UNIVERSITY OF EDUCATION, WINNEBA

AN INVESTIGATION INTO SAFETY CONSIDERATIONS IN WELDING OPERATIONS IN THE SUNYANI MUNICIPALITY

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OCTOBER, 2017

DECLARATION

STUDENT'S DECLARATION

I, MENSAH AGYEKUMHENE, declare that this dissertation with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE: ……………………………………........

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SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of Dissertation as laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: ENGR. C. K. NWORU

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DEDICATION

I dedicate this dissertation to my dear daughter Nyiraba Yaa Asiraa Agyekumhene and my late grandmother Nana Afia Serwaa.

TABLE OF CONTENTS

LIST OF TABLES

ABBREVIATIONS

CEC	Commission of the European Communities
DWI	Danish Welding Institute
HIWT	Hobart Institute of Welding Technology
IARC	International Agency for Research on Cancer
MIG	Metal Inert Gas
PAW	Plasma Arc Welding
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc Welding
TIG	Tungsten Inert Gas
WHO	World Health Organization

ABSTRACT

The study sought to investigate safety considerations in welding operations in the Sunyani Municipality. Specifically, the study investigated the health and safety hazards associated with welding operations, identified the unsafe work practices of welders, as well as examined the precautionary measures adopted by welders in the Sunyani Municipality. A survey research design was employed for the study adopting the quantitative approach to data analysis and using questionnaire as the main instrument for data collection; comprises all operators of welding shops within the Sunyani Municipality. The sample for the study comprised 65 welders selected from a population of welders plying their trade at the Sunyani Magazine Area. The study revealed that welders were exposed to various kinds of health and safety challenges in the course of undertaking their welding operations. The common health and safety hazards associated with welding operations were: skin irritation caused by excessive heat from welding flames, eye infections caused by ultraviolet rays and toxic substances, and lung infections and other respiratory complications caused by fumes and toxic gases. It was found that most of the health and safety hazards faced by welders were caused by gross negligence on the part of welders and deliberate disregard for safety rules and regulations. Among the major safety measures undertaken by welders to mitigate the safety hazards they encounter included the use of ultraviolet radiation filters during welding from protecting their eyes from the radiations, keeping one's head out of welding fumes to avoid inhaling the fumes, and wearing of personal protective equipment. Based on the results of the study, it was deduced that welding operations are highly hazardous and welders are at risk of being exposed to serious health and safety hazards.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

In time past, metals were joined by riveting, screwing or bolting. Over several decades now, welding has been widely adopted as a method for joining metals. It has been observed that the process of welding is being used extensively in recent times as one of the common techniques for joining various metallic structures including ships, airplanes, automobiles, bridges, pressure vessels, etc. (Singh & Anand, 2013). Welding involves the various processes used to join metal parts by producing a coalescence, called a weld, at a joint. Welding is defined as a process in which materials of the same type or class are joined together through the formation of primary bonds under the action of heat, pressure, or the combined action of heat and pressure (Messler, 1993). It consists of those processes where metals to be joined (parent metal) are melted by an electric arc or flame, in most cases using as filler materials, coated electrodes or wires (consumables), which are designed to contribute metal to the joint area resulting in a weld with the proper metallurgical and mechanical properties (WHO/CEC/DWI/IARC, 1985).

Generally, welding processes may be classified as either fusion welding or non-fusion welding, depending on whether or not significant melting is involved. Messler (1993) asserts that the primary reason for welding being used so extensively as a joining process is that it offers high integrity of joints, a wide variety of processes and approaches, and considerable opportunities for automation. Concurring with Messler's assertion, Kim, Kim, Lee, and Jung (as cited in Singh & Anand, 2013) posit that welding provides better performance in comparison to other joining techniques in terms of joint efficiency, mechanical properties, and applications.

The AFSCME Research and Collective Bargaining Department (2011) states that there are more than 80 different types of welding and associated processes. It claims that some of the most common types of welding are: arc welding, which includes "stick," or shielded metal arc welding (SMAW), the gas-shielded methods of metal inert gas (MIG) and tungsten inert gas (TIG), plasma arc welding (PAW) and submerged arc welding (SAW). Also, other welding processes may use oxyacetylene gas, electrical current lasers, electron beams, friction, ultrasonic sound, chemical reactions, heat from fuel gas and robots. Also, in his study on weld quality assurance practices in the metal welding industries in Ghana, Akpakpavi (2015) found that the welding processes used in the informal welding sector otherwise known as the local welding industry largely include shielded metal arc welding (SMAW) and sometimes oxyacetylene welding (OAW).

There is no gainsaying the fact that the safety and health of workers in every sector of the economy is extremely important. Over time, it has emerged that workers in the manufacturing, mining, oil and gas, construction and extraction industries are continually exposed to potential health and safety hazards. The welding sector as a quasi-manufacturing industry is not immune to the numerous health and safety hazards pertaining to the manufacturing industry. In a report by the Hobart Institute of Welding Technology [HIWT], (2009), it was indicated that there are a number of potential safety and health problems associated with welding, cutting, and allied processes. The report indicated further that, despite the numerous hazards that welders are continually exposed to during welding operation, when correct precautionary measures are followed, welding will be a safe occupation.

