Sudan University of Science and Technology

College of Post-Graduation studies

# INVESTIGATIONS OF HEAT STRESS PARAMETERS ON FOUNDRIES WORKERS PRODUCTIVITY

تقييم عوامل الاجهاد الحراري على إنتاجية عمال المسابك

Thesis submitted in Partial fulfillment of the requirements for the Degree of M.Sc. in Mechanical Engineering (Production)

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وَقُل رَّبِّ زِدْنِي عِلْمًا

صدق الله العظيم

# DEDICATION

This work is dedicated to my family and many friends. Special feeling of gratitude to my loving parents, whose words of encouragement and push for tenacity ring in my ears. My mother, my husband, my brothers and sisters.

Also, this work dedicated to many friends, they have supported me throughout the process. I will always appreciate all they have done.

In addition, I dedicate this work to ALBYAN FOUNDRIES family, where this work is done.

Last, but not least I dedicate it to my homeland Sudan.

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There are people like candles burn to light the way of the others, during this research I found many, give deep helping, the thanks is not give them their rights.

I would like to thanks, Dr. Yassin Mohammed Hamedan for his standing to complete this research.

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Finally, I wish to thank all project readers who offered countless interesting, valuable, and stimulating suggestions.

# ABSTRACT

The aim of this study is to measure the workplace heat stress in different sections of the foundries. The study was carried out in ALBYAN foundries. The heat is measured in furnace worker site, casting site, molds forming site, iron gathering point, power worker point , arm worker, crane worker, worker waiting point and finishing point measuring the dry bulb temperature (TDB °C) , wet bulb temperature (TWB °C), globe temperature (TG °C), wet bulb globe temperature (WBGT °C), and the relative humidity (RH%) at the work places. Extremely high levels of WBGT index was found in arm worker with an average of 29.77 °C followed by 29.13 °C in power worker point . The mean WBGT mean values obtained in other sections were 26.67 °C in crane worker, 24.18°C in furnace worker ,24.14°C in worker waiting point,23.17°C in Iron gathering point,22.93°C in finishing point , 22.73°C in iron ore area, 22.70°C in molds forming site and 22.65°C in casting site. The mean WBGT index levels are significantly higher in near the arm worker, power worker point, crane worker and furnace worker. The prescribed standard threshold limit value (TLV) of WBGT level was high in near the arm worker, power worker point, crane worker and furnace worker. The values of equivalent noise levels were under control as per OSHA guidelines in all the process sections. The heat may increase the health risk of worker with reduce the efficiency and consequently affect the production of the unit. The recommendations should be taken as indicative of stress areas and workers should be under constant medical supervision.

# المستخلص

الهدف من هذه الدراسة هو قياس الضغط الحراري في مكان العمل في أقسام مختلفة من المسابك. أجريت الدراسة في مسابك البيان. يتم قياس الحرارة في موقع عامل الفرن ، وموقع الصب ، وموقع تشكيل القوالب ، ونقطة تجميع الحديد ، ونقطة عامل الطاقة ، وعامل الذراع ، وعامل الرافعة ، ونقطة انتظار العمال ونقطة التشطيب التي تقيس درجة حرارة المصباح الجاف (TDB ° C) ، ودرجة حرارة المصباح الرطب (TWB ° C) ودرجة حرارة الكرة الأرضية (TG ° C) ودرجة حرارة الكرة الأرضية الرطبة (WBGT ° C) والرطوبة النسبي في أماكن العمل (RH%)

تم العثور على مستويات عالية للغاية من مؤشر WBGT في عامل ذراع بمتوسط 29.77 درجة مئوية تليها 29.13 درجة مئوية في نقطة عامل الطاقة. كانت متوسط قيم WBGT المتوسطة التي تم الحصول عليها في الأقسام الأخرى 26.67 درجة مئوية في عامل الرافعة ، 24.18 درجة مئوية في عامل الفرن ، 24.14 درجة مئوية في نقطة انتظار العامل ، 23.17 درجة مئوية في نقطة تجميع الحديد ، 22.93 درجة مئوية في نقطة النهاية ، 22.73 درجة مئوية في منطقة خام الحديد ، 22.70 درجة مئوية في موقع تشكيل القوالب و 22.65 درجة مئوية في موقع الصب. مستويات مؤشر WBGTالمتوسطة أعلى بشكل ملحوظ في قرب عامل الذراع ، نقطة عامل الطاقة ، عامل الرافعة و عامل الفرن.

كانت القيمة الحدية المعيارية المحددة (TLV) لمستوى WBGT عالية في قرب عامل الذراع ونقطة عامل القدرة وعامل الرافعة وعامل الفرن. كانت قيم مستويات الضوضاء المكافئة تحت السيطرة وفقًا لإرشادات OSHA في جميع أقسام العملية. قد تزيد الحرارة من المخاطر الصحية للعامل مع تقليل الكفاءة وبالتالي التأثير على إنتاج الوحدة. يجب أن تؤخذ التوصيات كدليل على مناطق الضغط ويجب أن يكون العمال تحت إشراف طبي مستمر.

