PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS OF HEAT EXPOSURE AMONG STEEL INDUSTRY WORKERS

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PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS OF HEAT EXPOSURE AMONG STEEL INDUSTRY WORKERS

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Occupational Safety and Health

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ABSTRACT

Exposed to hot working environment can results in variety of heat-related illness and safety problems. A study of physiological and psychological effects of heat exposure among steel industry workers was conducted in a steel industry located in Gebeng, Kuantan, Pahang. This study involves 20 steel industry workers who were exposed to heat sources. The purpose of this study are to determine the physiological (body temperature and heart rate) and psychological (fatigue feeling) effects of workers when they are exposed to sources of heat in hot working environment. The factors that contribute to heat exposure among the workers were identified first. After that, the relationship between physiological and psychological effects experienced by the workers with the exposure to heat sources is determined. The finding of this study reveals that the factors of heat exposure among the workers, which are air temperature or Wet Bulb Globe Temperature (WBGT) indoor, relative humidity, and air velocity were above acceptable range recommended by Industry Code of Practice Indoor Air Quality, DOSH Malaysia (2010) and also exceeded Permissible Heat Exposure Threshold Limit Value (TLV) recommended by ACGIH (2008). Besides that, it has been found that physiological indices of the workers which are body temperature and heart rate, shows an increment after they exposed to heat sources. There are significant differences between body temperature before and after working ($p=0.003$). However, for heart rate, the increment is not significant ($p=0.838$). Majority of the workers feel fatigue when exposed to heat sources, but they still can proceed work. Furthermore, the relationship between body temperature with WBGT indoor are weak ($r = 0.268$, $p > 0.05$). However, the relationship between heart rate with WBGT indoor are strong ($r=0.543$, $p<0.05$). Meanwhile, the relationship between WBGT indoor with fatigue feeling experienced by the workers is weak ($r= -0.119$, $p>0.05$). The results obtained prove that physiological changes happen when workers exposed to hot working environment.

ABSTRAK

Terdedah kepada persekitaran kerja panas dapat menyebabkan berbagai penyakit berkaitan dengan panas dan masalah keselamatan. Kajian mengenai kesan fisiologi dan psikologi pendedahan haba di kalangan pekerja industri besi telah dijalankan di industri besi yang terletak di Gebeng, Kuantan, Pahang. Kajian ini melibatkan 20 orang pekerja industri besi yang terdedah kepada sumber haba. Tujuan kajian ini dijalankan adalah untuk menentukan kesan fisiologi (suhu badan dan denyutan jantung) dan psikologi (rasa letih) pekerja apabila mereka terdedah kepada sumber haba dalam persekitaran kerja yang panas. Faktor-faktor yang menyumbang kepada pendedahan haba di kalangan pekerja telah dikenal pasti terlebih dahulu. Selepas itu, hubungan antara kesan fisiologi dan psikologi yang dialami oleh pekerja dengan pendedahan kepada sumber haba ditentukan. Keputusan kajian ini mendedahkan bahawa faktor pendedahan haba di kalangan pekerja adalah suhu udara atau "Wet Bulb Globe Temperature (WBGT) indoor", kelembapan relatif, dan halaju atau pergerakan udara di melebihi anggaran yang dicadangkan oleh "Industrial Code of Practice Indoor Air Quality, DOSH Malaysia (2010)" dan juga melebihi "Permissible Heat Exposure Threshold Limit Value (TLV)" yand dicadangkan oleh ACGIH (2008). Di samping itu, didapati bahawa indeks fisiologi para pekerja iaitu suhu badan dan degupan jantung, meningkat selepas mereka terdedah kepada sumber haba. Terdapat perbezaan yang signifikan antara suhu badan sebelum dan selepas bekerja ($p=0.003$). Walau bagaimanapun, untuk kadar denyutan jantung, kenaikan adalah tidak signifikan ($p=0.838$). Kajian ini juga mendapati bahawa majoriti pekerja berasa keletihan, tetapi mereka masih boleh meneruskan kerja. Selain itu, hubungan antara suhu badan dengan WBGT indoor adalah lemah ($r = 0.268$, $p>0.05$). Walau bagaimanapun, terdapat hubungan yang kuat di antara denyutan jantung dengan WBGT indoor ($r = 0.543$, $p<0.05$). Sementara itu, hubungan antara WBGT indoor dengan perasaan keletihan yang dialami oleh pekerja adalah lemah ($r= -0.119$, $p>0.05$). Ini menunjukkan terdapat perubahan fisiologi berlaku semasa pekerja bekerja di persekitaran yang panas.

TABLE OF CONTENTS

		Page
SUPERVISOR'S DECLARATION		iv
STUDENT'S DECLARATION		v
ACKNOWLEDGEMENTS		vi
ABSTRACT		vii
ABSTRAK		viii
TABLE OF CONTENT		ix
LIST OF TABLES		xiii
LIST OF FIGURES		xiv
LIST OF SYMBOLS		xv
LIST OF ABBREVIATIONS		xvi
CHAPTER 1	**INTRODUCTION**	
1.1	Background of Study	1
1.2	Problem Statement	4
1.3	Research Objectives	5
1.4	Research Questions	5
1.5	Research Hypothesis	6
1.6	Scope of Study	6
1.7	Significance of Study	7
1.8	Operational Definition	8
	1.8.1 Environmental Factors	
	1.8.2 Occupational Factors	
	1.8.3 Personal Factors	
	1.8.4 Air Temperature	

1.8.5 Radiant Temperature
1.8.6 Air Velocity
1.8.7 Relative Humidity
1.8.8 Clothing Insulation
1.8.9 Work Rate and Metabolic Heat
1.8.10 Dry Bulb Temperature, Tdb
1.8.11 Natural Wet Bulb Temperature, Tnwb
1.8.12 Globe Temperature, Tg
1.8.13 Wet Bulb Globe Temperature, WBGT
1.8.14 Heart Rate
1.8.15 Body Temperature
1.9 Conceptual Framework 11

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction 13
2.2 Steel Industry 13
2.3 Steel Manufacturing 14
2.4 Heat Exposure 15
2.5 Environmental Factors 15
2.5.1 Air Temperature 16
2.5.2 Radiant Temperature 17
2.5.3 Air Velocity 17
2.5.4 Relative Humidity 18
2.6 Non-environmental Factors 19
2.6.1 Clothing Insulation 19
2.6.2 Work Rate and Metabolic Heat 21
2.6.3 Weight and Physical Fitness 23
2.6.4 Age 24
2.6.5 Gender 24
2.6.6 Heart Rate or Pulse rate 24

2.6.7 Body Temperature 25

CHAPTER 3 METHODOLOGY

3.1 Research Design 27
3.2 Research Flow 28
3.3 Site Selection 30
3.4 Sampling Size 31
3.5 Inclusive and Exclusive Criteria 31
3.6 Instrumentation 31
3.7 Data Collection Technique 33
3.7.1 Pilot Study 33
3.7.2 Walkthrough Observation 34
3.7.3 Questionnaires 34
3.7.4 Area Monitoring 34
3.7.5 Personal Monitoring 35
3.8 Data Analysis 37
3.8.1 Descriptive Analysis 38
3.8.2 Inferential Analysis 38
3.9 Quality Assurance and Quality Control 38
3.10 Study Ethics 39
3.11 Study Limitation 39

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Introduction 40
4.2 Preliminary Assessment 40
4.2.1 Walkthrough Observation 41
4.2.2 Workers Assessment 42
4.3 Reliability Analysis of Questionnaire 43
4.3.1 Health Symptoms of Heat Illness 43
4.3.2 Assessment of the Frequency of Health Illness 43
4.4 Normality Test for Data Analysis 45

4.5 Background Information of Respondents 47
4.6 Environmental Heat Stress Monitoring 49
4.6.1 Wet Bulb Globe Indoor Temperature (WBGT indoor) 49
4.6.2 Relative Humidity 52
4.6.3 Air Movement or Air Velocity 54
4.7 Personal Heat Stress Monitoring 56
4.7.1 Comparison of Body Temperature to ACGIH (2006) 56
4.7.2 Comparison of Heart Rate to ACGIH (2001) and OSHA Technical Manual (1999) 57
4.8 Comparison of Body Temperature and Heart Rate of Respondents Before and After Work 59
4.9 Evaluation of Psychological Effects of Heat Exposure among Steel Industry Workers 60
4.9.1 Fatigue Feeling 60
4.10 Correlation between WBGTin with Body Temperature and Heart Rate 61
4.11 Correlation between WBGTin with Fatigue Feeling 62

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion 63
5.2 Recommendations 64
5.2.1 Steel Industry 64
5.2.2 Future Study 65

REFERENCES 66

APPENDICES

A Gantt Chart
B Questionnaires Form
C Photos Taken during Conducting this Study in Steel Industry
D Structure of the Steel Industry in Malaysia (2008)

LIST OF TABLES

Table No.	Title	Page
2.1	Clothing-Adjustment Factors for Some Clothing	22
2.2	Metabolic Rate of Employees by Job Category (ACGIH 2016)	23
2.3	Screening criteria for TLV and AL	23
3.1	Measuring Instruments	32
4.1	Reliability Test for Health Symptoms of Heat Illness	43
4.2	Health Symptoms of Heat Illness Faced by the Workers	45
4.3	Normality Test for Data Distribution	46
4.4	Background Information of Respondents	49
4.5	Average, Minimum, and Maximum Value of WBGTin	50
4.6	Average, Minimum, and Maximum Value of Relative Humidity	52
4.7	Average, Minimum, and Maximum Value of Air Velocity	54
4.8	Comparison of Body Temperature and Heart Rate of Respondents Before and After Work.	60
4.9	Level of Fatigue Feeling Experienced by Steel Industry Workers	61
4.10	Correlation Between WBGTin with Body Temperature and Heart Rate of the Workers	62
4.11	Correlation Between WBGT Indoor with Fatigue Feeling	63

LIST OF FIGURES

Figure No.	Title	Page
1.1	Conceptual Framework	13
3.1	Illustration of Research Flow	31
3.2	Map of steel manufacturing industry in Gebeng, Kuantan.	31
3.3	QUESTemp°34 Thermal Environment Monitor	35
3.4	Anemometer	35
3.5	Dotory Enhanced Contact Forehead Thermometer	36
3.6	Weighing Scale	40
3.7	OMRON HEM-7114 Blood Pressure Monitor	37
4.1	Workers welding in steel industry	41
4.2	Location of WBGT index meter and Anemometer	41
4.3	Natural ventilation surrounding steel industry	42
4.4	WBGTin at Steel Industry for 8-Hour Exposure	51
4.5	Relative Humidity at Steel Industry for 8-Hour Exposure	53
4.6	Air Velocity at Steel Industry for 8-Hour Exposure	55
4.7	Body Temperature of Respondents Before & After Work	57
4.8	Heart Rate of Respondents Before Working & After Work	59

LIST OF SYMBOLS

ACGIH	American Conference of Governmental Industrial Hygienists
BMI	Body Mass Index
Bpm	Beat Per Minute
CDC	Center for Disease Control
ºC	Degree Celsius
DOE	Department of Environment
DOSH	Department of Occupational Safety and Health
NIOSH	National Institute of Occupational Safety and Health
PPE	Personal Protective Equipment
SPSS	Statistical Package for the Social Sciences
Tdb	Dry Bulb Temperature
Tg	Globe Temperature
Tnwb	Natural Wet Bulb Temperature
TLV	Threshold Limit Values
WBGTin	Wet Bulb Globe Indoor Temperature

LIST OF ABBREVIATION

ACGIH	American Conference of Governmental Industrial Hygienists
BMI	Body Mass Index
Bpm	Beat Per Minute
CDC	Center for Disease Control
ºC	Degree Celsius
DOE	Department of Environment
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NIOSH	National Institute of Occupational Safety and Health
PPE	Personal Protective Equipment
SPSS	Statistical Package for the Social Sciences
Tdb	Dry Bulb Temperature
Tg	Globe Temperature
Tnwb	Natural Wet Bulb Temperature
TLV	Threshold Limit Values
WBGT	Wet Bulb Globe Temperature

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Steel is one of the important raw material that is widely used and supplied to the other sectors, such as engineering industry, machinery industry, construction industry, electrical or electronic industry, automotive industry, and furniture industry and it is the main ingredient for infrastructure projects. Malaysia is the fourth largest steel consuming country in ASEAN with a domestic steel consumption of 10 million tonnes in 2014, a marginal growth of 0.3%, driven by the government's mega infrastructure projects, while China ranks first (Malaysia Steel Industry Report, 2015).

The steel consumption in Malaysia has expanded widely over the years in order to become the second largest steel consumer in ASEAN region. According to Malaysian Iron and Steel Industry Federation, MISIF (2015) (Refer Appendix D), Malaysia's total steel demand has been expected to grow significantly about 4% of annual average rate from 2015 until 2018 in accordance with the roll-out of the government's mega infrastructure projects.

The Malaysian iron and steel industries sector cover the primary steel products like direct reduced iron, hot briquetted iron, blooms/slabs and steel billets and a very wide range of downstream flat and long products like hot rolled coils, cold rolled coils, coated steel coils, roofing sheets, steel pipes and sections, steel billets, steel bars, wire rods, wire mesh, hard drawn wires, galvanized wires, steel wire ropes, steel wire products, stainless steel pipes or pipes fittings and stainless steel wire and fasteners (Malaysian Investment Development Authority, 2017). Apart from that, Malaysian steel industry is focused on the country's construction and the needs of manufacturing. Table 1.1 as illustrated in Appendix E shows the structure of the steel industry in Malaysia in 2008, by product and the number of establishments.

Malaysia Steel Industry Report (2015) published that the iron and steel industry is a core sector that tracks and closely supports Malaysia's overall economic growth, contributing around 4% to the GDP. In the other hand, Malaysian Investment Development Authority, MIDA (2017) mentioned that there are currently 2,190 projects producing the primary steel products with total employment of 160,131 workers.

With the growing number of employments in steel industry, the safety and health of the workers is a concern. The workers who are working in a steel industry often exposed themselves with hot working environment. Basically, steel making is a high temperature process especially at hot rolling area, near the surfaces or at the casting platforms. Yi Wang *et al*. (2016) mentioned that the indoor thermal environment is normally unacceptable in naturally ventilated industrial buildings with high temperature heat sources, such as iron and steel plants and metallurgy plants. As a consequences, the workers in that industry might have health problems and their productivity decrease when directly exposed to the hot working environment.

In 2012, there was an accident occurred at a local steel manufacturing plant, where a worker in furnace division fainted during having his meal, and he was being diagnosed with heatstroke which resulting him to suffer slurred speech and generalised body tremor (Department of Occupational Safety and Health Malaysia, 2016). Other than that, in 2013 and 2014, there were also another three cases reported to DOSH Malaysia regarding to heat-related illness which has caused multiorgan failure. The three cases involved trainees during their field training which was under the hot sun. After further heat stress assessment and enforcement conducted by DOSH Malaysia, it was found that the workers were exposed to heat stress through high temperature process and machinery, and it was also found that both employers and the workers are lack of knowledge as well as awareness about the exposure to heat and its risk to health. The findings from the heat stress assessment and enforcement confirmed that it is very necessary to have standards or guidelines in order to evaluate the exposure to heat at workplace for guiding the organization and employers in Malaysia.

Department of Occupational Safety and Health, Malaysia (2016) described that exposure to abnormal or prolonged amounts of heat and humidity without relief or adequate fluid intake can lead to various types of heat related illness such as heat rash, heat cramps, heat exhaustion, heat syncope, and heat stroke. Moreover, as the temperature increases, workers may difficult to concentrate and unable to do mental tasks as well as unable to perform skilled tasks or heavy work.

In hot environment, the body needed to remove the excess heat so that it can maintain its normal body temperature. In order to remove or loss the excess heat to the environment, the heart rate increases pumping more blood through the outer parts of body and skin, and then sweating occurs. These changes causing additional demand on the body. A person's ability to perform physical and mental work will be reduced as the blood flow changes and there is excessive sweating. As the environmental temperature increases above 30°C, it can interfere with the mental task's performance.