Several studies and safety assessment reports have revealed that welding operations are characterized by various hazards which pose safety and health threats to welders and other workers in the industry. For instance, during the proceedings of the International Conference on Health Hazards and Biological Effects of Welding Fumes and Gases in Copenhagen, jointly organized by the Commission of the European Communities (CEC), World Health Organization (WHO), the Danish Welding Institute (DWI), and the International Agency for Research on Cancer (IARC, Lyon) in 1985, it was reported that welding produces a number of gaseous pollutants, either through the thermal decomposition of the electrode coating or the pyrolytic decomposition of organic substances such as paint, and anti-rust coating. It was revealed that as a result of the excessive gaseous pollutants emitted through welding activities, welders were exposed to respiratory infections such as lung cancer.

In their study on safety considerations in a welding process, Singh and Anand (2013) asserted that welding, cutting, and brazing are hazardous activities that pose a unique combination of both safety and health risks to more than 500,000 workers in a wide variety of industries. They claimed that some of the frequently encountered hazards encountered by welders and other related workers mainly include electric shocks, burns, fire and explosions, radiation, heat, noise, fumes and gases. The exposure of welders to any or all of these risks and hazards can be minimized by using an effective combination of control measures. In order to ensure safety when undertaking welding operations, Singh and

Anand recommended that preventive measures such as avoiding eye injury, respiratory protection, and ventilation of the work area, wearing protective clothing, and having safe equipment to use among others should be adopted by welders at the workplace.

Considering the nature of the Ghanaian welding industry which is mostly dominated by the informal sector, the possibility of welders being exposed to various health and safety hazards is apparent. With the lack of national policy on occupational health and safety regulations, the use of manual welding methods and techniques, and the high illiteracy rate among majority of welders in the informal sector, the rate of exposure of welders to health and safety in the course of their operation may be very alarming. However, for some time now, researchers have not given much attention to this critical issue in the welding industry. Therefore, an investigation into the health and safety hazards in the wielding industry in Ghana is very important in bringing to light the potential hazards that welders are exposed to and how these health and safety challenges can be mitigated.

1.2 Problem Statement

It is a fact that all workers engaged in welding activities are continually exposed to potential risks and hazards that threaten their health and safety. Most often, welders work under a variety of conditions including outdoors, indoors, in open areas, in confined spaces, high above the ground, and even under water. They utilize a large number of welding and cutting processes, which exposes them to fumes, gases, radiation and heat. That is to say that the use of specific welding processes or welding on particular metals can expose welders to a series of safety and health challenges.

Several studies have shown that there are a number of potential safety and health hazards associated with welding, cutting, and allied processes. The hazards in welding can be broadly grouped into the following major categories: (a) fire and explosion hazards; (b) health hazards; and (c) other hazards specific to the operation, such as loss of stability to structures (Occupational Safety and Health Branch Labour Department, 2010). In addition, hazards such as electrical shock, compressed gases, arc radiation, welding cleaning, and air contamination are associated with welding.

The AFSCME Research & Collective Bargaining Department (2011) indicates that many of the substances in welding smoke, such as chromium, nickel, arsenic, asbestos, silica, beryllium, cadmium, nitrogen oxides, phosgene, fluorine compounds, carbon monoxide, cobalt, copper, lead, selenium and zinc, can be extremely toxic with severe health implications. It states that the individual components of welding smoke can affect any part of the body, including the lungs, heart, kidneys and central nervous system and may cause health complications such as irritating of eyes; nose; chest; and respiratory tract, coughing, wheezing, shortness of breath, bronchitis, pulmonary edema (fluid in the lungs) and pneumonitis (inflammation of the lungs). Also, exposure to metal fumes (such as zinc, magnesium, copper, and copper oxide) can cause metal fume fever. Again, it has been found that gastrointestinal effects, such as nausea, loss of appetite, vomiting, cramps, and slow digestion, are associated with welding.

Considering the severity of the risks and hazards that welders are being exposed to at the workplace, the Hobart Institute of Welding Technology (2009) asserts that governments of most developed countries have become increasingly active concerning the safety and health of workers and have enacted laws prescribing safety regulations and the publication of safety information to insure the safety of workers. It claims that the most important welding standard is the American National Standard "ANSI Z49.1, on Safety in Welding, Cutting, and Allied Processes". This standard states that welding and cutting operations pose potential hazards from fumes, gases, electric shock, heat radiation, and sometimes noise.

From the foregoing, there is no doubt the welders are exposed to various life threatening risks and hazards at the workplace occasioned by the welding activities they engage themselves in. This situation calls for a thorough investigation into the potential risk and hazards that are associated with welding operations in the Sunyani Municipality and make sure that such health and safety challenges are properly and adequately handled to safeguard the health of welders. Therefore, a study that aims at investigating the safety risks and hazards in welding operations in the Sunyani Municipality and how they can be mitigated is deemed very relevant and worthwhile in the face of the hazards that welders are being exposed as a result of the nature of their work.