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# LIST OF ABBREVIATION

| ABBREVIATION | Name |
|---|---|
| WBGT | Wet bulb globe temperature |
| $WBGT_{in}$ | Wet bulb globe temperature Index |
| $WBGT_{out}$ | Wet bulb globe temperature outdoors |
| $T_{nw}$ | Natural wet temperature |
| $T_g$ | Glowing temperature |
| $T_{db}$ | Dry temperature |
| R.H | Humidity |
| $T_a$ | Air Temperature |
| SPSS | Statistical application under windows |
| TLV | Threshold limit value |
| NIOSH | National Institute for Occupational Safety and Health |
| OSHA | Occupational Safety and Health Administration |
| OSIH | Open Software Information Technology |

# CHAPTER ONE
# INTRODUCTION

## 1.1 Preface:

Heat stress occurs when the body’s means of controlling its internal temperature starts to fail. As well as air temperature, factors such as work rate, humidity and clothing worn while working may lead to heat stress. Therefore, it may not be obvious to someone passing through the workplace that there is a risk of heat stress.

Heat stress is significant factor in foundries, Heat stress occurs when the body absorbs or produces more heat than can be dissipated through thermoregulatory processes and illness and death can result from the increases in core temperature [1]. Hence the workshop whatever it is. Must assess the heat stresses for each individual labor at intervals, to keep them away from any heat disorders. Behavioral factors can amplify the risks, e.g., wearing impermeable clothing such as a protective suit. Individual susceptibility to heat stress varies as a function of several physiological risk factors. Heat stress creates a progression of heat disorders with increasingly severe symptoms that can culminate in death.

Throughout history, the man tried to upgrade their life and their comfort, so that the heat stresses is one have big deal. Its noisier, and other time its lethal when people subjected to lethal heat stresses, hence the primitive people try to cover their bodies using the leafage, and through the ages develop leather clothes to prevent the solar strike and other heat stresses when they work outdoor, as to prevent their self from the cold stresses. By time the human develops the clothing and method to promote the need of the new developments.

Nowadays, the industrial revaluation, built new conditions where the labors in direct contact with hot environments, and the excessive heat stresses. The power generation plants, foundries, industries, and others plants where is excessive heat stress, it's not possible to avoid the heat stresses without ergonomic thinking. So that there is a lot off methods used to calculate the heat stresses and human comfort to sustain good work environments.

There is an occupational heat related conditions. For example impairments in the body's system causing an appropriate elevation in Creatinine as well as Creatine Kinase levels. The risk of unintentional injuries increases substantially with exposure to heat stress. [2]

The previous studies found that 88.9% of Police Traffic Officers have Knowledge of health effects of hot environment and this is good according to "involuntary dehydration" did not occur in well informed workers. These workers must not only be aware of the inherent dangers of their occupation but also the dangers imposed by the environment. Inadequate thermal stress may cause discomfort and adversely affect the performance, safety, and harm to health. [3]

Previous study observes that workers having the most exposure to heat stress. Have increased heart rate and systolic and diastolic blood pressure, body deep temperature, skin temperature and sweat secretion; however, workers experience heat stress in daily basis, which has significant effect on their performance, safety and health. Studies recommends that workers, especially workers not adapted to heat, receive trainings necessary to work in such environments. [4]

## 1.2 The Problem Statement:

Foundries generate high heat from melting furnaces, so that the most equipment's dissipate thermal energy to surrounding where Labors are in contact, the exposer to such hot environment can lead to heat stresses, and effect negatively labor productivity.

## 1.3 Significance of This Research:

The project aims to find the reasons and the effect of heat stress on the workers who are working in the foundries where the temperature is main issue. And find a way to protect the workers from the risk of the heat stress, which is very vital to their health.

## 1.4 The Objectives of the Research:

To Study practically the stress parameters in a selected foundry

## 1.5 Materials:

Wet bulb globe temperature meter (WBGT METER).

## 1.6 Method:

The study will carry out on workers in foundries in any type of work. The sample population were workers. The study will conduct using the wet bulb thermometer, dry bulb thermometer, global thermometer, and swing vane anemometer. Or in presence of assembled Wet Bulb Global Temperature instrument an index was calculated for Wet Bulb Globe Temperature according to ISO7243 standard, and metabolism rate was estimated according to ISO 8996 standard.

# CHAPTER TWO
# THEORETICAL BACKGROUND

## 2.1 Preface:

"Heat stress" is the "net [overall] heat load to which a worker may be exposed from the combined contributions of metabolic heat, environmental factors (i.e., air temperature, humidity, air movement, and radiant heat), and clothing requirements." Metabolic heat is the heat produced by the body through chemical processes, exercise, hormone activity, digestion, etc. [5]

Other heat-related terms are defined at the end of this document in the Glossary of Terms. [6]

Heat may come from many sources. For example:

- In foundries, steel mills, bakeries, smelters, glass factories, and furnaces, extremely hot or molten material is the main source of heat.
- In outdoor occupations, such as construction, road repair, open-pit mining and agriculture, summer sunshine is the main source of heat.
- In laundries, restaurant kitchens, and canneries, high humidity adds to the heat burden.

In all instances, the cause of heat stress is a working environment which can potentially overwhelm the body's ability to deal with heat.

Most people feel comfortable when the air temperature is between 20°C and 27°C and when the relative humidity ranges from 35 to 60%. When air temperature or humidity is higher, people feel uncomfortable. Such situations do not cause harm as long as the body can adjust and cope with the additional heat. Very hot environments can overwhelm the body's coping mechanisms leading to a variety of serious and possibly fatal situations. OSH Answers document contains information about the health effects of hot environments.

In many jobs heat stress is an issue all year round (such as bakeries, compressed air tunnels, foundries and smelting operations), but this information is also applicable during the hot summer months where there may be an increased risk of heat stress for some people.

Heat stress occurs when the body's means of controlling its internal temperature starts to fail. As well as air temperature, factors such as work rate, humidity and clothing worn while working may lead to heat stress. Therefore it may not be obvious to someone passing through the workplace that there is a risk of heat stress.