During their working hours, the workers need to wear a substantial amount of clothing and personal protective equipment (PPE) which can protect them from getting burns or contact with the heat sources. Sometimes, while the clothing and PPE protecting the employee from the heat sources, this type of equipment itself may expose the workers to heat related illness and thermal discomfort to the workers. DOSH, Malaysia (2016) reported that the cases of heat-related illness which occurred among trainees during field training in 2013 and 2014 were caused by inappropriate PPE worn by them. Hence, it is crucial to determine how the clothing contributes to thermal comfort or discomfort by evaluating the level of protection of existing PPE worn by the workers so that their level of thermal comfort can be improved.

This study was conducted at the steel industry which located in Gebeng, Kuantan, Pahang by referring to the Guideline on Heat Stress Management at Workplace 2016. This guideline has been drawn up to provide guidance for the employers in avoiding discomfort from hot environment at workplace.

1.2 Problem Statement

In 2016, the global heat wave or Equinox phenomenon recently faced by Malaysia has obtained a significance concern since the increase in temperature give various impacts on health, ranging from heat rash, heat cramps to heat exhaustion, with heat stroke being the most serious form of heat injury and is considered as a medical emergency (Ministry of Health Malaysia, 2016). From March 1, 2016 until March 18, 2016, 14 heat-related illnesses cases in Malaysia were recorded by The Ministry of Health, Malaysia. Among the 14 heat-related illnesses cases recorded, it comprises of 11 heat exhaustion and 3 heat stroke cases (DOSH Malaysia, 2016). Steel industry workers are often vulnerable to expose with extremely hot sources of heat such as blast furnace, coke oven, rolling mills, and steel melting sections. Hot working environment can increase the chance of the workers to suffer heat related illnesses especially workers who perform manual work as well as reduce their productivity.

Exposure to the sources of heat in the workplace not only give negative impact to physical health, but also affect the physiological and psychological aspects of the worker's health. When a worker performed their work, heat is generated in their body. Similarly, there will be a rise of body temperature when the worker's body exposed to high temperature of heat sources. But the physiological systems will ensure the body to cool down and dissipate the heat generated by sweating. The body reacts to the heat generated by increase the blood flow to the surface of the skin and sweating, thus result in cooling since the sweat evaporates from the surface of the body. In the other hand, when an individual is exposed to heat chronically, physiological acclimatization process occurs in the body to enhance the capacity to loose heat. Bennett and McMichael (2010) explained that when the ambient temperature reaches or exceeds the human core temperature of 37°C, there are physiological effects on the human body, posing risks to some organ systems and also making it progressively harder to work productively. Besides that, Jay and Kenny, (2010) in their study described that at core temperatures beyond 38−39°C, there is an increased risk of heat exhaustion and beyond these temperatures, heat stroke can occur with an eventual failure of the central nervous thermoregulatory system.

Exposure to heat sources also can affect the psychological or mental health of the worker especially their cognitive performance. Some studies revealed that long duration of exposure to ambient heat reduced the cognitive performance of the workers while short exposure to ambient heat improved their task performance. When the workers exposed to ambient heat, they are difficult to focus in performing their work and facing fatigue. Workers who suffer heat related illness such as heat stroke, heat cramps, heat exhaustion, heat syncope, and heat rash, their sweat output often exceeds water intake which resulting to hypohydration and electrolyte losses (Vidhya Venugopal *et.al*, 2016). Hence, the physiological and psychological effects of heat exposure among the steel industry workers was studied in order to determine how the worker's body and mental respond or react when evxposed to sources of heat in their workplace.

1.3 Research Objectives

The objectives of this study are:

(i) To identify the factors of heat exposure among steel industry workers.
(ii) To compare the physiological indices of the steel industry workers before and after working hours.
(iii) To determine the psychological condition of steel industry workers who are exposed to sources of heat.
(iv) To determine the relationship between physiological indices and psychological condition of the steel industry workers with the exposure to heat sources.

1.4 Research Questions

The research questions in this study are as follows:

(i) What are the factors that contribute to the exposure of heat among the steel industry workers?
(ii) Do the physiological indices of the workers different before and after working?
(iii) What is the psychological condition of the workers during working near to the heat sources?
(iv) What is the relationship between physiological indices and psychological condition of the workers with the exposure to the heat sources?

1.5 Research Hypotheses

The research hypothesis in this study are as follows:

(i) Air temperature or Wet Bulb Globe Indoor Temperature (WBGTin) is the factor of heat exposure among steel industry workers.
(ii) The worker's body temperature and heart rate increases after performing their work.
(iii)The workers experienced fatigue feeling during working in the steel industry.
(iv)There is a significant relationship between physiological indices and psychological condition of the workers with the exposure to heat sources.

1.6 Scope of Study

This study was conducted by selecting several respondents which consist of steel industry workers working in steel industry located in Gebeng, Kuantan, Pahang. The respondents selected were about twenty workers who exposed to heat sources.

In order to achieve the first objective which is to identify the factors of heat exposure among steel industry workers, which are environmental factors and non-environmental factors, they were selected by considering their type of work activities, age, gender, body mass index (BMI), clothing, acclimatization, drink alcohol, and smoking or not. Besides, the area monitoring which is Environmental Heat Monitoring was conducted before and after working by using thermal environment monitor and anemometer to determine the environmental parameters which are dry bulb temperature, relative humidity, air velocity, air temperature, WBGT indoor index, and globe temperature that might contribute to thermal discomfort among the workers. While for the second objective, the physiological indices of the workers were compared before after working by conducting personal monitoring in which their body temperature and heart rate were measured. The worker's heat rate was measured using blood pressure monitor while their body temperature was measured using contact forehead thermometer.

To achieve the third objective which is to determine the psychological condition of steel workers who were exposed to heat sources, the questionnaire of Fatigue Assessment Scale Questionnaire developed by De Vries *et al*. (2004) was distributed to the workers. The worker's level of fatigue feeling was obtained from this questionnaire.

Meanwhile, to achieve the fourth objective, which are to determine the relationship between physiological indices and psychological condition of steel industry workers with the exposure to heat sources, statistical analysis was used. The statistical analysis used was descriptive analysis and inferential analysis.

1.7 Significance of Study

This study is effective in identifying the major contributing factors of heat exposure among the steel industry workers. After the major contributing factors have been identified, control measures can be implement by steel industry to control heat exposures or heat stress.

Besides, this study helps to determine the changes of physiological and determine the psychological condition of steel industry workers when exposed to heat sources. Other than that, the relationship between physiological indices and psychological condition of steel industry workers with the exposure to sources of heat can be determine throughout this study.

This study beneficial in determining the health status of the steel industry workers who are exposed to heat sources. It can also ensure or guide the industry to comply with the regulation and standard relating to occupational heat exposure, thus knowledge and awareness can be improved among the steel industry's top management and employees on coping with thermal discomfort in their workplace. Apart from that, this study aids in developing preventive measures and propose control measure for a steel industry to mitigate or reduce heat-related illness, fatigue feeling, and thermal discomfort among the workers.

The result of the evaluation and analysis conducted can be shared with the steel industry's management with the hopes that this study will not just be an extraction of truths, but will give them information with which they can better ensure the safety, health and welfare of their employees.

1.8 Operational Definition

1.8.1 Environmental factors

The workplace environment that changes with weather conditions which means that there are wide variations during the day, across days with the tendency contribute heat stress to the workers. The environmental factors include air temperature, and air humidity (DOSH Malaysia 2016).

1.8.2 Occupational factors

The physical factors that cause the workers expose to heat stress while they carry out their tasks in the workplace. For examples, working duration, and type of workload (DOSH Malaysia 2016).

1.8.3 Personal factors

Human factors which cause a person exposes to heat stress such as clothing, and acclimatization (DOSH Malaysia 2016).

1.8.4 Air temperature

The temperature of the air surrounding the body. It is usually given in degrees Celsius (°C) (DOSH Malaysia 2016).

1.8.5 Radiant temperature

Heat radiation is the heat that radiates from a warm object. Radiant heat may be present if there are heat sources in the environment. Radiant heat can affect people who are exposed to direct sunlight or close to process area which emits heat. Examples of radiant heat sources include: the sun, fire, heaters, cookers, dryers, hot surfaces and machinery, boilers, furnaces molten metals etc. (DOSH Malaysia 2016).

1.8.6 Air velocity

Air velocity is the speed of air moving across the employee and may help cool them if the air is cooler than the environment (DOSH Malaysia 2016).

1.8.7 Relative humidity

Relative humidity is the ratio between the actual amount of water vapor in the air and the maximum amount of water vapor that the air can hold at that air temperature. Relative humidity between 40% and 70% does not have a major impact on heat stress. In workplaces which are not air conditioned, or where the weather conditions outdoors may influence the indoor heat environment, relative humidity may be higher than 70%. In hot environments, humidity is important because less sweat evaporates when humidity is high (above 80%) (DOSH Malaysia 2016).

1.8.8 Clothing insulation

Heat comfort is very much dependent on the insulating effect of clothing on the wearer. Wearing too much clothing or PPE may be a primary cause of heat stress even if the environment is not considered warm or hot. Clothing is both a potential cause of heat discomfort as well as a control for it as employees adapt to workplace climate. It is important to identify how the clothing contributes to heat comfort or discomfort. By periodically evaluating the level of protection provided by existing PPE and evaluating newer types of PPE, employer may be able to improve the level of heat comfort (DOSH Malaysia 2016).

1.8.9 Work Rate and Metabolic Heat

Metabolic heat is the heat produced by the body through chemical processes, exercise, hormone activity, digestion, etc. The more physical work we do, the more heat we produce. The more heat we produce; the more heat needs to be lost so we don’t overheat. The impact of metabolic rate on heat stress is critical. A person’s physical characteristics should always be borne in mind when considering their heat stress, as factors such as their size and weight, age, fitness level and sex can all have an impact on how they feel, even if other factors such as air temperature, humidity and air velocity are all constant (DOSH Malaysia 2016).

1.8.10 Dry Bulb Temperature, Tdb

Measured by a thermal sensor, such an ordinary mercury in glass thermometer, that is shielded from direct radiant energy sources (DOSH Malaysia 2016).

1.8.11 Natural Wet Bulb Temperature, Tnwb

Measured by exposing a wet sensor, such as wet cotton wick fitted over the bulb of a thermometer, to the effects of evaporation and convection. The term natural refers to the movement of air around the sensor (DOSH Malaysia 2016).

1.8.12 Globe Temperature, Tg

The temperature measured inside a blackened, hollow, thin copper globe (DOSH Malaysia 2016).

1.8.13 Wet Bulb Globe Indoor Temperature, WBGTin

Composite temperature used to estimate the effect of temperature, humidity, wind speed, and solar radiation on human. The WBGT is used to determine appropriate exposure and activity levels to high temperatures (DOSH Malaysia 2016).

1.8.14 Heart Rate

The amount of times a person's heart beat per minute, or can be also known as the measurement of the cardiac activity. It is normally determined by level of individual physical fitness, circulating hormones and autonomic nervous system. The normal heart rate of a person is between the range from 60 to 100 beats per minute.

1.8.15 Body Temperature

Body temperature is defined as the average temperature of the human body. It is normally 37°C, but it may vary within a fraction of a degree, depending on the individual and such factors as time of day, sleep, and exercise and whether measured before or after a meal, and can vary depending on time of day, typically by 0.5°C in the evening compared to the morning (Farlex and Partners, 2009).

1.9 Conceptual Framework

The conceptual framework illustrates in Figure 1.1 shows the evaluation of physiological and psychological effects of heat exposure among steel industry workers. In the steel industry, the workers may expose themselves to the sources of heat from work activities or work process conducted. The work processes are including the production of iron or steel plate, production of coke, welding, smelting of iron ores, plate rolling, and production of ferrous metal where combustion at extremely high temperature occurs.

The workers may suffer heat-related illness when they are exposed to the environmental and non-environmental factors of heat exposure. The environmental factors comprise of air temperature, air velocity, relative humidity, and radiant temperature. Meanwhile, the non-environmental factors are clothing, health status, acclimatization, hydration, gender, age, body mass index (BMI), and metabolic heat and work rate.

All the factors of heat exposure may affect the physiological indices and psychological condition of the workers. Hence, the physiological indices and the psychological condition of the workers were measured in order to determine how the worker's body and mental respond or react to the heat. The physiological indices of the workers measured in this study were body temperature and heart rate. While, the psychological condition of the workers measured are fatigue feeling level.

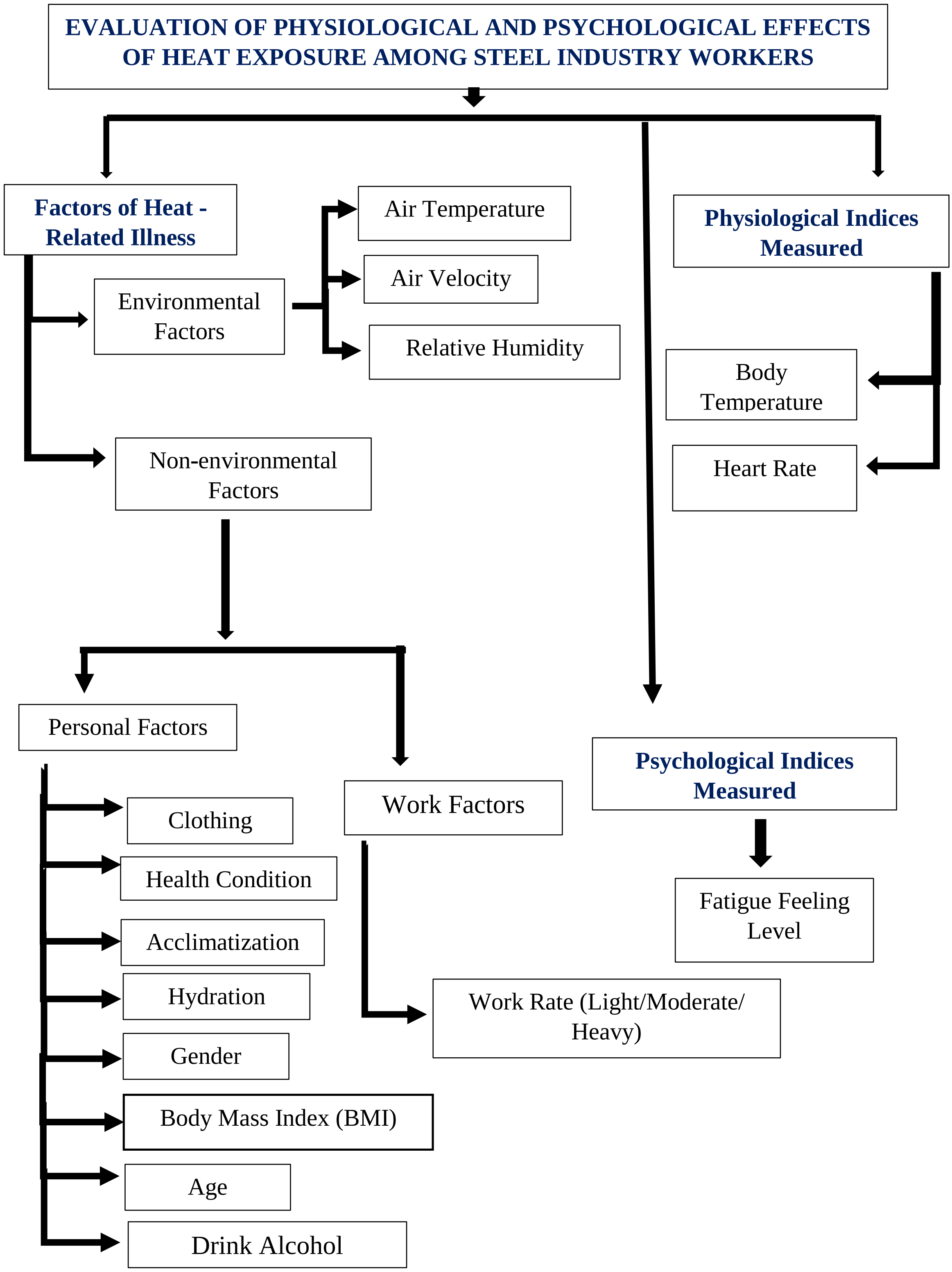


Figure 1.1: Conceptual Framework

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order to identify studies that relevant to this topic, all the literature review about physiological and psychological effects of heat exposure among steel manufacturing worker are referred and reviewed. The sources for the literature review are from Department of Occupational Safety and Health (DOSH) Malaysia, National Institute of Occupational Safety and Health (NIOSH), and USA American Conference of Industrial Hygienists (ACGIH). Other than that, all the journals related to this study are also used as a references.

