments

Based on the premise that some workers are relatively heat intolerant, the problem of how to predict individual heat tolerance becomes important. Medical evaluation is advised for all workers who enter hot environments in the normal course of their duties.

Wide variation exists among people with respect to heat stress tolerance, making it difficult to predict individual responses. However, several general physical and physiological characteristics are associated with some intolerance.

Overall fitness for work in hot environments will depend on the outcomes of

1) a purpose-developed general medical examination; and

2) a specific physical evaluation.

A. 4.3.1 General medical examination

The nature of the general medical examination may well include elements specific to a particular occupation and associated hazards. In the present context the following listing applies to environmental heat as a health hazard, most notably where physically demanding work is undertaken. The information presented is intended to provide guidance. The ultimate evaluation test lies with the examining physician.

4.3.1.1 History

a) Occupation related.

b) Medical, especially where treatment is based on medication which is likely to increase susceptibility to heat disorder significantly.

c) Family/social, including alcohol or substance abuse.

d) Heat disorders (cramps, exhaustion, stroke).

4.3.1.2 Urinalysis

a) Origins of haematuria, proteinuria and glycosuria must be established and assessed.

4.3.1.3 The examination should exclude testing for

a) Jaundice.

b) Anaemia.

c) Cyanosis.

d) Clubbing.

e) Oedema.

e) Abnormal lymph nodes.

f) Febrile disease.

4.3.1.4 Uncontrolled hypertension (>160/95) and gross cardiovascular abnormalities require a full investigation. So-called 'functional' murmurs should not be considered a problem. Specialist opinion regarding fitness for physically demanding work in heat may be required. Hypertension must be controlled.

4.3.1.5 The skin must be intact with no infections such as advanced athlete's foot, cellulitis scabies, etc.

1.3.1.6 The respiratory function, as determined by spirometry and chest X ray, must be normal.

1.3.1.7 An ear, nose and throat examination must exclude inflammation or infection (tonsillits, pharyngitis, chronic supportive otitis media, etc.).

1.3.1.8 No organomegally or hernias must be present. Sexually transmitted disease must be absent.

1.3.1.9 Gross neurological examination must be normal.

4.3.1.10 No other abnormality that may compromise physical work in heat must be present.

Occupational Medical Practitioners must develop knowledge such that difficult decisions in 'grey' areas are taken fairly and professionally, bearing in mind the avoidable dangers of heat disorders.

B. 4.3.2 Medication and substance abuse

It is useful in the present context to consider drugs or other substances that may compromise heat tolerance under two main headings, namely those taken for:

a) medical reasons, both prescription and non-prescription, and for

b) substance abuse.

Drugs may disrupt temperature regulation by two major mechanisms. Firstly, the "set-point" temperature can be changed through modifying the function of the effector systems. In the case of heat disorders interference with the heat loss pathways is of primary importance. Since peripheral vasodilatation and sweating are the physiological effectors involved, it can be predicted, at least potentially, that cutaneous vasoconstrictors (sympathomimetcis) and cholinergic blockers, respectively, will suppress these functions. However, there are anomalous cases, for example, some antihypertensive drugs, which induce peripheral vasodilatation, can also place the individual at risk due to other actions of the compounds aside from their primary therapeutic effect.

Temperature regulation can also be disrupted by drugs, which modify endogenous heat production. In this context excess muscle heat production may occur following the administration of drugs which lead to uncoupling of oxidative metabolism, which increase muscle tone, as in neuropletic syndrome, or which induce agitation, hyperactivity or seizures.

With few exceptions (such as malignant hypothermia), drug-induced hypothermia alone does not usually endanger life under normal environmental conditions; however, when factors are combined, as in strenuous work in heat, they may prove fatal.

Against this background, the following agents may impair heat tolerance:

a) Diuretics, especially thiazides.

b) Phenothiazines, especially long-acting.

c) Butyrephenones.

d) Thioxanthenes.

e) Tricyclic antidepressants.

f) Sedative hypnotics.

g) Sympathomimetics.

h) Thyroid agonsits.

j) Beta-blockers.

k) Vasodilators (controversial).

It is recommended that those patients (employees) on such medication:

1) receive counselling appropriate to the drug in use and its potential to lower heat tolerance and, concurrently, avoid non-prescription over-the-counter anticholinergic agents found in drugs such as cold preparations, sleep-inducing medicines and antihistamines; and

2) do not exhibit other risk factors which collectively constitute an unacceptable risk, as described in following sections.