Employees and managers must be aware of how to work safely in heat, the factors that can lead to heat stress, and how to reduce the risk of it occurring. [3]

## 2.2 Interaction Of The Body With Heat

The body reacts to heat by increasing the blood flow to the skin's surface, and by sweating. This results in cooling as sweat evaporates from the body's surface and heat is carried to the surface of the body from within by the increased blood flow. Heat can also be lost by radiation and convection from the body's surface.

Typical example of a heat stress situation

Someone wearing protective clothing and performing heavy work in hot and humid conditions could be at risk of heat stress because:

- sweat evaporation is restricted by the type of clothing and the humidity of the environment
- heat will be produced within the body due to the work rate and, if insufficient heat is lost, core body temperature will rise
- as core body temperature rises the body reacts by increasing the amount of sweat produced, which may lead to dehydration
- heart rate also increases which puts additional strain on the body
- if the body is gaining more heat than it can lose the deep body temperature will continue to rise
- eventually it reaches a point when the body's control mechanism itself starts to fail

The symptoms will worsen the longer someone remains working in the same conditions. [4]

## 2.3 The Effects Of Heat Stress:

Heat stress can affect individuals in different ways, and some people are more susceptible to it than others. Typical symptoms are:

- an inability to concentrate
- muscle cramps
- heat rash
- severe thirst - a late symptom of heat stress
- fainting
- heat exhaustion - fatigue, giddiness, nausea, headache, moist skin
- Heat stroke - hot dry skin, confusion, convulsions and eventual loss of consciousness. This is the most severe disorder and can result in death if not detected at an early stage[4]

## 2.4 Places Thermal Stress Occurs

Workplaces where people might suffer from heat stress because of the hot environment created by the process, or restricted spaces are:

- glass and rubber manufacturing plants
- mines
- compressed air tunnels
- conventional and nuclear power plants
- foundries and smelting operations
- brick-firing and ceramics plants
- boiler rooms
- bakeries and catering kitchens
- laundries

In these industries working in the heat may be the norm. For others it will be encountered more irregularly depending on the type of work being done and changes in the working environment, eg seasonal changes in outside air temperature can be a significant contributor to heat stress. [4]

## 2.5 The Human Body Reaction To Hot Environments:

The healthy human body maintains its internal temperature around 37°C. Variations, usually of less than 1°C, occur with the time of the day, level of physical activity or emotional state. A change of body temperature of more than 1°C occurs only during illness or when environmental conditions are more than the body's ability to cope with extreme heat.

As the environment warms-up, the body tends to warm-up as well. The body's internal "thermostat" maintains a constant inner body temperature by pumping more blood to the skin and by increasing sweat production. In this way, the body increases the rate of heat loss to balance the heat burden. In a very hot environment, the rate of "heat gain" is more than the rate of "heat loss" and the body temperature begins to rise. A rise in the body temperature results in heat illnesses. [4]

## 2.6 Control Heat Gain And Heat Loss:

The main source of heat in normal conditions is the body's own internal heat. Called metabolic heat, it is generated within the body by the biochemical processes that keep us alive and by the energy we use in physical activity. The body exchanges heat with its surroundings mainly through radiation, convection, and evaporation of sweat.

Radiation is the process by which the body gains heat from surrounding hot objects, such as hot metal, furnaces or steam pipes, and loses heat to cold objects, such as chilled metallic surfaces, without contact with them. No radiant heat gain or loss occurs when the temperature of surrounding objects is the same as the skin temperature (about 35°C).

Convection is the process by which the body exchanges heat with the surrounding air. The body gains heat from hot air and loses heat to cold air which comes in contact with the skin. Convective heat exchange increases with increasing air speed and increased differences between air and skin temperature.

Evaporation of sweat from the skin cools the body. Evaporation occurs more quickly and the cooling effect is more noticeable with high wind speeds and low relative humidity. In hot and humid workplaces, the cooling of the body due to sweat evaporation is limited because the air cannot accept more moisture. In hot and dry workplaces, the cooling due to sweat evaporation is limited by the amount of sweat produced by the body.

The body also exchanges small amounts of heat by conduction and breathing. By conduction, the body gains or loses heat when it comes into direct contact with hot or cold objects. Breathing exchanges heat because the respiratory system warms the inhaled air. When exhaled, this warmed air carries away some of the body's heat. However, the amount of heat exchanged through conduction and breathing is normally small enough to be ignored in assessing the heat load on the body. [4]

## 2.7 The Effects Of Heat On The Body:

When the air temperature or humidity rises above the range for comfort, problems can arise. The first effects relate to how one's feel. Exposure to more heat can cause health problems and may affect performance.

As the temperature or heat burden increases, people may feel:

- Increased irritability.
- Loss of concentration and ability to do mental tasks.
- Loss of ability to do skilled tasks or heavy work.

In moderately hot environments, the body "goes to work" to get rid of excess heat so it can maintain its normal body temperature. The heart rate increases to pump more blood through outer body parts and skin so that excess heat is lost to the environment, and sweating occurs. These changes place additional demands on the body. Changes in blood flow and excessive sweating reduce a person's ability to do physical and mental work. Manual work creates additional metabolic heat and adds to the body heat burden. When the environmental temperature rises above 30°C, it may interfere with the performance of mental tasks. [7]

## 2.8 The Reaction To Heat:

The risk of heat-related illness varies from person to person. A person's general health influences how well the person adapts to heat (and cold).