2.2 Steel Industry

Steel is defined as a commercial iron alloy that contains carbon from as low as 0.03 percent up to 2.5 percent by weight and also contains various amounts of other elements such as chromium, manganese, molybdenum, nickel, and silicon depending on its uses. According to Ramesh Singh (2012), steels are classified on the basis of chemical composition into unalloyed steels and alloyed steels. Steel is the most widely used alloy and it is an important material due to its flexibility in metal working and heat treating in the production of a variety mechanical, chemical, and physical properties. According Department of Environment, DOE Malaysia (2014), steel is an essential raw material which is widely used in the manufacturing sector, machinery and engineering industries, transportation equipment (e.g. automotive, railway, and shipping) as well as the major ingredient for infrastructure project.

Steel industry can be classified into two segments which are primary steel producers and secondary steel producers. Primary steel producers, also known as integrated steel producers, are involved in the entire range of iron and steel production commencing from exploration of iron ore to the production of finished steel products (Department of Environment Malaysia, 2014). While the secondary producers purchase iron ore or steel crap as raw material for production process that do not use coking coal (Department of Environment Malaysia, 2014). In addition, the secondary steel producers can be divided into three types which are major secondary players, mini steel plants, and steel re-rollers. The finished steel is utilized mainly in the form of long products, flat products (which in turn contain hot rolled and cold rolled and galvanized products, and alloy steels Department of Environment Malaysia, 2014).

Based on Malaysian Investment Development Authority (2017), the Malaysian iron and steel industries sector cover the primary steel products like direct reduced iron, hot briquette iron, blooms or slabs and steel billets and a wide range of downstream flat and long products like hot rolled coils, cold rolled coils, coated steel coils, roofing sheets, steel pipes and sections, steel billets, steel bars, wire rods, wire mesh, hard drawn wires, galvanized wires, steel wire ropes, steel wire products, stainless steel pipes/pipes fittings and stainless steel wire and fasteners.

2.3 Steel Manufacturing

Workers who are working in steel industry are exposed to extremely hot sources of heat from the coke oven, furnace, and steel mill since steel making is basically a high temperature process. In the hottest section of a steel mill, metal can heat up to 2,800º F or 1,538º C. Wang *et al*. (2016) mentioned that the sources of heat in steel plant are mainly from welding work, a furnace, hot steel beams, cooling bed, and packaged steels. The raw steel is placed into the furnace to be melted and formed into hot steel beams. After that, the hot steel beams are rolled and transferred to the cooling bed after being cut to the required lengths. Finally, the hot steel beams are cooled down and then transferred to the packaging zone. The temperature of the steel surface were 1100 ºC at the beginning of melting and about 140 ºC for packaging (Wang *et a*l., 2016).

Krishnamurthy *et al*. (2016) in their study state that workers in the furnaces areas of coke oven and blast furnace are engaged in heavy work and such continuous exposures to high-heat environments can potentially subjects to risks of adverse heat-related health illnesses. In addition, the workers at the area of furnaces and other slag handling processes have continuous exposures to high radiant heat even during breaks owing to lack of cooler resting areas in those work locations (Krishnamurthy *et al*., 2016). Meanwhile, Parameswarappa and Narayana (2014) mentioned that high levels of heat stress are found in the steel industry especially at rolling area, casting platforms and near the furnaces.

Several previous studies found the association between physiological and psychological indices of the steel industry workers with the exposure to heat. The study conducted by Parameswarappa and Narayana (2014) found that the correlation between air temperature in steel industries and the rises of core body temperature of workers was found significant with $r = 0.55$ and $p = < 0.01$. Besides air temperature, other factors such as humidity, physical workload, sweating rate, and type of clothing worn by the workers also influence the core body temperature rises.

2.4 Heat Exposure

Heat exposure can cause high incidence of morbidity and mortality (Lu and Zhu, 2007). According to the Center for Disease Control (CDC), between 1979 and 1995 a total death of 6,615 deaths in the United States were caused by excessive heat exposure.

In hot low- and middle-income countries, the threat of excessive heat exposure is perhaps even greater on account of hot climatic conditions either at work and at home, limited resources or access to cooling methods especially air-conditioning, and economic drivers to maintain productivity (Lucas et al., 2014). Other than that, Xiang et al. (2014) have explained that there are two types of external heat exposure sources in the workplace which are weather-related and man-made heat exposure. Workers in some industries such as iron and steel manufacturing, glass manufacturing, mining, military and other special facilities like aircrafts and submarines are exposed to heat in their working condition, thus it is a serious problem and can be a hazard to their safety and health.

2.5 Environmental Factors

Department of Occupational Safety and Health, DOSH Malaysia (2016) stated that environmental factors which contribute to heat stress or heat exposure are air temperature, radiant temperature, air velocity, and relative humidity. All the environmental factors of heat exposure when combine with physical work will causing heat stress and heat strain among the steel manufacturing workers. Parameswarappa and Narayana (2014) in their study described that environmental heat stress increases the sweating rate, core body temperature, and pulse rate among the workers who are exposed to heat hazard. Thus, all the environmental factors of heat exposure need to be measured and control in order to prevent heat-related illness among workers.

2.5.1 Air Temperature

DOSH Malaysia (2016) defined air temperature as the temperature of the air surrounding the body, in which it is usually given in degree Celsius (ºC). While, National Institute of Occupational Safety and Health, NIOSH (2013) defined air temperature or air (dry bulb) temperature as the temperature of the ambient air, measured with a thermometer, where the temperature units are also in degree Celsius (ºC). Besides that, air temperature is the temperature of the air surrounding the human body which is representative of that aspect of the surrounding which determine heat flow between human body and the air (S.B.Parameswarappa and Narayana, 2014). Air temperature affects the convection of heat transfer from the individual.

Lundgren *et al*. (2013) in their study explained that when the ambient air temperature reaches or exceeds the human core body temperature which is 37 ºC, there are well documented physiological effects on the human body by posing risk to some organ systems and also making it progressively harder to work productively. As the air temperature exceeds the core body temperature, the core body temperature begins to rise above its normal temperature of 37ºC, thus the skin blood flow increases and sweating occurs. When the air temperature exceeds 37ºC, evaporation of sweat becomes one of the mechanism to cool the body, but the evaporation of sweat is impaired by high air humidity and clothing (Krishnamurthy *et al.*, 2016). The heat cannot be transferred easily from the body when the work environment is hot or when the air humid and sweat evaporation is inefficient, thus it creates health impacts and loss of work capacity among the exposed workers (Krishnamurthy *et al.*, 2016).

2.5.2 Radiant Temperature

Radiant temperature also known as radiant heat is the heat that radiates from a warm object (DOSH Malaysia, 2016). If there are sources of heat in the environment, radiant heat might be present. Usually in steel manufacturing industry, the blast furnace and coke oven present a dominant sources of radiant heat since the temperature around them is extremely high.

Venugopal et al. (2016) in their study about heat stress and inadequate sanitary facilities at workplaces that concern on women, state that the maximum WBGT of 41.7 ºC was found in the steel industry where the women were exposed to high radiant heat from processes like smelting, casting, and furnaces because they were engaged in housekeeping and cleaning in the manufacturing area.

Meanwhile, Krishnamurthy *et al.* (2016) in their study found that the maximum WBGT recorded was 41.7 ºC in the coke oven area where the workers were exposed to high process generated radiant heat. In addition, they found that the workers who working around the furnaces and other slag handling process are continuously exposed to high radiant heat even during breaks due to lack of cooler resting areas in that work locations. Then, the statistical analysis performed by Krishnamurthy *et al*. (2016), found that workers who were exposed to direct heat sources including process generated radiant heat from furnaces, shows a significant direct losses compared to other workers who had indirect exposures.

Indoor workers, especially those working around welding work, furnaces, ovens, smelters and boilers are at higher risk of heat stress during hot days although they are not exposed to direct solar radiation, but they are exposed to heat and humidity produced from work process or equipment (Xiang *et al.*, 2014).

2.5.3 Air Velocity

Air velocity is an important factor in thermal comfort because people is sensitive to it. DOSH Malaysia (2016) describes air velocity as the speed of air moving across the employee and may help cool them if the air is cooler than the environment. Air that moving in warm or humid conditions can increase the loss of heat through convection without changing the air temperature. People can feel stuffy if the still and stagnant air in indoor environment are artificially heated. Therefore, it also leads to a build-up in odour.

According to Wang *et al.* (2016), the air velocity in the naturally ventilated industrial building with high temperature heat source was greatly related to the difference between mean radiant temperature and air temperature, and the results of their study show that the indoor air velocity has a very small influence on the indoor WBGT.

Air circulation should be sufficient in order to allow sweat evaporation, which is the body principal mechanism of cooling. Corleto (2012) published that in high humidity, more air needs to be moved, thus higher air velocity is required. In hot-dry conditions with low air velocity, the ability of the body to lose heat is limited to the evaporative capacity of the environment, thus it result in the rises of heart rate and oral temperature. But if the air velocity is high, the evaporative capacity of the environment of the environment increases, hence, excess heat is dissipated and reduce the extent of heat storage. Buildings which do not have either air conditioning systems or central air supply must be provided with windows that can be opened by the building occupants in order to provide fresh air and air movement (Auliciems and Szokolay, 2007).

2.5.4 Relative Humidity

DOSH Malaysia (2016) defines relative humidity as the ratio between the actual amount of water vapor in the air and the maximum amount of water vapor that the air can hold at the air temperature. Relative humidity is one of the important factor in determining the effectiveness of evaporative heat loss. DOSH Malaysia (2016) state that environment with high humidity that have a lot of vapor in the air prevents the sweat evaporation from the skin. Humidity is important in hot environments because less sweat evaporates when humidity is high, which is above 80%. Relative humidity between the range of 40% to 70% does not give major impact on heat stress.

On the other hand, if the workplaces are not air conditioned or the indoor heat environment are influenced by outdoor weather conditions, the relative humidity may be higher than 70%. Auliciems and Szokolay (2007) also explained that if the dry bulb temperature is below 35ºC and the relative humidity is less than 70%, fans may help to provide thermal comfort to the workers.

Besides that, when the workers wear non-breathable vapor-impermeable personal protective equipment (PPE), the humidity inside the garment increases as the workers sweat cannot be evaporated (DOSH Malaysia, 2016). Then, if the workers wear the type of PPE such as asbestos or chemical protection suits, the humidity will be high within the PPE.

When humidity is high, the ambient vapor pressure approaches that of moist skin and evaporation is greatly reduced, hence the avenue for heat loss is essentially closed even though large quantities of sweat are produced. This form of sweating represents a useless water loss that cause dehydration and overheating. Relatively high environmental temperatures still can be tolerated as long as the humidity is low. Meanwhile, Lundgren et al. (2013) in their research mentioned that if the humidity is high, sweat is still produced but evaporation is reduced, thus reduces the cooling effect.

Auliciems and Szokolay (2007) explained that low relative humidity may cause the mucous membrane to dry and causing respiratory problems, but if the relative humidity is high, it can make the area feel stuffy. Other that than, indoors environment that has high relative humidity can also contribute to bacteria and mold growth.

2.6 Non-Environmental Factors

Besides environmental factors, non-environmental factors also contribute to the exposure of heat to the workers. The non-environmental factors of heat exposure are clothing insulation, work rate and metabolic heat, heart rate, and oral or core body temperature.

2.6.1 Clothing Insulation

Thermal comfort is depending on the insulating effect of clothing on the wearer. Clothing is intended to create a barrier for the transport of heat between the skin and the environment. However, if too much clothing or PPE is worn, it may be a primary cause of heat stress or heat exposure although the environment is not considered as warm or hot (DOSH Malaysia, 2016). Similar to (Lundgren *et al.*, 2013), they also state that workers who are required to wear semipermeable or impermeable protective clothing or PPE, are at high risk because all of these clothing may severely impedes the exchange of heat through evaporation.

Due to the thermal discomfort caused by the clothing worn, the workers tends to take off protective clothing, hence putting the worker at high risk for dangerous exposure to the sources of heat and injury. Clothing affects the heat transfer from and to the body through resistance to air movement and water permeability and ventilation (Lundgren *et al.*, 2013). In other words, the transfer of heat is influenced by the clothing insulation characteristics.

During performing physical tasks, protective clothing worn by the workers can lead to heat strain to them, as their body temperature, heart rate, and sweating rate increases. Lucas et al. (2014) explained that protective clothing can cause serious heat stress problem, because it can have no or low moisture permeability and high insulating properties which are inhibit the evaporation of sweat and normal heat dissipation, increase the temperature of internal body and skin, and also lead to excessive sweating. Hence, to improve the level of heat comfort, the level of protection provided by existing PPE should be evaluate periodically.

ACGIH (2015) has designated the modification of clothing as shown in Table 2.1.

Table 2.1

Clothing-Adjustment Factors for Some Clothing Ensembles from TLVs and BELs by ACGIH 2015

Clothing Type	**Addition to WBGT (˚C)**
Work clothes (long sleeve shirt and pants)	0
Cloth (woven materials) coveralls	0
Double-layer woven clothing	3
SMS polypropylene coveralls	0.5
Polyolefin coveralls	1
Limited-use vapour-barrier coveralls	11

Source: ACGIH (2015)

2.6.2 Work Rate and Metabolic Heat

DOSH Malaysia (2016) defined metabolic heat as the heat produced by the body through chemical processes, exercise, hormone activity, digestion, etc. More heat will be produced when more physical work is performed, thus more heat is required to be lost so that no overheat occurs.

In addition to the exchange of heat between the body and environment, metabolic processes produced internal heat. At rest, the rate of body heat production is relatively low, the resting oxygen consumption is approximately 250 mL/min corresponding to a rate of heat production of 70W, but during working, the rate of oxygen consumption can increase eightfold, and the rate of heat production is correspondingly increased.

The metabolic heat dissipation during performing physical work in a hot environment is almost totally depends on the cooling effect of sweat evaporation. However, it causes extra demands on the body's fluid reserves and dehydration occurs.

Table 2.2 and Table 2.3 shows metabolic rate of employees by job category and screening criteria for Threshold Limit Value (TLV) and Action Limit (AL) based on ACGIH TLV

Table 2.2

Work Category	Metabolic Rate	Examples
Rest	115W	Sitting
Light	300W	Sitting with light manual work with hands or hands and arms and driving. Standing with some light arm work and occasional walking.
Moderate	300W	Sustained moderate hand and arm work, moderate arm and leg work, moderate arm and trunk work, or light pushing and pulling. Normal walking. Moderate lifting.
Heavy	415W	Intense arm and trunk work, carrying, shovelling, manual sawing, pushing and pulling heavy loads, and walking at a fast pace.
Very heavy	520W	Heavy materials handling Very intense activity at fast to maximum pace.