1.3 Purpose and Objectives of the Study

The study sought to investigate the health and safety hazards associated with welding operations in the Sunyani Municipality and proffer precautionary measures to mitigate the challenges. To achieve this aim, three specific objectives were set out to be achieved. The specific objectives were to:

1. investigate the health and safety hazards associated with welding operations in the Sunyani Municipality.

2. identify the unsafe practices of welders that expose them to risks and hazards in welding operations in the Sunyani Municipality.
3. examine the precautionary measures adopted in ensuring safety in welding operations in the Sunyani Municipality.

1.4 Research Questions

The following research questions will serve as a guide in achieving the specific objectives of the study:

1. What health and safety hazards are associated with welding operations in the Sunyani Municipality?
2. To what extent does unsafe practices of welders expose them to risks and hazards in welding operations in the Sunyani Municipality?
3. What precautionary measures are adopted in ensuring safety in welding operations in the Sunyani Municipality?

1.5 Significance of the Study

Over the years, welders have been exposed to various risks and hazards which pose a serious health challenge. Therefore, a study to investigate the various health and safety hazards encountered by welders is deemed necessary because it will help identify these hazards and proffer measures to mitigate them. Thus, if the hazards revealed in the study are properly and adequately handled, the welder is as safe as any other industrial worker. This will help improve safety in relation to welding operations and thereby save welders and other workers from these future injuries and health complications. Thus, the study will suggest ways and means of controlling safety risks and hazards associated with welding operations. Also, the study will contribute to knowledge by enriching and adding to the limited literature on safety considerations in welding operations in developing countries and Ghana in particular.

By contributing to the literature, the study will serve as a source of reference to future researchers in this area. In terms of policy formulation, the findings of the study will justify the need for the development of a national occupational health and safety regulations for the welding and associated industries that are exposed to various health and safety hazard. Lastly, it must be emphasized that this study will be beneficial to the researcher in the sense that it will be carried out in partial fulfillment of the requirements for the degree of Master Technology in Mechanical Technology Education.

1.6 Scope of the Study

The study focused on investigating the health and safety hazards associated with welding operations in the Sunyani Municipality. Thus, the study was confined to welding operations carried out within the Sunyani Municipality. The other major issues of concern were to examine the unsafe practices of welders that exposed them to safety risks and hazards and the precautionary measures adopted in ensuring safety in welding operations. The study did not involve an analysis of the future health implications of the various risks and hazards that were identified in the study.

1.7 Organization of the Study

The study will be structured into five chapters. The First Chapter will be the introduction to the study and will involve the background of the study, problem statement, purpose and objectives of the study, research questions, and significance of the study. In addition, the chapter will present the scope of the study, limitations of the study, definition of key terms used, and organization of the study. Chapter Two will present a review of relevant literature related topic of study and other related issues. Chapter Three will capture the methodology section of the study. It will involve description of the research design, study area, population, the sample and sampling techniques used. Also, the chapter will discuss the data collection instruments the will be used and the data collection procedures to be adopted as well as the methods used for data analysis. Again, issues relating to validity and reliability of the instruments, and ethical considerations will be discussed in the chapter. Chapter Four will comprise the presentation, analysis of results and discussion of the findings with reference to prior literature. Chapter Five will conclude the study by presenting a summary of the findings of the study, the relevant conclusion drawn based on the findings, the necessary recommendations and suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the review of literature relating to health and safety issues associated with wielding operations. It gives an overview of the welding industry, and describes the concept of welding and the types of welding techniques. The health and safety hazards associated with welding as well as the precautionary measures for mitigating these challenges are discussed in the chapter. The review is presented under headings and sub-headings based on the suitable themes developed from the objectives of the study to enhance coherency and readability.

2.2 Overview of the Welding Industry

The welding industry is an important facet of the broad metal industry and it consists of a number of welding fraternities such as welding workforce, welding materials and equipment supply group, welding education and training group, welding organization group as well as the end user group (Smallbone & Kocak, 2012). Over the last decades, the collective operations these groups have contributed enormously towards the development of the industry through the provision of energy for lighting and cooking, creation of efficient and effective transportation, provision of clean water, safe sanitation, accommodation both for living and working, and the creation of machinery for diverse industrial application especially in the developed countries.

The activity of welding can be traced back to the Bronze Age where small gold circular boxes were made by pressure welding lap joints. It is estimated that these boxes were made more than 2000 years ago.

During the Iron Age the Egyptians and people in the eastern Mediterranean area learned to weld pieces of iron together. Many tools were found which were made approximately 1000 B.C. During the Middle Ages, the art of blacksmithing was developed and many items of iron were produced which were welded by hammering. It was not until the 19th century that welding, as we know it today was invented. The process of welding dates back to the nineteenth century upon the discovery of the electric arc in 1802 by Petrov. Gas welding and its related process such as oxygen cutting evolved in the in the mid-nineteenth century upon the discovery of a chemical method of oxygen production by Bousingould in 1851 and the invention air liquefaction in 1887 of by Cailletet and Pietst. In 1883, Bernardos constructed a torch with a carbon electrode in the middle surrounded by a series of gas nozzles, creating the tool for combined electric arc/gas welding and the idea of the gas-shielded process. The evolvement of gas welding brought about more dynamic development and practical applications in welding operations. In 1895, Linde invented the simple liquefaction method which enabled the development of an economic industrial production of oxygen. The production of acetylene from calcium carbide contributed immensely to the use to use of gas welding and oxygen cutting in industry. However, history has it that the first attempt to adopt welding processes on a wide scale was made during World War I (Musa, 2012).