Those with extra weight often have trouble in hot situations as the body has difficulty maintaining a good heat balance. Age (particularly for people about 45 years and older), poor general health, and a low level of fitness will make people more susceptible to feeling the extremes of heat.

Medical conditions can also increase how susceptible the body is. People with heart disease, high blood pressure, respiratory disease and uncontrolled diabetes may need to take special precautions. In addition, people with skin diseases and rashes may be more susceptible to heat. Other factors include circulatory system capacity, sweat production and the ability to regulate electrolyte balance.

Substances -- both prescription or otherwise -- can also have an impact on how people react to heat.

The National Institute for Occupational Safety and Health (NIOSH) reports that several studies comparing the heat tolerances of men and women have concluded that women are less heat tolerant than men. While this difference seems to diminish when such comparisons take into account cardiovascular fitness, body size, and acclimatization, women tend to have a lower sweat rate than men of equal fitness, size and acclimatization. This lower sweat rate means that there can be an increase in body temperature. [7]

## 2.9 The Illnesses Caused By Heat Exposure:

Heat exposure causes the following illnesses:

### 2.9.1 Heat edema:

Is swelling which generally occurs among people who are not acclimatized to working in hot conditions. Swelling is often most noticeable in the ankles. Recovery occurs after a day or two in a cool environment.

### 2.9.2 Heat rashes:

Are tiny red spots on the skin which cause a prickling sensation during heat exposure the spots are the result of inflammation caused when the ducts of sweat glands become plugged.

### 2.9.3 Heat cramps:

Are sharp pains in the muscles that may occur alone or be combined with one of the other heat stress disorders the cause is salt imbalance resulting from the failure to replace salt lost with sweat. Cramps most often occur when people drink large amounts of water without sufficient salt (electrolyte) replacement.

### 2.9.4 Heat exhaustion:

Is caused by loss of body water and salt through excessive sweating. Signs and symptoms of heat exhaustion include: heavy sweating, weakness, dizziness, visual disturbances, intense thirst, nausea, headache, vomiting, diarrhea, muscle cramps, breathlessness, palpitations, tingling and numbness of the hands and feet. Recovery occurs after resting in a cool area and consuming cool drinks (e.g., water, clear juice, or a sports drink).

### 2.9.5 Heat syncope:

Is heat-induced dizziness and fainting induced by temporarily insufficient flow of blood to the brain while a person is standing It occurs mostly among UN acclimatized people. It is caused by the loss of body fluids through sweating, and by lowered blood pressure due to pooling of blood in the legs. Recovery is rapid after rest in a cool area.

### 2.9.6 Heat stroke:

Is the most serious type of heat illness Signs of heat stroke include body temperature often greater than 41°C, and complete or partial loss of consciousness Sweating is not a good sign of heat stress as there are two types of heat stroke - "classical" where there is little or no sweating (usually occurs in children, persons who are chronically ill, and the elderly), and "exertional" where body temperature rises because of strenuous exercise or work and sweating is usually present.

Heat stroke requires immediate first aid and medical attention. Delayed treatment may result in death. [7]

## 2.10 The Illnesses Caused By Long-term (chronic) Heat Exposure:

NIOSH reports that certain heart, kidney, and liver damage are thought by some researchers to be linked to long-term heat exposure. However, the evidence supporting these associations is not conclusive.

Chronic heat exhaustion, sleep disturbances and susceptibility to minor injuries and sicknesses have all been attributed to the possible effects of prolonged exposure to heat.

Heat exposure has been associated with temporary infertility in both women and men, with the effects being more pronounced in men. Sperm density, motility, and the percentage of normally shaped sperm can decrease significantly when the temperature of the groin is increased above a normal temperature. Workers exposed to high heat loads should inform their family doctors of their exposure.

Laboratory study of animals has shown that exposure of the pregnant females to high temperatures may result in a high incidence of embryo deaths and malformations of the head and the central nervous system (CNS). There is no conclusive evidence of teratogenic effects of high temperatures in humans. The NIOSH criteria document (Draft: 2013) recommends that a pregnant worker's body temperature should not exceed 39-39.5°C during the first trimester of pregnancy. [7]

## 2.11 Previous Study:

A study conducted by Abdel Karim Fahed, investigate the influence of heat load on workers' health and activity in Kardemir Steel Factory in Karabük-Turkey using several heat stress indices. Combined field measurements and questionnaires were carried out over a period from June to August 2016. A total number of 100 workers regularly working in the steel plant from five different workplaces were selected. The wet bulb globe temperature (WBGT), the physiological strain (PSI), and the heat stress (HSI) indices were calculated. Workers' productivity level was evaluated by analyzing the relationships between work capacities and different WBGT levels against work intensities' curves and by using the predicted mean vote (PMV)-productivity model. The highest values of WBGT were recorded in August, notably within the blast furnace area and continuous casting unit with mean values of 31.32 ± 0.8 C and31.34 ± 0.74 C respectively, while the maximum HSI was calculated at the rolling mills unit with a value of 137.83% ±18.45. About 86% of participants complained of thermal discomfort during summer as a result of heat waves, dirt and gas emissions. Strong correlations were found between PSI and WBGT indices with core body temperature (r = 0.725 and r = 0.721 respectively) as well as the rate of heartbeat (r = 0.648 and r = 0.517). These are considered as the most applicable indices for evaluating heat load impact on workers' health and performance. [8]