With regard to substance abuse, there are no unequivocal links between an increased incidence of heat disorders and substance abuse, mostly as a result of inadequate controlled data. However, this does not mean that substance abuse, where detected, should be underestimated. The following general comments, extracted from the referenced literature, provide further guidance.

a) The actions of amphetamines, via noradrenaline release, lead to hyperthermia via increased muscle activity and heat production, as well as enhanced cutaneous vasoconstriction

b) Cannabis (marijuana) smoking has little effect on body temperature and shows slight upwards or downwards drifts depending on environmental conditions.

c) Cocaine taken in "recreational" doses has been associated with terminal hyperpyrexia after severe physical activity.

d) Alcohol abuse, especially following "binges", appears to be a significant causal factor in the development of heat stoke. Dehydration is the most profound and direct underlying reason. Chronic alcoholism is probably not of lesser concern.

This section is not exhaustive nor is it intended to be so. However, the purpose is simply to raise medication and substance abuse as a potential additional risk factor, which, in isolation, need not necessarily preclude an employee from working in hot environments. Decisions on fitness to undertake work in heat should also take into account the full risk profile of the employee.

C. <u>4.3.3 Physical evaluation</u>

The physical evaluation must be conducted as part of the medical examination but with special emphasis on features, which would rule out physical work or exertion in heat.

Age

Age per se does not have a direct bearing on heat tolerance and should not serve as a contra-indication for work in heat, in isolation of other factors. Heat intolerance does, however, decline with reduced physical work capacity which in turn, could have cardiovascular origins which do not necessarily become manifested through routine medical examinations. The underlying mechanism is an obligatory age-associated reduction in cutaneous vasodilatation (widening of skin blood vessels) and sweat rate. A critical age limit of 50 years has been cited. This view is confirmed by local studies in the South African Mining Industry which show a decided increase in heat stroke susceptibility with advancing years.

As a general rule employees of 50 years and above must only be considered for strenuous work in hot environments, provided that there is a complete absence of any other personal risk.

Body dimensions

In this respect two criteria apply, namely

a) an acceptable body mass to height ratio to rule out both under- and overweight individuals, and

b) minimum body mass as a criterion of the capacity to cope with externally imposed work demands.

Body mass relative to height is often expressed in terms of the Body Mass Index or BMI.

It provides a better predictor of disease risk than weight (mass) alone. A high BMI leads to an increased risk to develop certain diseases, for example, hypertension, cardiovascular disease, dystipidaemia, adult-onset diabetes (type II), osteoarthritis and other conditions. The above examples constitute a condition of co-morbidity, i.e. any condition associated with obesity (BM1 of 30 to 35). Co-morbidity usually worsens as the degree of obesity increases, and often improves if successfully treated.

BMI can be calculated using the equation:

$$BMI = \text{body mass (kg)}/\text{height (m)}^2$$

The BMI is then expressed in terms of the following classification, the lower limit being based on the anthropometry of local mine workers:

< 15 : emaciated

15 to 19 : underweight

20 to 25 : normal body fat content

26 to 29 : overweight (warning)

30 to 35 : obese (over risk factor)

> 35 : exclusion

The BMI must be used in conjunction with the essentially nude body mass to assess the adequacy of body dimensions relevant to physical work in hot environments. A distinction must be made between prospective or new employees and existing employees. Calculated BMI values, for a wide range of body mass and height combinations, appear in table 7 and a protocol for this assessment, in conjunction with a recommended course of action, is given below. A BMI of 30 or more constitutes a definitive risk factor.

Table 2 – Body dimensions as criteria for physical work in hot environments

1	2	3
Employee status	**Criterion/standard**	**Interpretation and recommended course of action**
Prospective	Body mass < 50 kg Body mass 50 kg to 55 kg	Unsuitable (BMI irrelevant) : reject. Suitable but not for 'strenuous' work. Suitable.

	BMI 15 to 29 BMI 30 to 35 BMI > 35	Suitable with no medical contra-indications. Unsuitable : reject.
Existing	Body mass < 45 kg Body mass 45 kg to 50 kg Body mass 45 kg to 55 kg BMI < 15 BMI 15 to 19 BMI 20 to 29 BMI 30 to 35 BMI > 35	Unsuitable (BMI irrelevant) : reject. Suitable with no medical contra-indications or a history of heat disorders. No allocation to 'strenuous' work (> 160 $w.m^{-2}$). Unsuitable. Suitable with no medical contra-indications or history of heat disorders. Suitable. Suitable provided no medical contra-indications or history of heat disorders. Unsuitable.