Metabolic Rate of Employees by Job Category (ACGIH 2016)

Source: ACGIH 2016

Table 2.3

Screening criteria for Threshold Limit Value (TLV) and Action Limit (AL) based on ACGIH TLV

Work/rest regimen	Light	Moderate	Heavy
Continuous work	30.0˚C (86˚F)	26.7˚C (80˚F)	25.0˚C (77˚F)
75% Work, 25% rest, each hour	30.6˚C (87˚F)	28.0˚C (82˚F)	25.9˚C (78˚F)
50% Work, 50% rest, each hour	31.4˚C (89˚F)	29.4˚C (85˚F)	27.9˚C (82˚F)
25% Work, 75% rest, each hour	32.2˚C (90˚F)	31.1˚C (88˚F)	30.0˚C (86˚F)

Source: ACGIH (2007)

2.6.3 Weight and Physical Fitness

Susceptibility of heat varies between one person to other person. Based on Parameswarappa and Narayana (2014), body weight and physical fitness are one of crucial factors for assessing heat strain. As example, an overweight or obese person are more likely to experience heat related-illness. They need greater energy to perform a task, so higher metabolic heat is produced in their body because the person's ability to dissipate heat is reduced (S.B.Parameswarappa and Narayana, 2014). DOSH Malaysia (2016) also state that extra weight may have trouble in maintaining a good heat balance. Moreover, a person who have body mass index (BMI) 30 or more have less heat intolerance and they are in a high risk of heat stroke when they work in a hot environment. Moreover, a person who are physically unwell, especially with cardiovascular disease, high blood pressure, uncontrolled diabetes, respiratory disease skin disease, and rash are also prone to heat stress (DOSH Malaysia, 2016).

2.6.4 Age

Age is also one of the important factors in determining a person susceptibility to heat. Parameswarappa and Narayana (2014) in their study state that the older a person, the more likely they may suffer from the effect of heat exposure. An elderly people who aged over 50 years and older have poor general health and low fitness level are more are more prone to heat stress compared to younger people because their body may not adjust well to sudden or prolonged temperature change (Better Health Channel, 2015). They are also more likely to have a chronic medical condition and taking medication that can interfere with the ability of their body to regulate temperature.

2.6.5 Gender

Gender differences between men and women seem to diminish when such comparisons take into account cardiovascular fitness, body size, and acclimatization (DOSH Malaysia, 2016). Both gender have slightly different physiology, endocrinal physiology and body characteristics, in which men having average greater body size, weight, and strength. In general, women have a larger surface to mass ratio which means that women are more prone to heat loss (Lundgren *et al*., 2013).

Besides, women have a higher whole body and subcutaneous fat content compared to men, thus insulation increases. Women tolerate humid heat better and tend to have a lower sweat rate than men of equal fitness, size, and acclimatization (DOSH Malaysia, 2016). If the sweat rate is lower, it means that there can be an increased in body temperature. In the other hand, males have higher maximal sweat rates, which can enhance tolerance for extremely hot and dry environments.

2.6.6 Heart Rate or Pulse Rate

Heart rate which defined as the amount of times a person's heart beat per minute (bpm), is a general indicator of heat stress on the body. Pulse rate can be used as an effective measure of heat strain due to the way of the body responds to the increases of heat loads. Blood circulation is adjusted to move blood around the body to dissipate heat, which results in an increased of pulse rate (Parameswarappa and Narayana, 2014).

In general population, sustained level of heart rate associated with excessive heat strain vary between 180 beats per minute (bpm) less the person's age to 220 bpm minus age for cardiovascular-conditioned persons ACGIH (2001). ACGIH (2001) also sets a limit of 110 of 110 bpm for a recovery heart rate time of 1 minute. Meanwhile, Parameswarappa and Narayana (2014) in their study state that the heart rate of most average adults is 60-80 bpm, and under thermal stress, the heart rate is higher than normal heart rate.

According to Chen *et al.* (2003), during the workers exposed to heat, blood flow to the skin increases to dissipate heat imposed on the body, which copes with increase in cardiac output for the blood flow increase demand, hence results to an elevated heart rate. They also mentioned that a worker who are acclimatized able to work with much lower core temperature and heart rate, and higher sweating rate without any symptoms of heat exhaustion.

Lu and Zhu (2007) in their study found that heart rates were associated with work intensities, where the worker's heart rate who were performing heavy work were in the range of 140-160 bpm regardless of the values of oral temperature at the times of heat exposure limits. In the other hand, the workers who were performing moderate and light work, their heart rate were proportional to the oral temperature at heat exposure limits. This means the worker's heat rate increases when the oral temperature increases.

Apart from that, the study conducted by Tian *et al.* (2011) proved that the heart rate of the workers speed up when they were working in extreme hot environment.

2.6.7 Body Temperature

Body temperature is the temperature of the body as measured by a contact forehead thermometer placed at the forehead. World Health Organization, WHO recommends that body temperature should not be allowed to exceed 38˚C. Lu and Zhu (2007) in their study found that body temperature have a significant association with environmental heat conditions and work intensity, where the body temperature increases when the temperature of the environment and work intensity increase.

Meanwhile the study conduct by Tian *et al*. (2011) proved that the body temperature of the workers increase rapidly and the increment of the body temperature was large in the first 50 minutes from the beginning of heat exposure. Any increases of body temperature can lead to serious consequence. When the body is unable to cope with the hot environment, the body's heat gain exceed the ability of the body to lose heat, hence, the inner body temperature rises increasing the risk of heat related illness (Parameswarappa and Narayana, 2014).

CHAPTER 3: METHODOLOGY

3.1 Research Design

An experimental study and observational study were conducted in order to evaluate the physiological and psychological effects of heat exposure among workers in steel industry. The experimental study was conducted by comparing the physiological and psychological indices of exposed workers to the heat sources. This evaluation was carried out by two different ways which are area monitoring (real time instrumentation or environmental heat monitoring) and personal heat stress monitoring.

For area monitoring, QUESTemp°34 Thermal Environment Monitor, and Anemometer Model Velocicalc were used. While for personal heat stress monitoring, Dotory Enhanced Contact Forehead Thermometer, OMRON HEM-7114 Blood Pressure Monitor and weighing scale were used.

Meanwhile, observational study was conducted by walkthrough observation to observe the working environment in the steel industry and to determine the existence of the workplace ventilation, existing cooling provisions, nature of work, and work activities performed by the workers. Besides, questionnaires were also distributed to the workers and they were interviewed to evaluate their fatigue feeling and thermal discomfort during working in the steel industry.

3.2 Research Flow

This study was started with the site selection, where a steel industry was chosen to evaluate the physiological and psychological effect of heat exposure among steel industry workers. After that, walkthrough observation was carried out in order to achieve the first objective, which is to identify the factors of heat exposure among the workers.

Then, two types of questionnaires which are questionnaires of 'Fatigue Assessment Scale Questionnaire developed by De Vries *et al*. (2004) (Refer Appendix C) and Heat Stress Questionnaire developed by Hunt (2011) (Refer Appendix B) were adapted to be distributed to the workers in order to achieve the third objective, which is to determine the psychological condition of the workers when exposed to heat. Next, area monitoring and personal monitoring were conducted to achieve the first and second objective, which is to identify the factors of heat exposure among the workers and to compare the physiological indices of the workers before and after working.

After obtain all the data and information required for this study, all the data were analysed using Statistical Package for the Social Sciences, SPSS software. The data that has been analyse was then being interpret in order to achieve the fourth objective, which are to determine the relationship between physiological indices and psychological condition of the workers with the exposure to heat. Lastly, the results from the analysis of data were documented. Figure 3.1 shows an illustration of research flow throughout this study

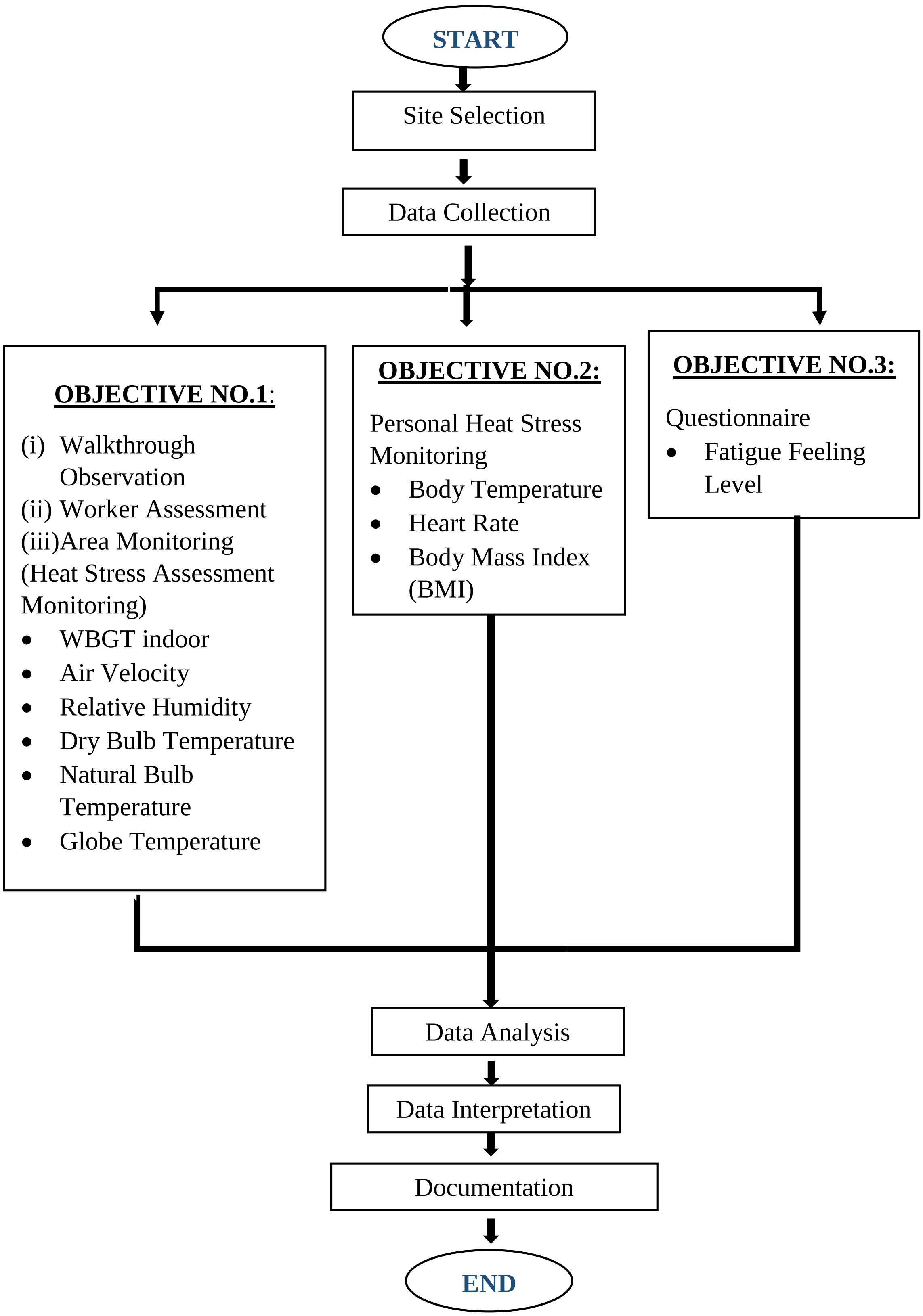


Figure 3.1: Illustration of Research Flow

3.3 Site Selection

This study was focused on steel industry located in Gebeng, Kuantan, Pahang. The workers in steel industry has high tendency to expose to the sources of heat during their working hours especially those who working at the steel production department. The activities that are carried out at that department are welding and conducted heat exchanger hydro test. These kind of work activities especially welding work that carried out in the steel industry might causing the employee to suffer heat related illness, fatigue, and thermal discomfort due to the exposure to heat source such as welding spark that is hot. Besides that, some of the machine and tool used by the workers during the hot work can cause the transmission of heat to the workers.

Other than that, the sources of heat in the steel industry are also from the climatic or weather conditions. Malaysia, a tropical country which experiences constantly high temperature which are between 24 ºC to 38 ºC and long hours of sunshine can be one of environmental factors which causes heat exposure to the workers. Figure 3.2 illustrates the location of steel manufacturing industry in Gebeng, Kuantan, Pahang.

Figure 3.2: Map of steel manufacturing industry in Gebeng, Kuantan, Pahang.

3.4 Sampling Size

In this study, respondents were selected among the workers in steel industry located at Gebeng, Kuantan, Pahang to evaluate their physiological and psychological effects of heat exposure. There were about twenty workers who exposed to hot work which is welding work were selected in this study.

The workers were selected according to their nature of work and the situation when they expose to heat source while working. Walkthrough observation was carried out to determine the nature of work that the workers usually carried out in the steel industry. The worker's health status was also being asked for genetic or other related diseases such as renal diseases, diabetes, and skin diseases, also other information like being under any medication. This study was opened to all the workers that are different races, ages, and gender.

3.5 Inclusive and Exclusive Criteria

Inclusive Criteria: All the steel industry workers who have at least three months working experience and their working hours are 8 hours per day were included in this study. This is because the worker who has been working at least three months were acclimatized with their working environment and their nature of work. DOSH Malaysia (2016) published that a complete heat acclimatization generally takes seven to fourteen days.

Exclusive Criteria: Steel industry workers who drink alcohol, consume drugs, and having health problem such as high blood pressure, respiratory disease, and diabetic were excluded in this study. This is because it can affect the result of this study by causing inaccuracy of the result obtained.

3.6 Instrumentation

For area monitoring, the environmental parameters which are dry bulb temperature, natural bulb temperature, globe temperature, relative humidity, WBGT indoor, and air velocity were measured before and after working by using QUESTemp°34 Thermal Environment Monitor and Anemometer Model Velocicalc.

In the other hand, the personal monitoring was conducted by determining the physiological indices and psychological condition of the exposed workers to the heat sources which are their body temperature, heart rate, Body Mass Index (BMI) and fatigue feeling. Dotory Enhanced Contact Forehead Thermometer Monitor was used to measure the worker's body temperature. The human's normal body temperature is 38°C. The worker's body temperature will be different at the beginning and after their working hours. While, OMRON HEM-7114 Blood Pressure Monitor was used to measure the heart rate of the workers by showing their blood pressure level and pulse rate. Human's normal heart rate is below 110 beats per minute (bpm), but the heart rate will arise while working. Next, the worker's body weight was measured using digital weighing scale.

Meanwhile, the psychological condition of the workers, which is their level of fatigue feeling was determined by using the questionnaire of "Evaluation of Subjective Symptoms of Fatigue' developed by Japan Society for Occupational Health

Table 3.1

Measuring Instruments

Type of Parameter	**Name Of Parameter**	**Instruments**
Environmental Parameters	Dry bulb temperature Relative humidity Natural wet bulb temperature Globe temperature Wet bulb globe temperature, WBGT indoor index	QUESTemp°34 Thermal Environment Monitor
	Air velocity	Anemometer

Physiological Indices	Body temperature	Dotory Enhanced Contact Forehead Thermometer
	Heart rate	OMRON HEM-7114 Blood Pressure Monitor
	Weight	Weighing Scale
Psychological Indices	Fatigue Feeling Level	Fatigue Assessment Scale Questionnaire
Worker's General Information		Questionnaires Form

3.7 Data Collection Technique

Data collection was done from October 2017 until November 2017 by conducting pilot study, walkthrough observation, distributed questionnaires, area monitoring, and personal monitoring.

3.7.1 Pilot Study

Before actual study is conducted at the steel industry, a pilot study was carried out first. This pilot study enables to estimate the suitability and feasibility of the actual study. At the beginning of the pilot study, face-to-face interview was conducted with the respondents. To make sure the respondents truly understand about this study, explanation especially the purpose of conducting this study will be given to them. Moreover, any errors that might influence the results obtained during pilot study can be used for the improvement during conducting the actual study so that actual study can be conducted smoothly and accurately.

In this pilot study, descriptive analysis and inferential analysis is used to analyze the result obtained.

3.7.2 Walkthrough Observation

Walkthrough observation was carried out in order to identify the sources of heat that might be exposed by the workers, determine the sampling locations for the environmental heat monitoring, and the work process in that industry. Besides that, it was carried out to determine the nature of work or daily work activities performed by the workers during their normal working hours, their workplace ventilation and existing cooling provisions.