Other study conducted in India, its aims were to measure the workplace heat stress and noise intensity levels in different sections of the foundries. The study was carried out in a small industrial city of Southern Peninsular of India, known for cluster of foundry establishments. The heat and noise level were measured in melting, fettling, gas cutting, heat treatment furnace, and administrative sections measuring the dry bulb temperature(TDB °C), wet bulb temperature (TWB °C), globe temperature(TG °C), wet bulb globe temperature(WBGT °C), and the relative humidity(RH%) at the work places. The noise level measurements were also carried out using portable integrated sound level meter. Extremely high levels of WBGT index was found in gas cutting section with an average of 33.73 °C followed by 29.68 °C in melting unit. The mean WBGT mean values obtained in other sections were, 28.37 °C in heat treatment, 28.25 °C in fettling and 25.84 °C in administrative sections respectively. The mean WBGT index levels are significantly higher ($p < 0.05$) in gas cutting, melting, heat treatment and fettling sections compared to the administrative section. The prescribed standard threshold limit value (TLV) of WBGT level was high in gas cutting, melting, and heat treatment and fettling units. The values of equivalent noise levels were under control as per

OSHA guidelines in all the process sections. The heat and noise may increase the health risk of worker with reduce the efficiency and consequently affect the production of the unit. The recommendations should be taken as indicative of stress areas and workers should be under constant medical supervision. [9]

# CHAPTER THREE
# METHDOLOGY

## 3.1 Measurement Of Heat

The monitoring of heat was carried out on workers in various sections of the ALPYAN foundry. The heat level were measured in near the oven ,casting place, iron ore place ,point of iron pool ,waiting point , point in the middle of the foundries and finishing sections .

The sample population were 30 male workers. The study will conduct using the wet bulb thermometer. In presence of assembled Wet Bulb Global Temperature instrument an index was calculated for Wet Bulb Globe Temperature according to ISO7243 standard, and metabolism rate was estimated according to ISO 8996 standard. For outdoors, to calculate WBGT according to ISO 7243, the Eq. (1) was used:

$$WBGT_{out} = 0.7T_{nw} + 0.2T_g + 0.1T_{db} \qquad \text{Eq. (1)}$$

Where Tnw denoted natural wet temperature, Tg, glowing temperature, and Tdb, denoted dry temperature. For indoors, to calculate WBGT according to ISO 7243, the Eq. (2) was used:

$$WBGT_{in} = 0.7T_{nw} + 0.2T_g \qquad \text{Eq. (2)}$$

According to standard used, if the environment is heterogeneous, it is necessary that WBGT is calculated in three parts of body, heels, lower back, and head.

$$WBGT_{in} = \frac{WBGT_{head} + 2 * WBGT_{waist} + WBGT_{ankle}}{4} \qquad \text{Eq. (3)}$$

WBGT index for different times of day during shift work is calculated according to standards as the following:

$$WBGT_{in} = \frac{WBGT*T_1+WBGT*T_2+\cdots+WBGT_n}{T_1+T_2+\cdots+T_n} \qquad \text{Eq. (4)}$$

The data will analyze by SPSS statistical application under Windows.

# CHAPTER FOUR
# RESULTS

## 4.1. Results

Table 1: Permissible Heat Exposure Threshold Limit Values (TLVs) (values in °C WBGT)

**Table 6. WBGT Threshold limit values (°C)**

| Work-rest regimen | Work load | | |
|---|---|---|---|
| | Light | Moderate | Heavy |
| Continuous work | 30.0 | 26.7 | 25.0 |
| 75% work+25% rest; each hour | 30.6 | 28.0 | 25.9 |
| 50% work+50% rest; each hour | 31.4 | 29.4 | 27.9 |
| 25% work+75% rest; each hour | 32.2 | 31.1 | 30.0 |

From ACGIH (1996)

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**Table 2:** Values of parameters related to heat stress in different work place in the foundry

| ***Work places*** | ***Statistics*** | ***Measured Parameters*** | | | |
|---|---|---|---|---|---|
| | | **WBGT** °C | **Tg** °C | **Ta** °C | **R.H** % |
| worker Furnace site | Mean | 24.18 | 41.40 | 37.8 | 8.06 |
| | Std. | ± 1.01 | ± 2.52 | 0.99± | ± 1.13 |
| | Range | 22.90-25.70 | 40.50- 44.30 | 36.40 -39.20 | 7.10 –10.20 |
| Casting site | Mean | 22.65 | 38.15 | 37.30 | 7.05 |
| | Std. | ± 0.122 | ± 0.258 | ± 0.126 | ± 0.866 |
| | Range | 22.50- 22.80 | 37.80- 38.50 | 37.10 -37.40 | 6.10- 7.90 |
| Molds forming site | Mean | 22.70 | 38.25 | 37.35 | 7.00 |
| | Std. | ± 0.141 | ± 0.071 | ± 0.071 | ± 0.282 |
| | Range | 22.60 – | 38.20 – | 37.30 –37.40 | 6.80 -7.20 |
| Iron ore area | Mean | 22.73 | 37.90 | 37.67 | 6.03 |
| | Std. | ± 0.321 | ± 0.435 | ± 0.058 | ± 0.153 |
| | Range | 22.50- 23.10 | 37.40- 38.20 | 37.60- 37.70 | 5.90- 6.20 |
| Iron gathering point | Mean | 23.17 | 39.77 | 38.17 | 5.97 |
| | Std. | ± 0.058 | ± 0.153 | ± 0.058 | ± 0.252 |
| | Range | 23.10- 23.20 | 39.60- 39.90 | 38.10- 38.20 | 5.70- 6.20 |
| | Mean | 29.13 | 57.43 | 40.47 | 5.30 |