IV. 4.4 Work practices

Once a worker has been passed as medically fit for work in a hot environment, it is recommended that he takes up his normal duties. However, because he may not be fully heat acclimatized, certain precautions need to be introduced. Normally, within a period of twelve shifts, workers will develop an adequate degree of acclimatization. It is strongly recommended that the following work practices be adopted as standard routine.

Safe work practices comprise:

a) ensuring that acceptable work rates are maintained in order to avoid the early onset of fatigue; this would be achieved through work-rest cycles where work is of necessity strenuous and ongoing or by instilling, through constant reminders, a sense of self-pacing. (Resting should take place in a cooler environment);

b) ensuring that fluid replacement beverages (preferably only water or hypotonic fluids) are available at the place of work and that a fluid replacement regimen of at least 2 × 300 ml per hour is observed;

c) checking workers for overt signs of ill health and removing those persons from the place of work for attention appropriate to the situation;

d) the detection of early signs and symptoms of heat disorders (workers to be thoroughly briefed on these signs and symptoms in order to recognize them in themselves and their co-workers); and

e) ensuring that emergency treatment and communication facilities are available and fully functional.

The effect of dehydration due to sweat loss may be reversed by drinking enough fluid to replace the sweat. The common advice is to drink when thirsty. There are, however, some very important problems in this. One is that the urge to drink is not strong enough to replace the simultaneously occurring water loss; and secondly, the time needed to replace a large water deficit is very long, more than twelve hours. Lastly, there is a limit to the rate at which water can pass from the stomach (where it is stored), to the intestine (gut) where the absorption takes place. This rate is lower than observed sweat rates during hard physical work in hot conditions. Workers should thus be encouraged to drink more than their urge, also between shifts.

V. 4.5 Induction and awareness training

Induction is recognized as an integral component of most industrial training programmes. This certainly applies in Eskom. Whereas induction could be considered as the "how" in any awareness campaign, the "why" can only be achieved through education.

These fundamental principles are relevant to the implementation of Heat Stress Management and the importance of proper education and induction cannot be over-emphasised.

The primary targets of such a training programme are the workers exposed to heat stress and their supervisors. In addition, the emergency response team and nursing or other staff responsible for first-aid need to be proficient in recognizing and treating heat illnesses.

For general training, emphasis could be placed on the basic understanding of causes of heat stress, the physiological and psychological responses, and heat illnesses. The purpose of the training is to teach the worker how to deal with heat stress and especially how to recognize when he is nearing overexposure. Knowledge of the causes of heat stress and the physiological responses to it provides the foundation for understanding the safe work practices to be introduced.

First-aid treatment of heat illnesses is of cardinal importance. Because early treatment is important, the individuals responsible for the first-aid must know how to recognize and treat the most common and the most serious forms of heat illnesses.

Initial education and induction should be reinforced through regular awareness retention assessments. Heat disorders are notoriously multi-factorial in origin, the root of the problem being complacency. It is, therefore, essential that high levels of awareness are maintained and, ideally, such assessments could well be incorporated in both internal and external audits of the entire Heat Stress Management Programme.

Heat Stress Management should not be implemented in the absence of a well-structured programme of education and induction.

VI. 4.6 Organization framework for heat stress management

By definition Heat Stress Management is based on multi-disciplinary inputs and control and it is proposed that the overall control cannot be delegated but that it remains a management function. The multi-disciplinary nature of Heat Stress Management does, however, suggest the need for some form of central co-ordination, a function that certainly can be delegated.

An organizational framework for the control of Heat Stress Management is outlined in figure 5. This should be viewed as a general guide which would be tailored to meet particular requirements of each unit.