Smallbone and Kocak (2012) contend that joining metals and new materials such as transformation induced plasticity (TRIP) steels, advanced ferritic steels, super austenitic and super duplex stainless steels, and dissimilar materials for diverse applications is a head-ace to the welding industry. As a means of joining metals, welding has many applications, both domestically and industrially with some of the major welding activities involving the manufacture, repair and maintenance of products such as ships, aircraft, automobiles, electric and electronic parts, and in building and construction work (Davison, 1999).

In the early to mid-twentieth century, the most widely used welding technique was gas welding. However, the continuous improvement in electric arc welding shot it into prominence at the latter part of the century. It must be emphasized that during these times, manual arc welding was equally making a big step forward due to the coated electrodes developed by Andrews and Stresau and improved by Kjellberg (Saunders, 2009)

2.3 The Welding Industry in Ghana

According to Gyasi (2013), activities in welding in West African states such as Ghana, Nigeria and Cameroon growing tremendously as a result of industrial sectors utilizing welding in their operations. Generally, welding operations in Ghana can be grouped under two sectors namely the formal welding sector and the informal welding sector.

The formal welding sector comprises welding operations undertaken by trained and qualified welders with the requisite modern welding technologies who ply their trade in well-equipped workshops or welding environment with their activities focusing on industries such as manufacturing, automobile, heavy equipment, mining and drilling (oil and gas), shipping and construction. Some of the major companies operating in the aforementioned industries have their own welding shops with the companies' premises with qualified welders who take care of their welding operations. Companies who do not have separate welding units may hire the services of professional welders when the need arises.

In a detailed description of the formal welding sector in Ghana, Akpakpavi (2015, p.112) had this to say: "the formal sector of the welding industry in Ghana comprises of companies operating as medium and large enterprises (MLEs) registered in Ghana's trade register with clear-cut business objectives. The formal welding sector among other things designs and manufactures such products as palm kernel crackers, corn mill, block making machine, vegetable processing machine, metal tanks, containers, gas and oil tanks, pipeline construction and installation and reconstruction of mining equipment". It must be emphasized that welding operations in the formal sector is somewhat regularized and more organized. Also, modern welding techniques and practices are adopted in the formal sector.

On the other hand, the informal welding sector comprises welding operations carried out by artisans in roadside welding shops, under trees and local welding shops in light industrial areas. Welders in this sector engage in repair and manufacture of car seats, aluminum containers for shops, brick/block moulding machines, wagon and chassis (trucks), coal pot, oil/fluid storage tanks, iron gates, car seat frames, billboards, burglarproof windows and doors, vehicle body repairs, etc. Akpakpavi (2015) asserts that main welding activities undertaken in the informal sector include fabrication of plate and sheet metals, manufacturing of metal products, and maintenance and repairs of metallic products. He adds that though the level of professionalism in the informal welding sector is low, welders in this sector are experienced as a result of constant practice in the welding operations. The welding methods used mostly in the informal welding sector are electric arc welding and oxyacetylene welding.

Moreover, Studies have shown that about 65% of welding operations in Ghana are carried out in the informal sector because individuals and companies without in-house welding workshops or welding technicians prefer to hire local welders operating in the informal sector for reasons of proximity, accessibility and relatively low works charges.

2.4 The Concept of Welding

Welding is an ancient art which has been in use since the bronze age. Welding is the process of joining two pieces of metals together by melting a metal work piece along with a filler metal to form a strong joint (Occupational Safety and Health Branch, 2010). In other words, welding is a process of joining two or more pieces of metallic parts by raising the temperature of the surface of the metals to a plastic or molten condition with or without the application of pressure or filler metal (Musah, 2012). Therefore, the basic concept underlying welding is that, it is a process of joining pieces of metal by the use of heat, pressure, or both.

It must be emphasized that the process of welding does not necessarily mean the mere bonding of two metals together as in brazing and soldering, but the joining of metals together through the use of extreme heat and sometimes the addition of other metals and gases causing the metallic structures of the two pieces to join together and become one. Kim, Kim, Lee, and Jung (as cited in Singh & Anand, 2013) posit that welding provides better performance in comparison to other joining techniques in terms of joint efficiency, mechanical properties, and applications.

Studies have shown that the process of welding has being used extensively for the last several decades as one of the most commonly used joining techniques for various metallic structures including ships, airplanes, automobiles, bridges, pressure vessels, etc. (Singh & Anand, 2013). It has been asserted that the welding processes currently in use include arc welding, resistance welding, solid state welding, submerged welding, electro-slag welding among others (Musah, 2012).