3.7.3 Questionnaires

The questionnaires used in this study were consist of two which are Heat Stress Questionnaire adapted from Hunt (2011) and Fatigue Assessment Scale Questionnaire adapted from De Vries et al. (2004). Heat Stress Questionnaire (refer to Appendix B) is divided into five sections which are Section 1 until Section 5. In Section 1, the general information (i.e., age, weight, and height), and type of work activities of the respondents are taken. Section 2 is about the work environment of the workers, Section 3 is Hydration, Section 4 is Health Symptoms of Heat Illness, and Section 5 is Medical Conditions. Meanwhile, the second questionnaire, entitled Fatigue Assessment Scale Questionnaire (refer Appendix C) was used to determine the level of fatigue feeling of the workers. A person's health can be considered as affected by fatigue if he/she experienced one of the following heat related symptoms at work i.e., excessive sweating, excessive thirst, tiredness, cramps, headache, nausea or vomiting, fainting or prickly heat. The results obtained from the questionnaire were used to determine the correlation between psychological condition of the steel workers with the exposure to heat sources.

3.7.4 Area Monitoring

For area monitoring, QUESTemp°34 Thermal Environment Monitor was used to determine the environmental parameters which are dry bulb temperature, natural bulb temperature, globe temperature, relative humidity, WBGT indoor index in the steel industry. Besides that, Anemometer was used to measure the air movement or air velocity.

During conducted area monitoring, QUESTemp°34 Thermal Environment Monitor and Anemometer were placed at the height of 3.5 feet which is 1.1 meter for standing individuals or 2 feet which is 0.6 meter for seated individual. These instrument were mounted to the tripod in order to avoid anything that can block the airflow and radiant heat. Figure 3.2 and Figure 3.3 and Figure 3.4 shows QUESTemp°34 Thermal Environment Monitor and Anemometer.

Figure 3.3: QUESTemp°34 Thermal Environment Monitor

Figure 3.4: Anemometer

3.7.5 Personal Monitoring

For personal monitoring, Dotory Enhanced Contact Forehead Thermometer, OMRON HEM-7114 Blood Pressure Monitor, weighing scale were used during conducting this study in order to determine the changes of physiological indices of the workers before and after exposed to heat sources.

Dotory Enhanced Contact Forehead Thermometer as illustrated in Figure 3.5 was used to determine the body temperature of the workers, in degree Celsius (˚C). It was used to measure worker’s body temperature before and after working. It is able to read the worker’s body temperature without need to convert the reading. Human’s normal body temperature is 38ºC, but the body temperature increases when working. When the body unable to cope with hot environment, it will increase the chances of affecting by heat related illness such as heat stroke. Normally, the body temperature of person who suffer heat stroke is 40 ºC.

Figure 3.5: Dotory Enhanced Contact Forehead Thermometer

While weighing scale was used to determine worker's body weight and Body Mass Index (BMI). Body fat can influence worker's adaptation to heat as extra weight may have trouble in maintaining good heat balance. Figure 3.6 shows digital weighing scale.

Figure 3.6: Digital Weighing Scale

To determine the heart rate of the workers, OMRON HEM-7114 Blood Pressure Monitor as illustrated in Figure 3.6 was used to measure the heart rate of the workers by showing their blood pressure level and pulse rate. Human's normal heart rate is below 110 beats per minute (bpm). The heart rate of exposed workers to the sources of heat was compared before and after working. The result obtained was then used to determine the relationship between physiological indices of the workers with the exposure to heat sources.

Figure 3.7*:* OMRON HEM-7114 Blood Pressure Monitor

3.8 Data Analysis

The environmental parameters that obtained during the real time monitoring or environmental heat monitoring were used to calculate the WBGT indoor index value for the exposure. WBGT for radiant heat exposures in the steel manufacturing industry will calculate using the formula below:

For indoor conditions without solar load, WBGT is calculated as in Eq. (1.0)

$$WBGTind = 0.7\ Tnwb + 0.3\ Tg \qquad 1.0$$

Where,

WBGTind		= wet bulb globe temperature indoor index
Tnwb		= natural wet bulb temperature
Tg		= globe temperature

All the data obtained from area monitoring and personal monitoring were analysed by using Statistical Package for Social Sciences (SPSS) version 22.0 for Windows to identify the significant differences of worker's body temperature and heart rate before and after working, statistical analysis and the significant relationship between physiological effects and psychological condition of steel industry workers with the exposure to heat sources. In this study, normal distribution was tested by using parametric test, while non-parametric test was used for non-normally distributed data.

3.8.1 Descriptive Analysis

Descriptive analysis was used in this study to provide an overview information or description about the respondents. As example, the respondent's demographic data such as gender, age, body mass index (BMI), and their employment period in steel industry were described by using percentage (%), frequency (n), mean, standard deviation, minimum and maximum value. Then, all the data was shown in the form of histogram, graph, and data distribution which is normal distribution. The test used in this descriptive analysis was normality test.

3.8.2 Inferential Analysis

In inferential analysis, normality test was used to test the normality of environmental parameters, and the physiological indices of the workers before and after working. Paired Sample T-test was used to compare the body temperature and heart of the exposed workers to the heat sources. This test shows whether there is a significant difference between body temperature and heart rate before and after or not. Meanwhile, to determine the relationship between physiological indices and psychological condition of the respondents with the exposure to heat sources, correlation test was used. The Pearson's correlation and Spearman's Rho correlation were used to show whether there is a significant relationship between body temperature and heart rate of the workers with the exposure to heat sources or not.

3.9 Quality Assurance and Quality Control

Before conducting the real time monitoring which is the environmental heat monitoring, the calibration of instrument like QUESTemp°34 Thermal Environment and Anemometer was done to ensure the accuracy of the instrument's reading and to avoid systematic error. The researcher herself was trained by the laboratory assistant on the proper and correct use of the instruments in order to ensure significant as well as valid data collection.

Moreover, before distribute the questionnaire to the respondents, explanation and guidance were given to them to give understanding about the purpose of this study. The researcher asked the respondents by interview technique about the questions inside the questionnaire so that the respondents can understand all the questions more easily.

3.10 Study Ethics

During conducting this study, there are few study ethics that needed to consider. The information collected during this study should be for academic and study purpose only. Therefore, the industry and respondent's information must be kept as privacy and confidential in order to protect their human right and sensitivity.

3.11 Study Limitation

There are few limitations that can influence the result obtained from the research study that was conducted. The personal factors such as the worker's lifestyle such as drinking alcohol during can limit the result obtained of this study. Moreover, the workers who are unwilling to give cooperation during conducting this study may also influence the data collection progress. There were some workers refused to answer the questionnaires. Thus, this will affect the data collection progress.

Other than that, some environmental factors in the steel manufacturing industry, such as haze and rain can affect the result of this study. If haze occurs, it can result to the air temperature that is warmer than normal daily temperature. Besides that, haze also can result to higher relative humidity and weak wind speed or air velocity. Meanwhile, rain will cause the air temperature outside and inside the workplace of the workers to be much cooler than normal. Hence, both haze and rain can affect the reading of Wet Bulb Globe Temperature (WBGT) and influence the result of this study.

There was also time limitation or time constraint during conducting this study. This is due to the late approval from the steel industry to conduct this study at there. Moreover, it was a bit difficult in asking cooperation from some steel industries to conduct this study at their company since their company's policy not approving university students to conduct any project at their company. Besides that, there were also some company did not give approval as their steel production was shutdown.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter consists of result and discussion after all the data have been collected by using instruments such as Wet Bulb Globe Temperature, Anemometer and statistical analysis using Statistical Package for the Social Sciences (SPSS) Version 22. The topic that will be discuss in this chapter are preliminary assessment, background information of respondents, environmental heat stress assessment, personal heat stress assessment, comparison of body temperature and heart rate of workers before and after working, correlation between WBGTin with body temperature and heart rate of workers in steel industry. The result obtained will be compared with acceptable limit recommended by American Conference of Governmental Industrial Hygienists (ACGIH) 1992 and Industry Code of Practice for Indoor Air Quality (ICOP) DOSH Malaysia (2010).

4.2 Preliminary Assessment

In this research, preliminary assessment was conducted in order to identify and evaluate the potential hazards and heat sources that exist in the workplace. Preliminary assessment was divided by walkthrough observation and worker assessment. Before collecting the data, walkthrough observation was carried out to identify environmental condition, nature of work, sources of heat and potential hazards that might be exposed by the workers in the steel industry.

4.2.1 Walkthrough Observation

From the walkthrough observation in the steel industry, the sources of heat that exposed by the workers was from the hot work which is welding. Figure 4.1 shows welding work performed by the workers, while Figure 4.2 shows QUESTemp°34 Thermal Environment and Anemometer were placed near the welding work. Other than that, the type of ventilation system also had been identified during walkthrough observation. The workplace area is naturally ventilated, where the surrounding of the building is an open space that adequate fresh air from outside of the building can flow into the work area and the air inside the work area can flow to the outside of the building. There were also a few mechanical fans provided near the work area to minimize hot working environment.

Figure 4.1: Worker in a steel industry was welding a steel pipe

Figure 4.2: QUESTemp°34 Thermal Environment and Anemometer were placed near to welding work

Figure 4.3: Natural ventilation surrounding the steel industry building

The type of work activities performed by the workers was welding steel pipe and conducted heat exchanger hydro test in which it is considered as moderate work. Welding is categorized as moderate work as it involved sustained moderate hand and arm work, moderate arm and leg work, moderate arm and trunk work, normal walking and moderate lifting.

Moreover, it can be found that the worker's working hour are 8 hours per day which is started from 9.00 a.m. until 5.00 p.m. While the official resting hours for the workers are 1 hour, which is from 1 p.m. to 2.00 p.m. The workers were also provided with 2 times short break for about 15 minutes at 10.00 a.m, and 4.00 p.m. Thus, the workers had enough resting time in compliance to Permissible Heat Exposure Threshold Limit Value (TLV) recommended by ACGIH 2015, which is 75% work and 25% rest was require for moderate work category.

4.2.2 Workers Assessment

During conducting worker assessment, type of clothing worn by the workers had been assessed. It was found that majority of the workers in the steel industry wore cloth (woven material) coveralls, short and long sleeve shirt, long pants, safety helmets, safety boots, socks, gloves, welding face shield, and safety glasses that give no addition in WBGT values. Type of clothing worn during working is crucial as it can affect the final temperature for WBGT indoor.

4.3 Reliability Analysis of Questionnaire

Reliability test, which is Cronbach's Alpha was used in this study to determine the reliability and validity of the questionnaires. A questionnaire is valid and reliable if the alpha value in the range of 0.65 < alpha < 0.95. One of the element that was undergo reliability test, was Health Symptoms of Heat Illness.

4.3.1 Health Symptoms of Heat Illness

Exposure to excessive or prolonged amounts of heat and humidity without relief or insufficient fluid intake can lead to heat stress. In order to determine whether the workers in steel industry have health symptoms of heat stress, questionnaire was distributed to the workers. There were 17 types of health symptoms of heat illness that were studied in this study. As illustrated in Table 4.1, the value of alpha obtained from the reliability test is 0.898, which is in the range of 0.65 < alpha < 0.95. Thus, it can be concluded that the questionnaires of health symptoms of heat illness were valid and reliable

Table 4.1:

Reliability Test for Health Symptoms of Heat Illness

Number of Variables	Cronbach's Alpha
17	0.898

4.3.2 Assessment of the Frequency of Health Symptoms of Heat Illness

Table 4.2 shows the frequency and percentage of the respondents who have health symptoms of heat illness. Based on the table, the most frequent symptoms of heat illness were fatigue and high body temperature. Both of the symptoms were recorded with same percentage, which is 80%. Then, followed by headache and dizziness, where both of the symptoms also have same percentage (75%). While, the least frequent health symptoms of heat illness experienced by the workers was convulsions, with 0% as none of the workers answer convulsions as the health symptoms of heat illness.

It can be clearly shown that most of the workers were fatigue and they felt their body temperature was high. Fatigue can be considering as the main symptoms of heat illness since the work task that needed to perform by the workers made them to feel fatigue. Meanwhile for convulsions, it can be assumed that, the hot working environmental condition surrounding the workers was not enough to make them to have convulsions.

Table 4.2

Health Symptoms of Heat Illness Experienced by the Workers

Health Symptoms	Frequency	Percentage (%)
Red rash on skin	7	35.0
Muscle Cramp	8	40.0
Fainting	3	15.0
Headache	15	75.0
Nausea	8	40.0
Vomiting	6	30.0
Weakness	14	70.0
Fatigue	16	80.0
Dizziness	15	75.00
Clammy/Moist Skin	13	65.0
Irritability	12	60.0
Hot and Dry Skin	11	55.0
High Body Temperature	16	80.0
Confusion	11	55.0
Irritational behaviour	5	35.0
Loss of Consciousness	9	45.0
Convulsions	0	0

N = 20

4.4 Normality Test for Data Analysis

In order to identify the type of data distribution for each variable before analyse it by using appropriate test, normality test was used. The type of data distribution consists of two types, which are normally distributed and not normally distributed. In this research, there are 25 elements that has been undergoes Normality test and the result can be shown as in Table 4.3.

In Normality test, the data will be normally distributed or significant if the p-value is ($p>0.05$) and will be not normally distributed if p-value is ($p<0.05$). Based on the Table 4.4 below shows that some of the data are ($p>0.05$) which is normally distributed. But, there are also some of the data that are ($p<0.05$), not normally distributed. Thus, Paired Sample T-Test, Wilcoxon signed-ranks, Pearson Correlation, and Spearman Correlation test will be used.

Table 4.3

Normality Test for Data Distribution

Variables	Kolmogorov-Smirnov	Shapiro-Wilk
	p-value	p-value
WBGT Indoor Temperature	0.098*	0.059*
Relative Humidity	0.025	0.045
Air Velocity	0.003	0.000
Body Temperature Before Work	0.067*	0.113*
Body Temperature After Work	0.200*	0.132*
Heart Rate Before Work	0.200*	0.837*
Heart Rate After Work	0.200*	0.170*
Fatigue	0.003	0.033
Rash	0.000	0.000
Cramp	0.000	0.000
Fainting	0.000	0.000

Headache	0.010	0.001
Nausea	0.000	0.000
Vomiting	0.000	0.000
Weakness	0.001	0.006
Clammy Moist Skin	0.001	0.002
Dizziness	0.001	0.006
Irritability	0.009	0.005
Hot Dry Skin	0.001	0.001
Dizziness	0.001	0.006
Irritability	0.009	0.005
High Body Temperature	0.000	0.003
Confusion	0.001	0.000
Irritational Behaviour	0.000	0.000
Loss Consciousness	0.000	0.000

*. Significant at $p > 0.05$

4.5 Background Information of Respondents

Table 4.4 shows the background information of respondents in this research. The respondents are 20 steel industry workers, where all of them are from production department that were exposed to sources of heat through welding work. All of the respondents are male. Their age was between 24 to 56 years old. There were about 25% of respondents that age less than 25, 55% of respondents were between 25 – 39 years old, 15% of respondents were age between 40 – 55 years old, and 5% of respondents were age more than 55 years old. DOSH Malaysia (2016) stated that a person who are 50 years old and older usually have poor general health and low level of fitness, thus will make them more susceptible to feel the extremes of heat compared to other person who are younger than them. The working hours of all of them are 8 hours per day, which was from Monday to Friday.

While for the Body Mass Index (BMI) of the respondents, 10% of the respondents have an underweight BMI, 55% have normal BMI, 30% were overweight, and only 5% of the respondents were obese. DOSH Malaysia (2016) stated that a person with extra weight (overweight or obese) may have trouble maintaining good heat balance.