| | | | | | |
|---|---|---|---|---|---|
| Power worker point | Std. | ± 0.451 | ± 0.907 | ± 0.551 | ± 0.100 |
| | Range | 28.70- 29-60 | 56.40- 58.10 | 40.10- 41.10 | 5.20- 5.40 |
| Arm worker | Mean | 29.77 | 58.77 | 41.10 | 5.03 |
| | Std. | ± 0.450 | ± 0.808 | ± 1.044 | ± 0.153 |
| | Range | 29.30- 30.20 | 58.30- 59.70 | 40.40- 42.30 | 4.90- 5.20 |
| Crane worker | Mean | 26.67 | 49.50 | 40.47 | 5.03 |
| | Std. | ± 0.153 | ± 0.964 | ± 0.252 | ± 0.058 |
| | Range | 26.5.- 26.80 | 48.80 -50.60 | 40.20- 40.70 | 5.00-5.10 |
| Workers waiting point | Mean | 24.14 | 39.84 | 39.34 | 5.82 |
| | Std. | ± 1.43 | ± 0.181 | ± 0.152 | ± 0.517 |
| | Range | 23.40-26.70 | 39.60-40.00 | 39.10-39.50 | 5.30-6.60 |
| Finishing point | Mean | 22.93 | 39.30 | 37.60 | 6.13 |
| | Std. | ± 0.58 | ± 0.100 | ± 0.265 | ± 0.057 |
| | Range | 22.90-23.00 | 39.20-39-40 | 37.30-37.80 | 6.10-6.20 |

Table 1 showed the values of heat stress by measuring the four parameters; WBGT, Tg, Ta and R.H at ten points of different workplaces of the foundry. The statistics measurements include; means, standard deviations and the ranges (min, max values).

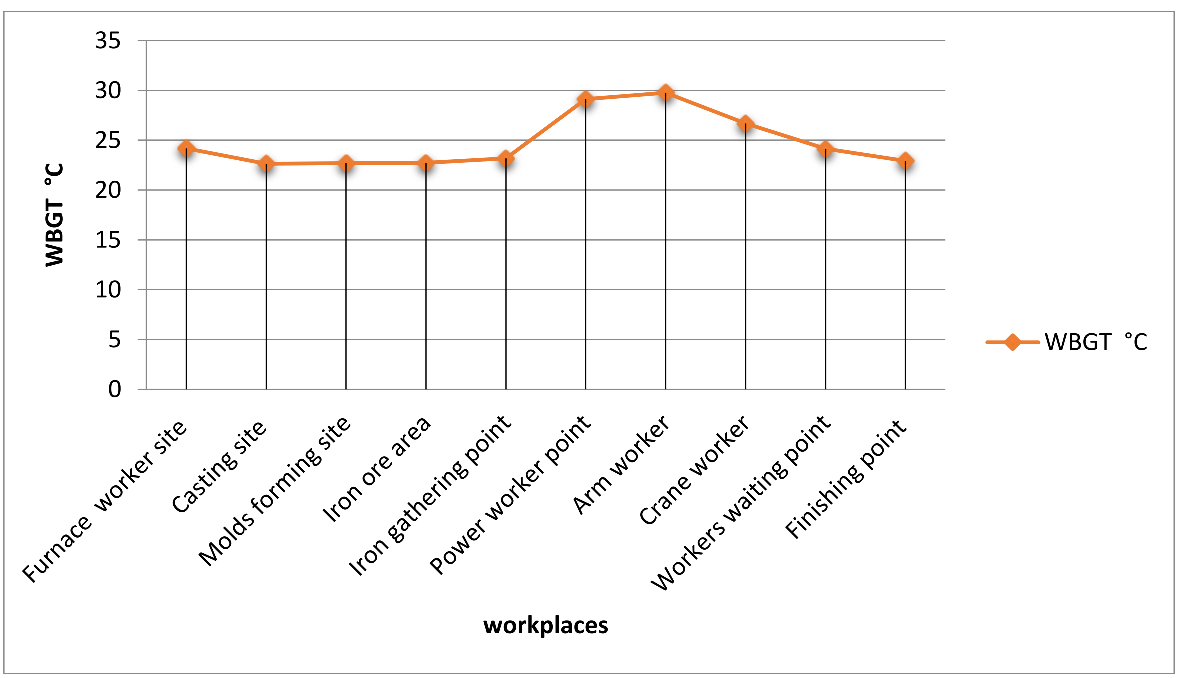

Chart 4.1: Wet bulb globe temperature at different workplaces of the foundry

Wet bulb globe temperature (WBGT°C) high levels of WBGT were recorded in arm worker and power worker points of averages (29.77 and 29.13°C respectively), while the lowest levels were found at casting and Molds forming points of averages (22.65 and 22.70°C respectively). The recorded levels exceeded the threshold limit values of WBGT recommended by ACGIH 1996.