2.5 Classification of Welding

Singh and Anand (2013) assert that there are more than 80 different types of welding and associated processes with the most common types comprising "stick" or shielded metal arc welding (SMAW), the gas-shielded methods of metal inert gas (MIG) and tungsten inert gas (TIG), plasma arc welding (PAW), and submerged arc welding (SAW), some of which may use oxy-acetylene gas to carry out different operations. However, Messler (1993) had earlier contended that even though there are several classification systems for welding processes, welding is typically classified as either fusion welding or non-fusion welding, depending on whether or not significant melting is involved.

2.5.1 Fusion Welding

Fusion welding involves the processes where the materials to be joined are heated to a temperature that lies above the melting points of both of them (Messler 1993). In this kind of welding, the melting or fusion of portions of substrates play a significant role in the formation of joining. Thus, it requires significant melting, and usually produces a joint via the application of heat rather than pressure (Ageorges, Ye, & Hou, 2001).

Types of Fusion Welding

The major types of fusion welding include arc welding, gas welding, high-energy beam welding, and resistance welding. The ensuing sections present a detail description of the various types of fusion welding.

Arc Welding

Arc welding is the most widely used form of welding due to its fastness and the ability to produce strong welds and therefore preferred for commercial use. It involves the creation of an arc between an electrode and a workpiece to generate heat for melting or cutting (Construction Industry Institute [CII], 2003). A very important feature of arc welding is the shielding that is done to prevent oxidation of the highly reactive molten weld metal, thereby helping to stabilize the arc (Messler, 1993). In describing the process of arc welding, Davison (1999, p.4) explains that "an electric welding machine consisting of an electric circuit is used to produce a high current/low voltage output. The parts to be welded are connected to one terminal of the circuit, and an electrode is connected to the other. The electrode is a rod of filler metal and this metal is usually about the same composition as the metal being worked on. When the electrode is touched to the workpiece and slightly withdrawn, an arc (like a tiny lightning bolt) is produced. This happens because the two ends of the electric circuit are close enough for the current to jump the gap. The temperature of the arc is about 5500 degrees °C which will melt most metals. As the arc is drawn along the joint, the tip of the electrode melts together with the electrode. The electrode is coated with chemicals which partly turn into gas and partly melt in the arc.

The melted chemicals are called a slag which forms a protective blanket over the new weld. The gas acts as a shield by keeping out the atmosphere".

Arc welding can be further divided into non-consumable-electrode processes and consumable-electrode processes, depending on whether the electrode is intended to be permanent or not (Messler, 1993). The non-consumable-electrode arc welding methods include Gas–tungsten arc welding and plasma arc welding.
On the other hand, consumable-electrode arc welding methods includes Gas–metal arc welding, shielded-metal arc welding, flux-cored arc welding, submerged-arc welding, electrogas welding, and electroslag welding.

Gas Welding

As a type of fusion welding, gas welding includes any welding process in which the source of heat is a combustible fuel such as natural gas, propane, or butane (Messler, 1993). The most common type of gas welding is oxyacetylene gas welding. Oxyacetylene welding is a form of gas welding which combines oxygen and acetylene in a cylinder with a torch fed which is ignited to produce a burning gas with a temperature of around 3000 degrees °C (Davison, 1999). It involves the process of fusing metals together using the oxyacetylene flame as a heat source with the addition of a filler rod for added strength.

In this method, the oxygen is supplied from steel cylinders, and the acetylene from cylinders or an acetylene generator. Acetylene is passed to the blowtorch, where it is mixed with oxygen in approximately equal proportions and then passed into the tip to be burned (Davies, 1993). It has been observed that the oxy-acetylene gas welding process is very simple and highly portable, and the equipment needed for its use is inexpensive as compared to other methods of welding. Davison explains that in using this method of welding, the welder has good control of the weld, as they hold the oxyacetylene torch in one hand and a rod of filler metal in the other so that the heat of the torch causes the filler metal to gradually fuse with the joint.

Studies on the use of oxyacetylene welding process have shown that the method is very simple and highly portable, and the equipment needed for its use is inexpensive.
Messler (1993) contends that despite the many benefits associated with other methods of welding, the oxyacetylene welding process is very flexible to use and the equipment used for the process is well mobile and less expensive compared to other methods of welding. However, the method is limited in its applicability, in that it provides small amount of energy and provides relatively little in the way of protective shielding and require high skill to weld (Messler, 1993). That notwithstanding, the method is still in use mostly by small welding shops operating in the informal welding sector in Ghana. The major equipment needed for oxyacetylene welding include acetylene hose, oxygen cylinder with pressure reducer, welding rod, workpiece, oxygen hose, welding nozzle welding torch, acetylene cylinder with pressure reducer, and welding flame.

High-Energy Beam Welding

According to Construction Industry Institute [CII] (2003), high-energy beam welding is the method of welding where heat is generated from collisions of electrons and photons using a high-intensity beam as the heat source. Though, high-energy beam welding is quite expensive, the joint fit it produces is excellent, on account of the fact that the process takes place autogenously (Messler, 1993). High-energy beam welding, is subdivided into two categories: electron-beam welding and laser-beam welding.