Other than that, employment period might also give effects to heat stress occurrence. This is because acclimatisation process is depending on the employment period. According to DOSH Malaysia (2016), a complete heat acclimatisation generally takes about seven to fourteen days. Thus, the longer the employment period, a person will be fully acclimatized. In this research, it was found that about 20% of the respondents were working at the company for less than one year, specifically 5 months. 15% of the respondents, their employment period was between 1 – 2 years. There were also 15% of the respondents that work in that company for 3 – 4 years, then followed by 50% of the respondents were work for more than 5 years. Hence, it can be concluded that majority of the respondents were fully acclimatized.

Table 4.4

Background Information of Respondents

Variables	Frequency	Percentage (%)
Age (years)		
< 25	5	25.0
25 - 39	11	55.0
40 - 55	3	15.0
> 55	1	5.0
Gender		
Male	20	100.0
Female	0	0
Body Mass Index (BMI)		
< 18.5 (underweight)	2	10.0
18.5 - 24.9 (normal)	11	55.0
25 – 29.9 (overweight)	6	30.0
30 – 34.9 (obese)	1	5.0
Employment Period		
< 1 year	4	20.0
1- 2 year	3	15.0
3 – 4 year	3	15.0
> 5 year	10	50.0

N = 20

4.6 Environmental Heat Stress Monitoring

In order to determine the environmental factors of heat exposure among steel industry workers, environmental heat stress monitoring was conducted by measuring all the environmental parameters which are Wet Bulb Globe Indoor Temperature (WBGTin), relative humidity and air velocity at the work area. This assessment was conducted for about 8 hours during the worker's working hour. After obtained the result, it was compared with the acceptable range recommended by Industry Code of Practice for Indoor Air Quality (ICOP) DOSH Malaysia (2010) and ACGIH Threshold Limit Value (TLV) in order to determine whether the environment temperature in the work area at steel industry is safe or not.

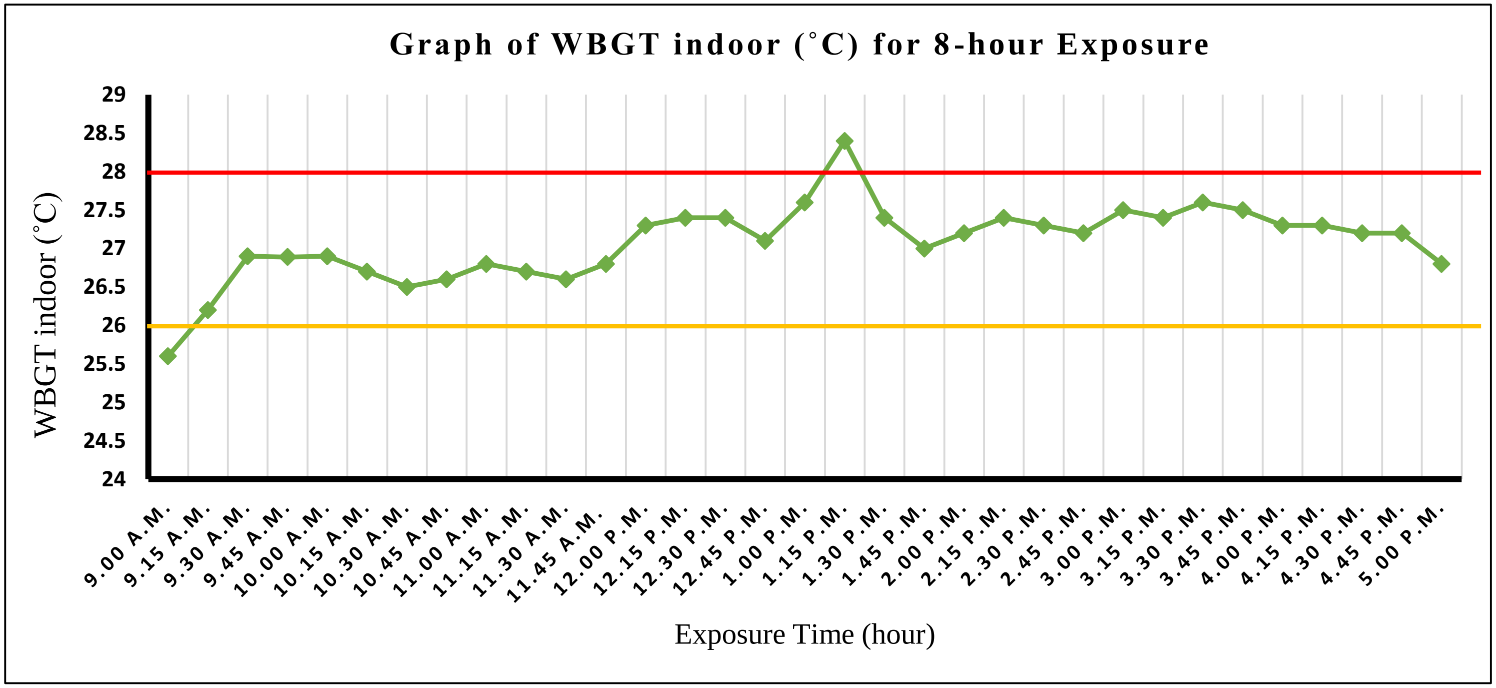
4.6.1 Wet Bulb Globe Indoor Temperature (WBGT indoor)

Figure 4.1 shows the air temperature or WBGT indoor at the welding area in production department. Based on the result obtained, it was found that the average WBGT indoor was 27.08˚C. While the minimum WBGT indoor was 25.60˚C and maximum WBGT indoor was 28.40˚C. The WBGT indoor was the highest during afternoon at 1.15 p.m. But at that time, the workers were having their resting time for 1 hour which started from 1.00 p.m. until 2 p.m. Overall, the air temperature or WBGT indoor in the steel industry are above Permissible Threshold Limit Value (TLV) of WBGT indoor recommended by ACGIH (2008) which is 28.00˚C and also exceeded acceptable range of 23˚C - 26˚C for moderate work (75% work and 25% rest for each working hour) recommended by Industrial Code of Practice (ICOP) of Indoor Air Quality, DOSH Malaysia (2010). From the result obtained, it can be said that in ACGIH (2008) point of view, the working environment is safe for the workers, but in ICOP Indoor Air Quality DOSH Malaysia (2010) point of view, the working environment is not safe for the workers since the WBGT indoor reading exceeded the acceptable range.

Table 4.5

The Average, Minimum, And Maximum WBGT indoor in Production Department.

Environmental Parameter	Minimum Value	Maximum Value	Average	ACGIH TLV	Acceptable Range (ICOP) DOSH Malaysia 2010
WBGT indoor (˚C)	25.60	28.40	27.08	28.00	23˚C - 26˚C



Note: Permissible threshold limit value (TLV) of WBGT indoor at 28˚C (ACGIH, 2008)

Acceptable range of WBGT indoor or Air Temperature (23˚C - 26˚C) recommended by Industrial Code of Practice Indoor Air Quality DOSH Malaysia (2010)

Figure 4.4: WBGT indoor at Steel Industry for 8-Hour Exposure

4.6.2 Relative Humidity

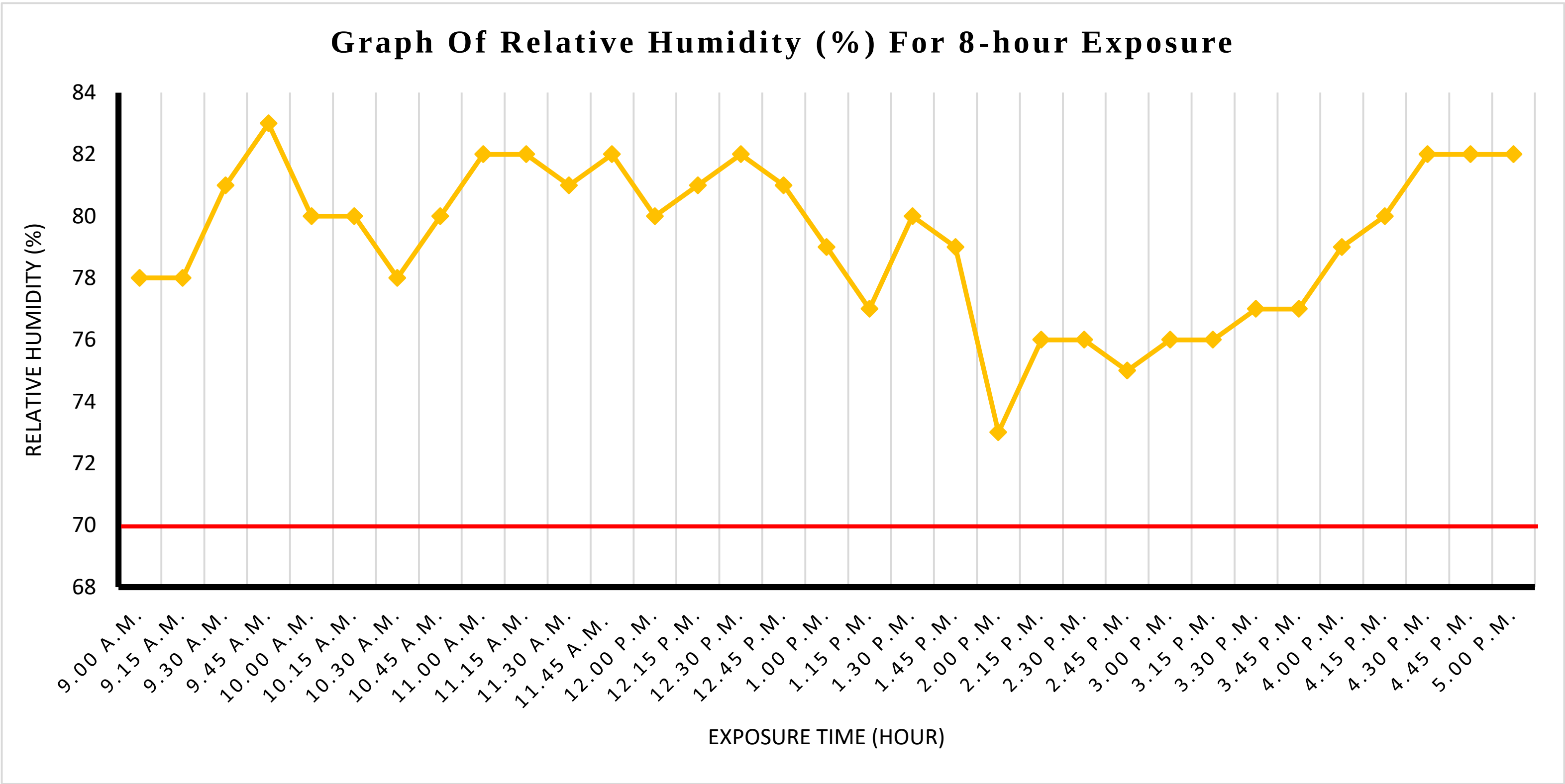
Figure 4.5 shows the relative humidity at welding area in production department. The average relative humidity obtained which is 79.24%, was above the acceptable range of 40 – 70% recommended by ICOP DOSH Malaysia (2010). While the highest value of relative humidity recorded was 83% and the lowest value was 73%. At 12.00 p.m. until 12.30 p.m., there were raining occurs. Ismail et al. (2010) stated that during a rainy day, relative humidity will increase and it can also decrease slightly from morning to evening. Therefore, the conditions of weather can affect the relative humidity in the steel industry.

According to DOSH Malaysia (2016), high humidity environment contains a lot of vapour in the air, in which it prevents the sweat evaporation from the skin. Besides that, humidity in a hot environment is important because there will be less sweat evaporates when humidity is high (above 80%). The evaporation of sweat is the main method of heat reduction. DOSH Malaysia (2016) also stated that relative humidity between 40% and 70% does not give a big impact on heat stress, and in workplaces that are not air conditioned or where the weather conditions outdoors may affect the indoor heat environment, the relative humidity might be higher than 70%. In the other hand, if the relative humidity is lower than 40%, the higher the environmental temperature. So it can affect the worker's performance and causing heat stress. Overall, it can be said that the relative humidity in the steel industry is still acceptable.

Table 4.6

The Average, Minimum, and Maximum Relative Humidity in Production Department.

Environmental Parameter	Minimum Value	Maximum Value	Average	Acceptable Range (ICOP) DOSH Malaysia 2010
Relative Humidity (%)	73	83	79.24	40 - 70%



Note: ———— Acceptable range of relative humidity of 40% - 70% (ICOP DOSH Malaysia, 2010)

Figure 4.5*:* Relative Humidity (%) at steel industry for 8-hour exposure

4.6.3 Air Movement or Air Velocity

Figure 4.6 shows the air movement or air velocity at the welding area in production department. The average air velocity obtained in this study was 0.53 m/s exceeded the acceptable range recommended of 0.15 – 0.50 m/s by ICOP DOSH Malaysia (2010). While the highest value of air velocity was 1.59 m/s, also exceeded the acceptable range. In the other hand, the lowest value was 0.10 m/s, not exceeding the acceptable range.

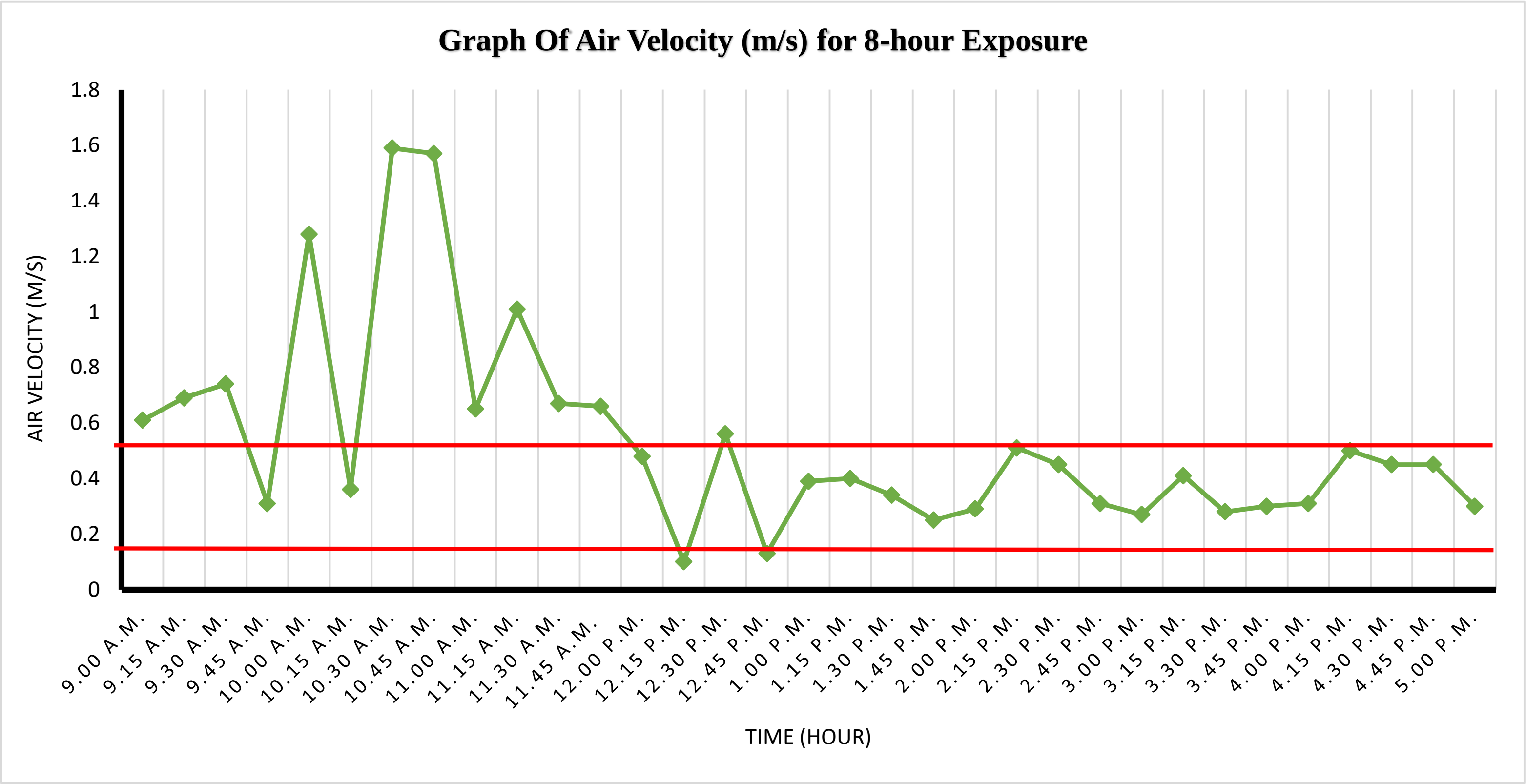
The air movement in the welding area was influenced by the natural ventilation, where fresh air from outside of the building flow into the welding area. Moreover, the air movement also influenced by the mechanical fans that were placed nearby the welding area.