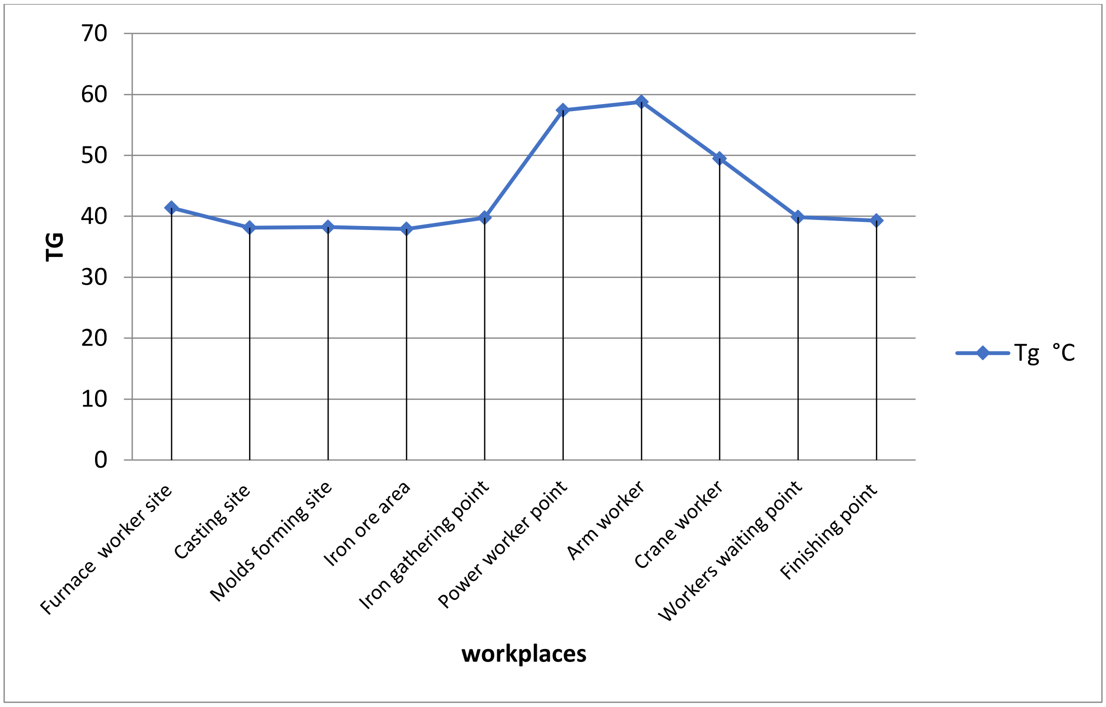


Chart 4.2: Globe temperature at different workplaces of the foundry

Globe temperature (TG°C), high levels were found at arm worker point and power worker points of averages (58.77 and 57.43°C respectively), while the lowest level was measured at iron ore area points of average (37.9).

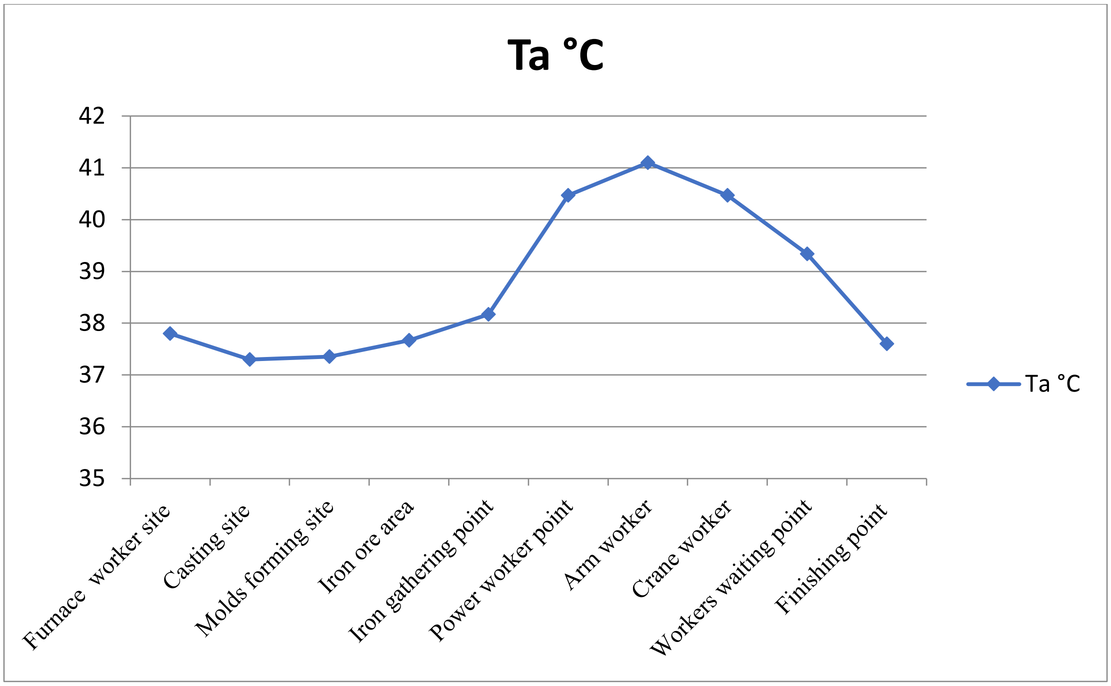


Chart 4.3: Dry temperature (Ta) at different workplaces of the foundry

(Ta°C), high levels were found at arm worker point, power worker point and crane worker point of averages (41.10, 40.47, 40.47 °C respectively), while the lowest level was measured at the casting point of average (37.3).