Electronic beam welding refers to the process where focused beam of electrons is used to produce high precision and deep penetration welds whilst laser welding uses a focused beam of light to produce very precise welds (AFSCME Research & Collective Bargaining Department, 2011). AFSCME Research & Collective Bargaining Department (2011) avers that the major hazard associated with this form of welding is its powerful beam which blind the eyes of the welder if special eye protection goggles are not used.

Resistance Welding

Resistance welding is defined as the process that takes advantage of a workpiece's inherent resistance to the flow of electric current such that as current is passed through the parts to be welded, a force is simultaneously applied the parts resist the passage of the current, thus generating the welding heat (CII, 2003). Unlike other forms of welding, resistance welding does not utilize additional materials such as fluxes and filler rods, the weld nugget is rather formed directly from the base materials (Messler, 1993). Though resistance welding is usually used for joining overlapping sheets or plates, the rapid rate of heating coupled with the extremely short welding time, and rapid rate of cooling allow resistance welding to be used wherever heat input must be minimized, such as in joining refractory metals and alloys (CII, 2003). The major types of resistance welding are resistance spot welding, resistance seam welding, projection welding, flash welding, upset welding, and percussion welding (Messler, 1993).

2.5.2 Non-Fusion Welding

Non-fusion welding is defined as a welding process that occurs through plastic deformation by the application of pressure, or a combination of heat and pressure, at a temperature that lies below the melting point of the base material and without the addition of a filler that melts (Messler, 1993). Messler indicates that during the process of non-fusion welding, the base metals are heated but not significantly melted, and melting is not directly responsible for the joining process. In this regard, non-fusion welding has an advantage over fusion welding, in that the heat-affected zone is kept to a minimum, resulting in negligible alterations in the characteristics of the materials involved. Non-fusion welding is divided into four categories with respect to the source of energy: cold pressure, hot pressure, friction, and diffusion welding (CII, 2003).

Cold Pressure Welding

Cold pressure welding is a method of joining sections of metal together by the application of pressure but using no heat or flux (Davies, 1993). The process uses substantial pressure at room temperature to produce joining of materials through plastic deformation at the weld (CII, 2003). Though the process is of limited applicability, because it requires extremely clean surfaces and high pressures (CII, 2003), cold welding provides a valuable option for joining materials in the environment of outer space (Messler, 1993).

Hot Pressure Welding

Hot pressure welding is another form of non-fusion welding which uses heat and pressure as an energy source to accomplish the joining of materials through plastic deformation (CII, 2003). Hot pressure welding includes forge welding, hot roll welding, and explosion welding (Messler, 1993).

Friction Welding

As the name indicates, friction welding relies on friction to cause the heating that is needed to produce a weld. During the process of friction wielding, the resistance between the machines produces heat at the joint that is to be welded. Thus, in friction welding, materials are joined under the compressive-force contact of workpieces moving relative to one another, either linearly or in rotation (Messler, 1993).

Diffusion Welding

Diffusion welding is a process where two surfaces are brought together under a load to produce heat and pressure to accelerate diffusion while producing joining through mass transport in the solid state (Messler, 1993). Brandon and Kaplan (1997) indicate that in applying diffusion welding, the solid-state bonding process based on the combined application of pressure and heat is also termed diffusion welding. CII (2003) states that under conditions of both high temperature and high pressure, there is considerable plastic flow in the region of greatest surface asperity, which continues until the interfaces have achieved a high degree of conformity with each other. At this point, Schwartz (1979) posits that the joint will have achieved considerable strength as a result of metallic bonding. It must be noted that though diffusion welding offers precise joining, with no fusion zone and no heat-affected zone (CII, 2003), its use is limited, because of the expense of the materials involved and the small dimensional tolerance with which the pieces/components must comply (Messler, 1993).

2.6 Common Welding Methods used in Ghana

In their study on Radiation-Related Eye Diseases among Welders of Suame 'Magazine' in the Kumasi Metropolis, Kumah, Cobbina, and Duodu (2011) found that 40% of the sampled welders at the Suame Magazine use oxy-acetylene gas for their welding operations. Gyasi (2013) examined the quality, productivity and economy in welding manufacturing in West Africa, and found that majority of the welding companies in Ghana, Nigeria and Cameroun employ manual welding technique, and shielded metal arc welding (SMAW) as the commonly used welding process. The welding process and technique mostly employed in the manufacturing process in both the formal welding sector and the informal welding sector is shielded metal arc welding (SMAW) process and manual welding technique respectively. However, in the formal welding sector, the use of tungsten inert gas (TIG) welding process and metal inert gas / metal active gas (MIG/MAG) welding processes are on the increase. Activities in welding operations have therefore been focused on the use of the aforementioned welding processes and welding technique, thus limiting the use of other welding processes and welding techniques such as submerged arc welding (SAW), plasma arc welding (PAW), laser welding, and automatic welding techniques and robotic welding techniques respectively.

Also, in his study on weld quality assurance practices in the metal welding industries in Ghana, Akpakpavi (2015) found that the welding processes used in the informal welding sector otherwise known as the local welding industry largely include shielded metal arc welding (SMAW) and sometimes oxyacetylene welding (OAW).