According to DOSH Malaysia (2016), air movement across workers may help cool them if the air is cooler than the environment. Moving air in warm or humid conditions can increase heat loss through convection without any change in air temperature.

Table 4.7

The Average, Minimum, And Maximum Relative Humidity in Production Department

Environmental Parameter	Minimum Value	Maximum Value	Average	Acceptable Range (ICOP) DOSH Malaysia 2010
Air Movement/ Air Velocity (m/s)	0.10	1.59	0.53	0.15 – 0.50



Note: ——— Acceptable range air velocity of 0.15 – 0.50 m/s (ICOP DOSH Malaysia, 2010)

Figure 4.6: Air velocity (m/s) at steel industry for 8-hour exposure

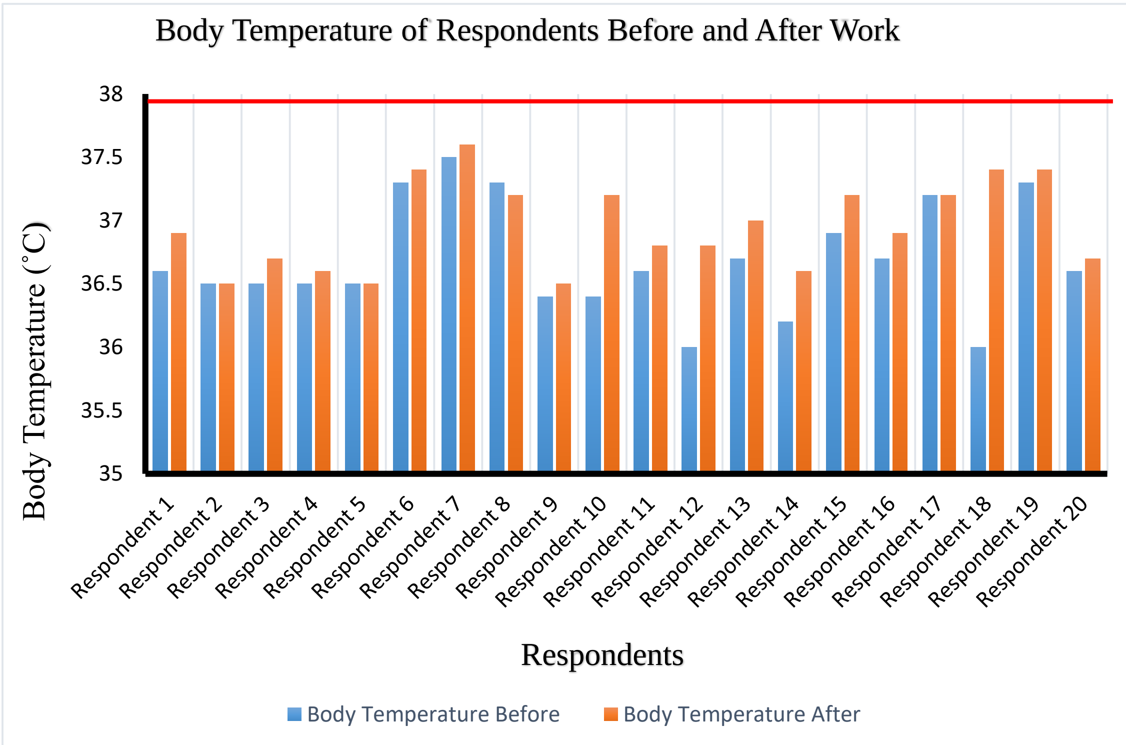
4.7 Personal Heat Stress Monitoring

Workers who are engaged in hot work normally will undergo physiological responses in their body. Any changes in the environmental conditions especially the air temperature, relative humidity, and air movement can affect their body temperature and heart rate. Besides environmental conditions, clothing and personal factors such as Body Mass Index (BMI), gender, age, medical conditions, and hydration also can influence the physiological responses to heat exposure. Excessive exposure to heat sources can cause thermal discomfort and harm the worker's health, thus resulting to heat stress and reduce their working productivity. In order to determine the physiological effects of heat exposure among the steel industry workers, personal heat stress assessment was conducted by measuring and comparing the worker's body temperature and heart rate at the beginning of working hours and after working hours.

4.7.1 Comparison of Body Temperature to ACGIH (2006)

The body temperature of the 20 steel industry workers who were working at the production department has been measured at the beginning of their working hours and after working hours to identify is there any increases of body temperature after the workers started performing their work. Moreover, the worker's body temperature was also collected to compare the results obtained with the ACGIH TLV (2006)

According to Permissible Heat Exposure Threshold Limit Value (TLV) recommended by ACGIH (2006), the body temperature of workers who are acclimatized and healthy must not exceeded 38˚C. As illustrated in Figure 4.7, the workers body temperature was below the TLV recommended by ACGIH, which is 38 ˚C. For the reading of body temperature before working, the highest and lowest body temperature were 37.50˚C and 36˚C respectively. While for the reading after working, the highest was 37.60 ˚C and the lowest was 36.50˚C. Other than that, most of the worker's body temperature reading increases from before to after working. Thus, both body temperature of the workers before and after working was not exceeded the ACGIH TLV (2006).



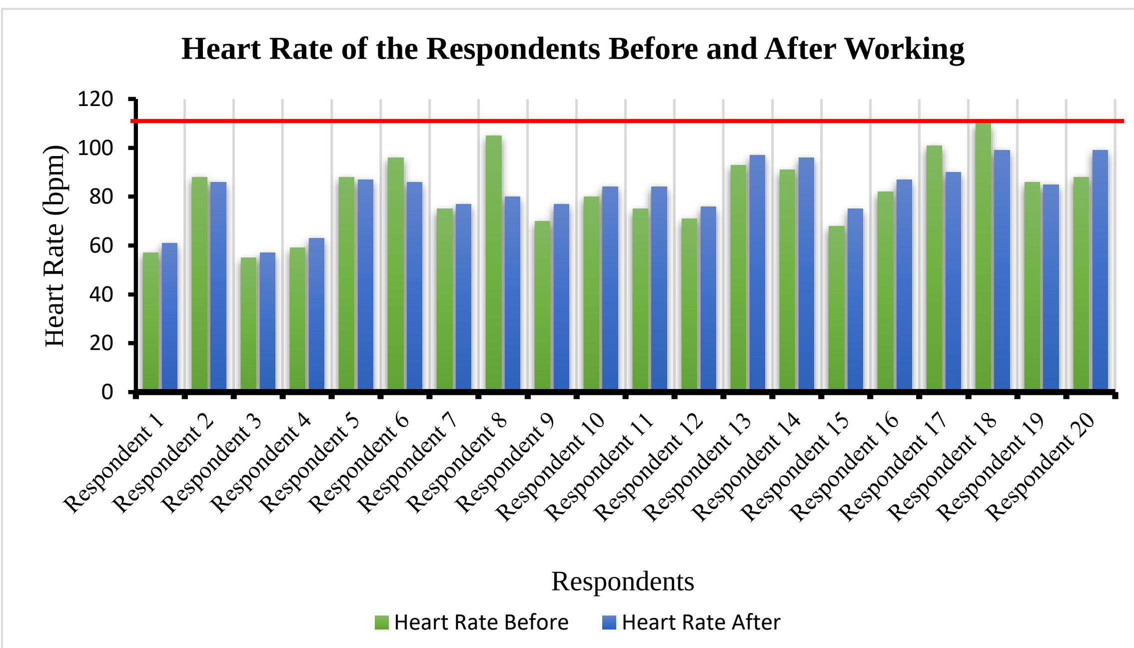
Note: ———— Permissible Heat Exposure Threshold Limit Value (TLV) of Body Temperature (38˚C) by ACGIH (2006)

Figure 4.7: Body Temperature of Respondents Before and After Work

4.7.2 Comparison of Heart Rate to ACGIH (2001) and OSHA Technical Manual (1999)

Similar to body temperature, the heart rate of the steel industry workers also was measured at the beginning and after working in order to identify if there were any increases occur. The result of the heart rate obtained was then compared with standard of OSHA Technical Manual (1999) and TLV by ACGIH (2001).

According to OSHA Technical Manual (1999) and ACGIH (2001), the normal heart rate is below than 110 beats per minute (bpm). Figure 4.8 shows that the reading of all worker's heart rate were recorded below 110 bpm. There was only one worker who his heart rate was 110 bpm. For the reading of heart rate before working, the lowest was 55 bpm, while the highest was 110 bpm. Meanwhile for the reading of heart rate after working, the highest and lowest were 99 bpm and 57 bpm respectively. Same to body temperature, most of the worker's heart rate reading increases from before working to after working. Thus, both heart rate of the workers before and after working was not exceeded the ACGIH TLV (2006).



Note: ———— Standard of Normal Heart Rate (110 bpm) by OSHA Technical Manual 1999

Figure 4.8: Heart Rate of Respondents Before Working and After Working

4.8 Comparison of Body Temperature and Heart Rate of Respondents Before and After Work

In order to compare the respondent's body temperature and heart rate before and after working, paired sample t-test was used since the data of both it was normally distributed ($p > 0.05$). For the body temperature before and after working, it can be deduced according to the paired sample t-test as illustrated in Table 4.9, the significant value is smaller than 0.05 ($p = 0.003$). It indicates that there was a significant difference between the body temperature before and after work. This result match with Tian *et al.* (2011) study that stated the worker's body temperature significantly increase after working. It can be proven that, there was a physiological effects of heat exposure among the respondents in hot working environment.

Compared to body temperature, there was no significant difference between heart rate before working and after working. This is because the significant value obtained from paired sample t-test as tabulated in Table 4.8 was bigger than 0.05 ($p = 0.838$). It can be assumed that the environmental condition surrounding the respondents was not enough to affect their heart rate.

Table 4.8

Comparison of Body Temperature and Heart Rate of Respondents Before and After Work.

Variables	**t**	**p-value**
Body temperature before – body temperature after	-3.396	*0.003
Heart rate before – heart rate after	-0.207	0.838

N = 20, *significant at $p < 0.05$

Note: Paired Sample T-Test

4.9 Evaluation of Psychological Effects of Heat Exposure Among Steel Industry Workers

4.9.1 Fatigue Feeling

Normally, workers who are working in the steel industry are prone to experience fatigue feeling, especially to those who are exposed to sources of heat. Table 4.9 shows the fatigue feeling level among the steel industry workers. Based on the table, it can be clearly seen that majority of the workers, which are 15 workers (75%) out of 20 feel fatigue but can proceed work. This means that the workers still can perform their work in the hot working environment although they felt fatigue.

Other than that, there were 2 workers (10%) experienced fatigue, physical fatigue, and hard to endure which means that their level of fatigue was quite high compared to other 18 workers. Thus, control measures have to be taken so that the workers will not experience heat stress or heat exhaustion.

Table 4.9

Level of Fatigue Feeling Experienced by Steel Industry Workers

Score	**Fatigue Level**	**Frequency**	**Percentage (%)**
10	Unfatigued	1	5.0
11 – 20	Feel fatigue but can proceed work	15	75.0
21 – 30	Fatigue, physical decline, and inattentive	2	10.0
31 – 40	Physical, and physic fatigue, and hard to endure	2	10.0
41 - 50	Extreme fatigue and need immediate rest	0	0

4.10 Correlation Between WBGT Indoor with Body Temperature and Heart Rate

Table 4.10 shows the relationship between WBGT indoor temperature in steel industry with the worker's body temperature and heart rate. The correlation between these two variables were determined by using bivariate correlation which is Pearson Correlation Test. As illustrated in Table 4.10, there were no significant relationship between WBGT indoor temperature with worker's body temperature ($r = 0.268$, $p > 0.05$). In the other hand, unlike body temperature, there were strong relationship between WBGT indoor temperature with the heart rate of the workers ($r = 0.543$, $p < 0.05$).

The relationship between WBGT indoor with body temperature were not significant as the worker's body temperature may not much affected by the changes of environmental temperature surrounding them as the hot working environment was not enough to affect the worker's body temperature. Besides that, their working area was provided with natural ventilation and mechanical ventilation such as fans, thus it can reduce the hot environment.

While between WBGT indoor and heart rate, there were strong correlation between these two variables because heart rate reacted to the air temperature surrounding the workers.

Table 4.10

Correlation Between WBGT indoor with Body Temperature and Heart Rate of the Workers

Main Variables	Related Variables	r	p-value
WBGT Indoor	Body Temperature (after work)	0.268	0.127
	Heart Rate (after work)	0.543*	0.007

Note: Pearson Correlation Test

*. Correlation is significant at $p < 0.05$ (1-tailed)

4.11 Correlation Between WBGT Indoor with Fatigue Feeling

Beside affecting body temperature and heart rate of workers, environmental temperature or WBGT indoor also can cause fatigue to the steel industry workers. In order to determine the relationship between WBGT indoor with fatigue feeling experienced by the workers, Nonparametric Correlation test which is Spearman's rho. If the p-value is ($p < 0.05$), there will be a significant relationship between WBGT indoor with fatigue feeling.

As tabulated in Table 4.11, the result shows that there was no significant relationship between WBGT indoor with fatigue feeling experienced by the workers ($r = -0.119$, $p > 0.05$). This depicts that the environmental temperature or WBGT indoor in steel industry was not much affecting the fatigue feeling experienced by the workers. It might be the workload performed by the worker itself that caused the workers to feel fatigue during working. Moreover, it can be assumed that although the workers were exposed to hot working environment, they had enough rest (70% work and 25% rest).

Table 4.11

Correlation of WBGT indoor with Fatigue Feeling Experienced by Steel Industry Workers

Main Variables	Related Variables	r	p-value
WBGT Indoor	Fatigue Feeling	- 0.119	0.618

Note: Spearman's Rho Correlation Test

N = 20

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the findings obtained from this study, high air temperature or hot working environment is the main factor of heat exposure among steel industry workers. The source of heat exposure was from welding work performed by the workers.

The physiological indices of the workers, which are body temperature and heart rate before and after working has been compared in this study in order to determine the physiological changes or response when exposed to hot heat sources. The results showed that the physiological changes were happen since the worker's body temperature and heart rate increases when exposed to sources of heat. There was a significant difference between the worker's body temperature before and after work. However, for heart rate, the increment was not significance.

Moreover, this study also found out that majority of steel industry workers feel fatigue when working in hot environment but they still can proceed work since they have enough resting time (75% work, 25% rest). Only 2 workers experienced fatigue, physical fatigue, and hard to endure. Thus, control measures have to be taken so that the workers will not experience heat stress or heat exhaustion.

While in determining the relationship between physiological indices of the workers with the exposure to sources of heat, it has been found that there was no relationship between air temperature or WBGT indoor with worker's body temperature. In contrast to body temperature, the was a strong relationship between WBGT indoor with heart rate. Furthermore, in determining the relationship between worker's psychological condition with heat exposure, this study has proved that the was a weak relationship between WBGT indoor with fatigue feeling experienced by the workers.

It can be concluded that although the air temperature in steel industry was quite high, but the worker's body temperature was not much affected by it, since the air movement and relative humidity were enough to reduce the hot temperature. However, the heart rate of the workers was affected the most.