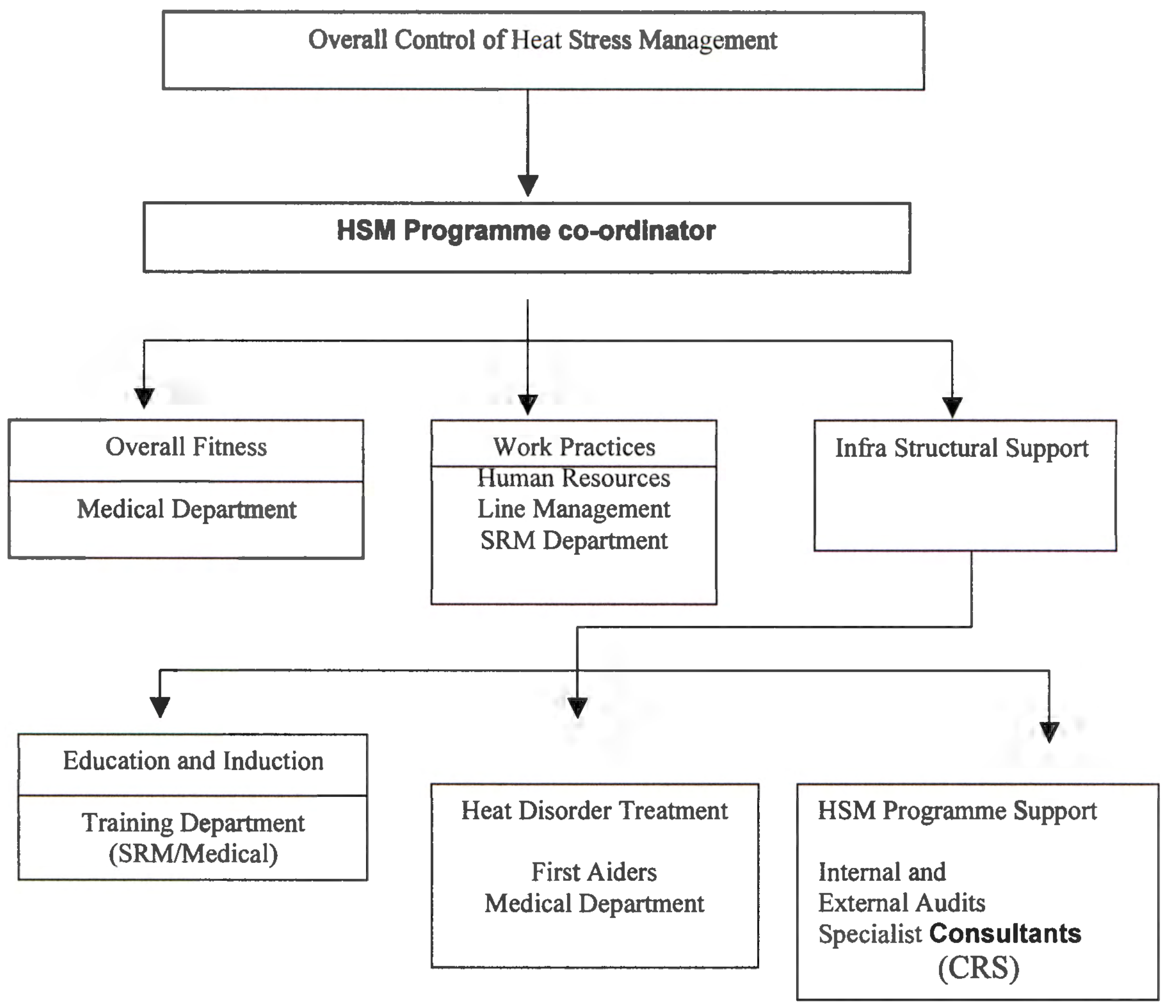

Figure 1 – Organizational Structure for Heat Stress Management

VII. 4.7 Clothing

In an industrial setting clothing serves as a barrier between the skin and the environment to protect against hazardous chemical, physical and biological agents. Clothing interferes with heat loss from the skin, and skin temperature rises predictably with increased clothing. Because the insulation induces rise in skin temperature and the resultant limited ability to dissipate heat that has been transferred from the core to the skin, core temperature also rises when clothing is worn.

Generally the above effects are dependent on the surface area covered and the fabrics. The thicker and greater the air and vapour impermeability, the greater is its interference with the convective, radiative, and evaporative heat exchange. Studies of clothing have led to the conclusion that the insulation provided by clothing is generally a linear function of it. Differences in fibres or fibric weave, unless they directly affect the thickness or vapour or air permeability of the fabric, have only minor effects on insulation.