2.7 The Concept of Occupational Health and Safety

The concept of Occupational Health and Safety (OHS) is a combination of two things, health and safety. Hence, to better understand the concept it is only appropriate that we first define the constituent terms which make up the concept. Though a broad term, health may be defined as the state of a person's life when he/she experiences a general well-being of body and mind and is under stable condition free from illness, stress, or any bodily complications (Hughes & Ferret, 2008). On the other hand, safety is a state where there is conscious effort to prevent all forms of risks and hazards which poses danger to the human body or immediate environment such that there is maximum protection of people from physical injury. (Hughes & Ferret, 2008; Muiruri & Mulinge, 2014). Describing the two terms, Lingard and Rowlinson (2005) assert that health and safety is a cross-disciplinary concept that is concerned with protecting the safety, health and welfare of people engaged in work or employment.

Knowing what the major components of OHS mean, we proceed to define the concept of OHS as "a discipline which aims at the: promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations; prevention among workers of adverse effects on health caused by their working conditions; protection of workers in their employment from risks resulting from factors adverse to health; placing and maintenance of workers in an occupational environment adapted to physical and mental needs; and adaptation of work to humans (International Labour Organization [ILO], 1996). A careful review of the definition of ILO shows that though the definition may seem broad, it focuses solely on the general well-being of the workers in terms of physical, mental and social aspects of the workers.

In more simple terms, Jorma (2004) defines OHS as the science of designing, implementing and evaluating comprehensive health and safety programmes that maintain and enhance employee health, improve safety and increase productivity in the workplace. Jorma emphasized that it is not always possible to eliminate all forms of health and safety risks at the workplace, hence he contends that a healthy workplace is an environment where health risks are recognized and controlled if they cannot be removed. To this end, he opines that, the main objective of every health and safety programme should be to enhance employee health; improve on the safety of workplace; and thereby increasing organizational performance. Like other health and safety programmes, OHS in welding operations deals with both physical and psychological well-being of welders and other workers whose health is likely to be adversely affected by welding activities.

Touching on the issue of healthy workplace in the definition by Jorma (2004), it must be noted that the World Health Organization (WHO) in its 1999 report on organizational health and safety emphasized the need for a healthy workplace and a conducive environment for the worker. WHO described a healthy and safe workplace as the one in which workers and managers collaborate to use a continual improvement process to protect and promote the health, safety and well-being of workers and the sustainability of the workplace. According to WHO, a healthy workplace requires that the following issues are taken into consideration:

i. health and safety concerns in the physical work environment;
ii. health, safety and well-being concerns in the psychosocial work environment including organization of work and workplace culture; personal health resources in the workplace;
iii. and ways of participating in the community to improve the health of workers, their families and other members of the community.

The importance of health and safety standards and policies in safeguarding the safety of workers cannot be overemphasized.

The ILO Occupational Safety and Health Convention 155 of 1981, and its Recommendation 164, makes a strong case for the national occupational health and safety policy. It was recommended that the design of an OHS policy should include among other things a detailed description of the actions to be taken by governments and within enterprises to promote occupational safety and health and improve the working environment. Also, the importance of a national OHS policy was emphasized by WHO in its 1994 Declaration on Occupational Health and Safety. In its declaration, WHO sought to encourage national governments to prepare a special national policy and programme for occupational health and safety that include actions for providing competent occupational health services for all people at work which includes the development of appropriate legal provisions, and systems for enforcement, and inspection by competent authorities especially responsible for occupational health.

In line with the ILO and WHO recommendations, the Hobart Institute of Welding Technology (HIWT), (2009) asserts that governments have become increasingly active concerning the safety and health of workers and have enacted laws prescribing safety regulations and the publication of safety information to insure the safety of workers. For instance, in the United States, there is the Occupational Safety and Health Act (OSHA) that guides all categories of workers and the American National Standard "ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes" which specifically guides welding operations. ANSI Z49.1 standard was enacted based on the premise that welding and cutting operations pose potential hazards from fumes, gases, electric shock, heat radiation, and sometimes noise. Therefore, all personnel shall be warned against these hazards where applicable by the use of adequate precautionary labeling.

From the foregoing, it has been noted that the concept of OHS does not operate in a vacuum. In countries where issues of workers' health and safety at the workplace is taken very serious, there is always a conscious effort by the relevant stakeholder and policymakers to design effective and worker-friendly OHS policies or standards which guide various categories of workers in the country. As revealed by Kheni (2008), OHS legislation is a very important step in ensuring the health and safety of workers. He describes an OHS legislation as a means by which the work environment can be controlled to ensure the safety, health and welfare of employees and persons likely to be adversely affected by the work environment are protected.