In order to avoid excessive heat exposure among steel industry workers, the steel industry should add more mechanical fans and install local exhaust ventilation system. Besides that, training and information about heat stress management should be provided to worker and supervisor so that they are aware with the safety and health hazard of heat stress.

5.2 Recommendations

There are a few recommendations that can be proposed in this study for steel industry and future study.

5.2.1 Steel Industry

In order to avoid excessive heat exposure among steel industry workers, the steel industry can apply or implement the recommendation as below:

i) Engineering Control

Ventilation system in the steel industry can be improvised by adding more mechanical fans as the existing mechanical fans in the work area were not enough to cool down the hot working environment. Although there were natural ventilation surrounding the steel industry building, but it is not enough as the problem is the radiant heat produced from welding work. In conjunction to that, local exhaust ventilation should be installed to reduce the air temperature.

ii) Training

The workers who are working in steel industry who are exposed to heat sources as well as the supervisor should undergo training related to heat stress management. Moreover, they need to be informed about the health symptoms of heat illness and the control measures to prevent or treating heat stress. U.S National of Occupational Safety and Health (NIOSH) stated that the following elements should be cover in heat stress training. The elements are:

i. Knowledge of heat stress hazards
ii. Recognition of risk factors, danger signs and symptoms
iii. First-aid procedures awareness and awareness of heat stroke potential health effects
iv. Responsibilities of employees in preventing heat stress
v. Dangers of drug usage (including prescription drugs) in hot working environment.

5.2.2 Future Study

There are also a few recommendations for future research that may help to improve findings and increase validity of the results. Below are the recommendations that can be apply:

i) Study Location

The location of this study is quite small compared to previous study due to production activities in this steel industry was not as much as before. Only welding work that was ongoing during this study conducted. Hence, it is advisable to select steel industry that have more hot work such as steel manufacturing industry that contain coke oven or furnaces.

ii) Sample Size

Compared to previous study, the sample size in this study is quite small due to limited number of steel industry workers present during conducting this study. So, to obtain more valid and significant data, it is advisable to increase the number of sample size.

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APPENDICES

Appendix A Gantt Chart

CONTENTS	FEB 2017	MARCH 2017	APR 2017	MAY 2017	JUNE 2017	JULY 2017	AUG 2017	SEP 2017	OCT 2017	NOV 2017	DEC 2017
1. Designing the research study											
2. Literature review											
3. Data Collection - Walk through observation (identify sampling locations and work activities)									MILESTONE 1		
4. Data collection conduct interview and distribute questionnaires)									MILESTONE 3		
5. Data collection (Conduct environmental monitoring and personal monitoring)									MILESTONE 1 AND 2		
6. Data Analysis									MILESTONE 4		
7. Documentation											

Appendix B Questionnaires Form

PARTICIPATION INFORMATION SHEET

TITLE: Evaluation of Physiological and Psychological Effects of Heat Exposure Among Steel Manufacturing Workers

The purpose of this study is to determine the factors that contribute to heat exposure among steel manufacturing workers in steel industry, and also to determine the effects of heat exposure to the worker's body and mental. This questionnaire has been design to collect the information to achieve the desired target and will be used only for learning purposes. Your participation in this research is completely voluntary. All your information will be kept private and confidential.

Please answer this question as best as possible. This question only takes 5 minutes to answer. Please return the questionnaire after you have answer it. Any enquiries related to this questionnaire, you can contact **Izzati Binti Isahak** at **017-5887881** or email to ezatyisahak@yahoo.com. Thank you for your cooperation.

Tujuan kajian ini adalah untuk menentukan faktor-faktor yang menyumbang kepada pendedahan haba dikalangan pekerja di industri pembuatan besi, dan menentukan kesan-kesan haba terhadap pekerja. Borang soal selidik ini telah direka bertujuan untuk mengumpul maklumat untuk mencapai sasaran yang dikendaki dan hanya akan digunakan untuk tujun pembelajaran. Penyertaan anda dalam penyilidikan ini adalah secara sukarela. Semua maklumat anda akan dirahsiakan.

Sila jawab soalan ini sebaik mungkin. Soalan ini hanya mengambil masa 5 minit untuk dijawab. Sila pulangkan kembali borang soal selidik ini selepas anda menjawabnya. Sebarang pertanyaan yang berkaitan soal selidik ini, anda boleh hubungi ***Izzati Binti Isahak*** *di* ***017-5887881*** *atau emel ke* ezatyisahak@yahoo.com*. Terima kasih diatas kerjasama anda.*

Prepared by/*Disediakan oleh*

Izzati Binti Isahak

SECTION A: GENERAL CHARACTERISTICS

BAHAGIAN A: MAKLUMAT UMUM

1. Age / *Umur :* < 25 yrs □ 25-39 yrs □

40-55 yrs □ >55 yrs □

2. Gender / *Jantina :* Male / *Lelaki* □ Female / *Perempuan* □

3. Height / *Tinggi :* 150 – 159 cm □ 160 – 169 cm □

170 – 179 cm □ 180 – 189 cm □

4. Weight / *Berat* : 50 – 59 kg □ 60 – 69 kg □

70 – 79 kg □ 80 – 89 kg □

5. Job Position/*Jawatan*: ______________________________

6. Department/*Jabatan;* ______________________________

7. How long have you been employed?

Berapa lama anda telah diambil bekerja?

<1 yr □ 1-2 yrs □ 3-4 yrs □ >5 yrs □

8. Working hours: < 8hours □ 8 hours □ > 8 hours □

Jam bekerja : <8 jam □ *8 jam* □ *> 8 jam* □

9. How many breaks do you have on your shift?

Berapa kali waktu rehat dalam waktu bekerja?

1 □ 2 □ 3 □ 4 □ 5 or more / *atau lebih* □

10. How long of your breaks?

Berapa lama anda berehat?

<15 minutes □ 16 – 30 minutes □ 31 – 45 minutes □ □ 46 – 60 minutes

11. At the end of a regular shift, how often do you feel **<u>physically tired</u>**?

Pada akhir waktu bekerja, adakah anda kerap merasa ***<u>letih secara fizikal</u>****?*

Never □	Rarely □	Sometimes □	Often □	Always □
Tidak pernah	*Jarang*	*Kadang-kala*	*Kerap*	*Selalu*

12. At the end of a regular shift, how often do you feel **<u>mentally tired</u>**?
Pada akhir waktu bekerja, adakah anda kerap merasa ***<u>penat secara mental</u>****?*

Never ☐	Rarely☐	Sometimes ☐	Often ☐	Always☐
Tidak pernah	*Jarang*	*Kadang-kala*	*Kerap*	*Selalu*

13. Are you drinking alcohol?
Adakah anda minum minuman beralkohol?
Yes / *Ya* ☐ No / *Tidak* ☐

14. Are you smoking cigarette?
Adakah anda merokok?
Yes / *Ya* ☐ No / *Tidak* ☐

SECTION B: WORK ENVIRONMENT

BAHAGIAN B: PERSEKITARAN PEKERJAAN

1. Please tick all (Yes/ No) of the items of clothing you wear while working.
   Tandakan semua (Ya/Tidak) jenis pakaian yang dipakai sewaktu bekerja.

Type of clothing / ***Jenis Pakaian***	**Yes /** ***Ya***	**No/** ***Tidak***
Short sleeve shirt / *Baju lengan pendek*		
Long sleeve shirt / *Baju lengan panjang*		
Short / *Seluar pendek*		
Long pants / *Seluar panjang*		
Singlet / *Singlet*		
Coveralls / *coverall*		
Boots / *Kasut but*		
Socks / *Stokin*		
Gloves / *Sarung Tangan*		
Safety helmet / *Helmet keselamatan*		
Safety Goggle / *Pelindung mata*		

2. How would you describe the temperature of the environment you work in?
   Bagaimana suhu persekitaran di tempat kerja anda?

   Very Cold ☐ Cool ☐ Neutral ☐ Hot ☐ Very Hot ☐
   Sangat sejuk *Sejuk* *Neutral* *Panas* *Sangat panas*

3. How much time do you spend working close to hot machinery or surfaces?
   Berapa lama anda bekerja berdekatan dengan mesin atau pemukaan yang panas?

   < 8hours ☐ 8 hours ☐ > 8 hours ☐
   <8 jam ☐ *8 jam* ☐ *> 8 jam* ☐

SECTION C: HYDRATION

BAHAGIAN C: HIDRASI

1. How often do you sweat at work? *Berapa kerapkah anda berpeluh?*

   None / *Tiada* □ Some of the time / *Waktu tertentu* □

   Half of the time / *Setengah waktu* □ Most of the time **/** *Kerap* □

   All of the time / *Sepanjang waktu* □

2. Is drinking water is freely accessible during work?

   Adakah dibenarkan minum air semasa bekerja?

   Yes / *Ya* □ No / *Tidak* □

3. How often do you drink during your shift? *Berapa kerap anda minum ketika bekerja?*

   1-3 times □ 4-6 times □ 7-9 times □ 10 and more □

4. What type of drink do you consume most often **during work**?

   Apakah jenis minuman yang anda minum setiap kali ***semasa bekerja****?*

   Plain water/ *Air* kosong □ Tea/ Coffee/ *teh / kopi* □

   Soft drink (eg. Coke**)** □ Isotonic drink (eg. 100plus**)** □

5. How much water do you consume each time **during your shift***? Berapa banyak air anda minum* ***ketika waktu bekerja****?*

   None □ <330 ml (can/*tin***)** □ 330-600 ml (small bottle/*botol kecil*) □

   600-1250ml (large bottle/ *botol besar*) □ >1250 ml □

6. How often do you urinate during your work shift?

   Berapa kerapkah anda membuang air kecil ketika dalam waktu bekerja?

   ________ times per shift/*kali setiap waktu berkerja*

SECTION D: SYMPTOMS OF HEAT ILLNESS
BAHAGIAN D: TANDA-TANDA PENYAKIT HABA

Have you experienced any of the following symptoms, which of you think is related to heat illness, at work in the past 12 months?
Please circle one number for each symptom in the table below:

Pernahkah anda mengalami tanda-tanda berikut, yang manakah berkaitan dengan penyakit haba, ditempat kerja dalam masa 12 bulan lepas?
Tandakan bulat pada simptom-simptom yang anda alami dalam kotak dibawah:

1	2	3	4	5
Never/ Tidak pernah	**Rarely/ Jarang**	**Sometimes/ Kadang-kala**	**Often/ Kerap**	**Always/ Selalu**

Sign and symptoms / *Tanda-tanda dan gejala*	**Frequency /** *Kekerapan*				
Red rash on skin / *Ruam merah pada kulit*	1	2	3	4	5
Muscle Cramp / *Kekejangan otot*	1	2	3	4	5
Fainting / *Pitam*	1	2	3	4	5
Headache / *Sakit kepala*	1	2	3	4	5
Nausea / *Mual*	1	2	3	4	5
Vomiting / *Muntah-muntah*	1	2	3	4	5
Weakness */ Rasa lemah*	1	2	3	4	5
Fatigue / *Keletihan*	1	2	3	4	5
Dizziness / *Pening*	1	2	3	4	5
Clammy / Moist skin *Kulit melekit/lembap*	1	2	3	4	5
Irritability / *Cepat marah*	1	2	3	4	5
Hot and Dry Skin / *Kulit kering*	1	2	3	4	5
High Body Temperature / *Suhu badan meningkat*	1	2	3	4	5
Confusion / *Keliru*	1	2	3	4	5
Irrational Behaviour / *Tidak rasional*	1	2	3	4	5
Loss of Consciousness / *Hilang fokus*	1	2	3	4	5
Convulsions / *Sawan*	1	2	3	4	5

SECTION E: MEDICAL CONDITIONS

BAHAGIAN E: SYARAT PERUBATAN

1. Have you been diagnosed with any of the following medical conditions? (Please tick all that apply)
   Adakah anda dikenalpasti dengan mengalami kondisi kesihatan seperti berikut?

Medical conditions/ *Kondisi Kesihatan*	**Yes / *Ya***	**No / *Tidak***
Diabetes / *Kencing manis*		
High Blood Pressure / *Tekanan darah tinggi*		
Heart Disorder / *Masalah Jantung*		
Anaemia / *Kekurangan sel darah merah*		
Kidney Disease / *Penyakit buah pinggang*		
Skin Disorder / *Masalah kulit*		
Respiratory Disorder / *Gangguan pernafasan*		
Blood circulatory Disorder / *Gangguan peredaran darah*		

Appendix C Fatigue Assessment Scale Questionnaire

Please circle one number for each statement in the table below.
Sila bulatkan satu nombor untuk setiap kenyataan di dalam jadual di bawah.

1	2	3	4	5
Never/*Tidak pernah*	**Sometimes/ *Kadang-kala***	**Regularly/ *Kerap***	**Often/*Sering***	**Always/*Selalu***

SIGN AND SYMPTOMS	RATING				
1) I am bothered by fatigue / *Saya terganggu oleh keletihan*	1	2	2	4	5
2) I get tired quickly / *Saya cepat letih*	1	2	3	4	5
3) I do not do much during the day / *Tidak banyak yang saya lakukan ketika hari siang*	1	2	3	4	5
4) I do not have enough energy for everyday life / *Saya tidak mempunyai tenaga yang mencukupi untuk kehidupan setiap hari*	1	2	3	4	5
5) I feel exhausted physically / *Saya rasa letih secara fizikal*	1	2	3	4	5
6) I have problems to start things / *Saya ada masalah untuk memulakan sesuatu*	1	3	3	4	5
7) I have problem to think clearly / *Saya ada masalah untuk berfikir dengan jelas*	1	2	3	4	5
8) I feel no desire to do anything / *Saya rasa tidak ada keinginan untuk berbuat apa-apa*	1	2	3	4	5
9) I feel exhausted mentally /*Saya rasa letih secara mental*	1	2	3	4	5
10) I cannot concentrate quite well when I'm doing something / *Saya tidak dapat menumpukan perhatian apabila melakukan sesuatu*	1	2	3	4	5

SCORE	FATIGUE LEVEL
10	Unfatigue
11 – 20	Feel fatigue but can proceed work
21 – 30	Fatigue, physical decline, and inattentive
31 – 40	Physical, and physic fatique, and hard to endure
41 - 50	Extreme fatigue and need immediate rest

Source: De Vries (2004)

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE

TERIMA KASIH KERANA MELENGKAPKAN BORANG SOAL SELIDIK INI

Appendix D Photos Taken During Conducting this Study in Steel Industry

Briefing was given to the workers before starting data collection

Heart rate of the workers were measured

Workers answering questionnaire

A worker welding a steel pipe

Workers welding steel pipe

QUESTemp°34 Thermal Environment Monitor and Anemometer were placed near the welding area

The environmental condition of the steel industry

Taking photos with the supervisor and the workers

Appendix E Structure of the Steel Industry in Malaysia (2008)

Sub-Sector	Product Type	Number of Establishments	Rated Capacity ('000 MT)
Primary Products	Direct Reduced Iron	2	2,700
	Hot Briquetted	1	720
	Billets	6	5,250
	Bloom	1	750
	Slabs	1	2,500
Rolling/Finished Products	Light sections	5	500
	Medium to heavy sections	1	700
	Hot Rolled Coils	1	3,000
	Cold Rolled Coils	4	2,380
	Plates	2	850
Secondary Products - Longs	Wire Mesh	40	500
	Galvanized Wire	6	250
	Hard Drawn Wire	40	120
	Bolts and Nuts	15	150
	Nails	14	84
	Welding Electrodes	10	40
	High Carbon	4	154
	Shafting Bars	7	60
	Others	6	120
Secondary Products - Flats	Steel and cement-lined	31	2,300
	Pipes	4	-
	Pipe Fittings	1	250
	Tinplate	5	700
	Galvanizing	9	517
	Colour Coating	50	500
	Roll-Formers	45	5,000

Source: Malaysian Iron and Steel Industry Federation, MISIF (2008)