Clothing insulation is normally measured using an arbitrary unit, called the "clo". (The value of insulation provided by 1 clo is what is required to keep a sedentary person comfortable at 21°C). The insulating value of a typical industrial clothing ensemble (e.g. cotton pants and shirt with open neck) is approximately 0,5 clo to 0,7 clo, compared to the 0,8 clo to 1,0 clo of heavy overalls. (Bernard et al., 1986)

VIII. 4.8 Work in abnormally hot environments

Certain activities, such as maintenance and emergency work, often have to be undertaken in environments where heat loads exceed limits prescribed for routine work. A review of both local and international standards indicated that the available information on safe exposure times is very limited.

D. 4.8.1 Safe exposure limits

Guidelines on safe exposure limits have recently been prepared for the South African Mining Industry. The relationship between Wet Bulb Temperature and safe tolerance times is given in figure 6. (Ramsey, et al. 1983)

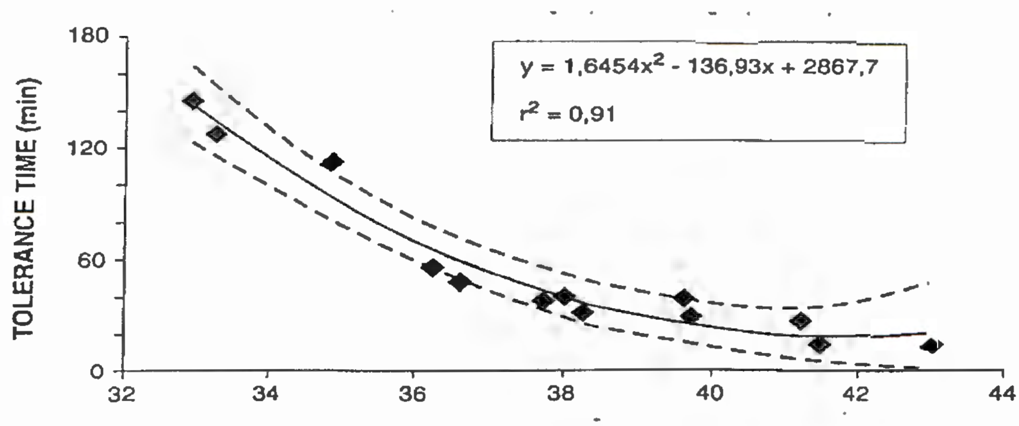

Figure 2 – Predicted Tolerance Times for WBGT Values

WBGT could be used as an index to determine tolerance times, or alternatively, the "Emergency Heat Stress Index" or EHSI developed for the South African Mining Industry could be used. (ESHI is the arithmetic mean of wet-bulb temperature and dry-bulb temperature). Estimated tolerance times using ESHI are given in table 2. (Schutte & Kielblock, 1997).

Table 3: – Tolerance times for various WBGT levels with and without the benefit of body cooling garments

1	2		
WBGT	**Tolerance time (minutes) : Recommended limit**		
(°C)	**Moderate work**	**Strenuous work**	**Body cooling garment benefit(min)**
30	230	230	+30
31	200	180	+30
32	175	140	+30
33	150	110	+30
34	130	85	+30
35	110	60	+30
36	90	40	+30
37	70	25	+30
38	60	No work	+20
39	50	No work	+20
40	40	No work	+20
41	30	No work	+20
42	30	No work	+20
43	20	No work	+20
44	20	No work	+20
45	15	No work	+20

(ACGIH. 1978.) (Schutte & Kielblock, 1997)

E. **4.8.2 Other special precautions**

Any operation in abnormally hot conditions must be undertaken only under the direct supervision of line management. The impact element is that of observing recommended

precautions as well as the early detection of the onset of fatigue and heat disorders. Proper instruction is, therefore, indicated during operations.

Workers involved in work in abnormally hot environment must have passed heat tolerance screening and been declared fit for work in heat. They also should have rested since the previous shift.

Apparent signs of alcohol over-indulgence and incipient illness represent serious contra-indications and such cases should not be allowed to participate in any operation in heat.

The importance of self-pacing as a means to avoid the onset of fatigue should be stressed. Steps should be taken to ensure that drinking water is available at the place of work and that regular water breaks are observed. Any employee showing early signs of heat disorders, notably behavioural changes must be removed to a cool area immediately and treated accordingly. This implies that emergency body cooling facilities should be readily available.

The use of body cooling garments during work in abnormally hot conditions should also be considered. (Kielblock & Schutte, 1998.)