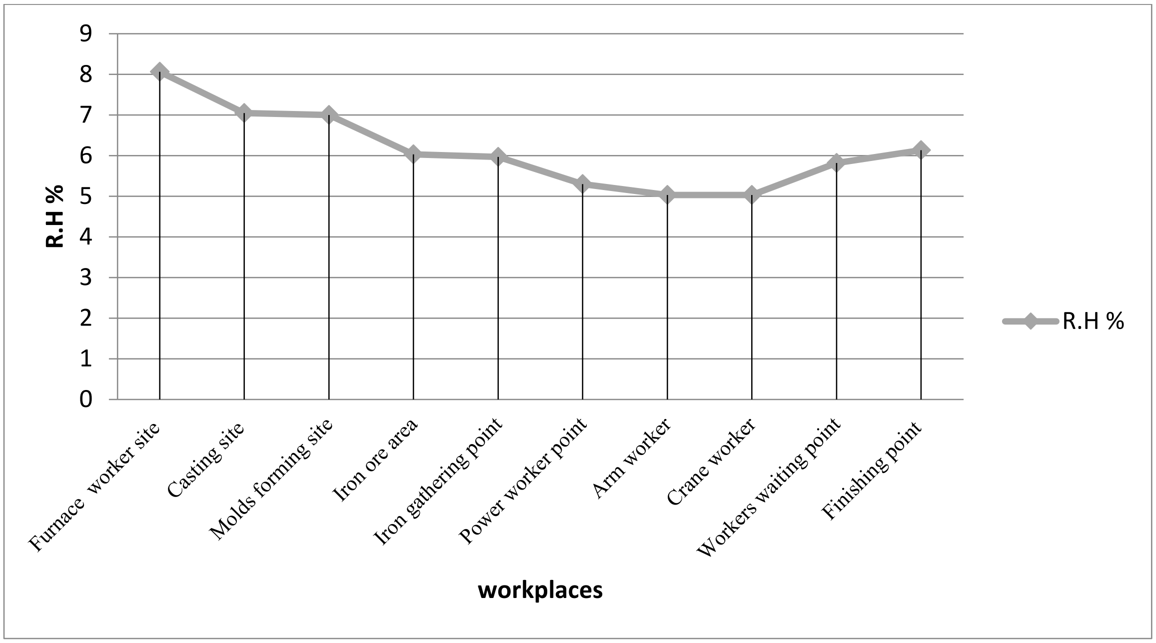


Chart 4.4: Relative humidity at different workplaces of the foundry

Relative Humidity (R.H %), higher level was found at furnace worker point of average (8.06, while the lowest level was measured at points of arm worker and crane worker of average (5.03).

## 4.2 Results Discussions

The heat stress parameters recorded in various sections of the foundry are statistically highlighted in Table 2. Extremely high levels of WBGT index were found in arm worker with an average of 29.77 °C, followed by 29.13 °C in power worker point where the workers are involved in performing their job with molten metals having temperature of 1200–2000 °C. The mean WBGT mean values obtained in other sections were crane worker 26.67 °C, furnace worker 24.18 °C, worker waiting point 24.14 °C, iron gathering point 23.17°C, finishing point 22.93°C, iron ore area 22.73°C,molds forming site 22.70°C and casting point 22.65°C respectively. The mean WBGT index levels are significantly higher in worker arm worker, power worker point and crane worker compared to the workers waiting point. In arm worker, power worker point and crane worker the recorded levels exceeded the threshold limit values of WBGT prescribed by ACGIH.” The permissible heat exposure TLV is 26.7 ºC prescribed for moderate category of work (ACGIH, 1996). Compared to this value, heat stress was highest in arm worker than in other sections. In the power worker unit, heat exposure exceeded the ACGIH recommended level of WBGT index (26.7 °C). In the melting section, steel making process is carried out in electrical induction furnace. The raw materials used different grades of carbon steels and foundry returns which are charged in furnace and melted at 1200–2000 °C. During this process, possibility of high exposure of heat occurs to workers, because the distance between the heat source and workers was very less. This may lead to high exposure of intense heat among the workers working in that particular zone. Fettling is the process wherein the unwanted protrusions from castings are removed. This is done with help of gas flame (or) sharp cutting tools depending on situation. As the duration of working hours increases the flaming requirement also increases, which may lead to continuous source heat in the section.

At the end of this process, the material undergoes a heat treatment process in furnace, to compose hard material at 1500 ºC. Due to this, the heat is transmitted to surrounding area and the heat reside stable up to 2 to 4 h. The temperature range varies slightly from morning to evening due to other weather factors. Compared to other units, the WBGT level in worker waiting point was found within the prescribed limits and it was observed that there was no heating elements (or) heat furnace nearby.

# CHAPTER FIVE
# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions:

The heat exposure represents a major factor which may increase the health risk of worker with reduced efficiency and consequently affect the production of the unit. The recommendations of ACGIH should be taken as indicative of stress among workers and they should be under constant medical supervision for better healthy workforce. This would enhance the efficiency of the workers resulting in reduced reject quantity, improved production and hence increased profits. The physiological strain related to heat stress and noise levels should not be ignored by the management. Strategies for managing heat stress and noise exposure include engineering controls, administrative and work practice controls, personal protective equipment, I will send the study to the ALBYAN foundry for implementation.

## 5.2 Recommendations

1. To device methods to translate the heat stress parameters in this study into heat stress values, then compare the values obtained with international standards and then recommend relief measurements.
2. Study the effect of noise pollution on heat stress tolerance.

## 5.3 References


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# APPENDIX

**(A)**

**WBGT METER**


HEAT STRESS Meter
SET
NEXT
MODE
EXTECH
INSTRUMENTS
A FLIR COMPANY
HT30

## (B)

## ELECTRIC INDUCTION FURNACE

**(C)**

## ELECTRIC INDUCTION FURNACE

# (D)

# Iron gathering point

## (E)

## Point in the middle of the workshop

## (F)

## Molds forming site

**(G)**

**Sand worker site**

**(G)**

**Finishing point**

**(I)**

## Casting point