Whilst some developed countries such as the UK, US, Germany, Sweden among others have well-structured OHS programmes and standards for welding operations, Ghana is yet to design a policy that seeks to streamline the activities of welders and safeguard them against health and safety risks. Despite the recommendations of ILO and WHO on the need for a national policy on OHS, health and safety issues at the workplace has not received the needed attention by the government and other relevant stakeholders in the country. It is quite surprising that the non-existence of a national policy on OHS after the laudable recommendations by ILO and WHO has still not received any major attention despite the alarming rate of workplace accidents and injuries most in the construction and manufacturing industries (Laryea & Mensah, 2010). At best, the existing regulations in Ghana that seem to somewhat guide against health and safety challenges of workers are the Factories, Offices and Shops Act (1970) and the Labour Act, 2003 (Act 651). Whilst Part XV of Act 651 focuses on occupational health, safety and environment in general, Sections

118, 119, 120 and 121 of the Act 651 deals with general health and safety conditions of workers; exposure to imminent hazards; the requirement that employers report occupational accidents and injuries as soon as possible to the appropriate government agencies, and specific measures provide by the minister in charge to safeguard the health and safety of workers respectively. None of the provisions in the Act 651 addresses the issue of health and safety in welding operations.

2.7.1 Occupational Health and Safety in Welding

The HIWT (2009) opines that in a welding establishment, welding managers and supervisors are responsible for ensuring that workers are trained on the safe conduct of their day to day activities. Thus, workers in welding operations must be trained health and safety management such that they will be able to detect risks and hazards and how they can protect themselves from them to avoid any injuries or accidents.

Considering the increasing health and safety risks posed by welding operations, the United States Department of Labour in its Occupational Safety and Health Administration (OSHA) regulations on welding: OSHA Standard 29 CFR 1910.252 provides specific requirements for assuring the safety of welding, cutting, and brazing operations. The OSHA Standard 29 CFR 1910.252 covers many aspects of welding work, including welding safety, welding in confined spaces, handling of compressed gases, fire and electrical safety, ventilation, protective equipment, and worker training. Notable among the requirements of the standard are:

i. Compressed gas cylinders must be kept away from radiators and other heat sources and stored upright in a well-ventilated, dry location at least 20 feet from highly combustible materials such as oil. Cylinders should be kept away from elevators, stairs, or other spaces where they can be knocked over or damaged.

ii. Piping systems must be tested and proved gastight at 1 1/2 times the maximum operating pressure, and shall be thoroughly purged with air before being placed in service. Service piping systems must be protected by pressure relief devices.

iii. Hoses showing leaks, burns, worn places, or other defects must be repaired or replaced.

iv. Cutters and welders must be suitably trained in the safe operation of their equipment and the safe use of the process.

v. The welder should be enclosed in an individual booth, or by non-combustible screens, that are painted with a finish of low reflectivity such as zinc oxide or lamp black (to absorb ultraviolet radiation). People next to the welding area must be protected by noncombustible or flameproof screens or be required to wear appropriate goggles. The booths or screens should permit circulation of air at the floor level.

vi. All movable fire hazards in the vicinity of welding operations must be taken to a safe place. If all the fire hazards cannot be moved, guards must be used to contain the heat, sparks, and slag.

vii. Suitable fire extinguishing equipment must be maintained and ready for instant use.

viii. Fire watchers are required whenever welding or cutting is performed in a location where other than a minor fire might develop. A fire watch must be maintained for at least 1/2 hour after completion of welding or cutting operations to detect and extinguish possible smoldering fires.

ix. No welding, cutting, or other hot work shall be performed on used drums, barrels, tanks, or other containers until they have been thoroughly cleaned (a purge with an inert gas is also recommended).

x. Eye protection with the proper shade number must be used during all arc welding or arc cutting operations, gas welding, oxygen cutting, resistance welding, or brazing operations.

xi. When a welder must enter a confined space through a manhole or other small opening, an attendant with a pre-planned rescue procedure must be stationed outside to observe the welder at all times and to put the rescue operation into effect, if necessary.

xii. Special ventilation and/or respirators are required in confined spaces, for cleaning compounds, when fluorine compounds, zinc, lead, beryllium, cadmium, and mercury are encountered, and when cutting stainless steel.

xiii. Warning labels are required for all filler metals, brazing filler metals containing cadmium, and fluxes containing fluorine compounds (fluorides).

(Source: OSHA, 2015)

2.8 Health and Safety Hazards associated with Welding Operations

It is important to note that welders work under a variety of conditions including outdoors, indoors, in open areas, in confined spaces, high above the ground, and even under water (HIWT, 2009). By the nature of their work welders are exposed to various forms of risks and hazards at the workplace. The welding activity is such that welders utilize a large number of welding and cutting processes, however most of these have in common the exposure to fumes, gases, radiation and heat.

Hence, the use of specific welding processes or welding on particular metals can present potential health risks. The HIWT states that apart from working in hot climates, welders are sometimes required to weld on, or inside, preheated weldments with high temperatures.

According to Smallbone and Kocak (2012) the health and safety of welders as well as environmental issues also remain a challenge to the welding industry. They argue that even though smart welding equipment such as reverse fume extraction, helmets with sensors and air blowers have been introduced in the welding industry, welders and the environment are exposed to some level of welding fumes, radiations and bad disposable practices respectively. It has been found that increasing amount of such exposure leaves welders in Repetitive Strain Injury (RSI) and Cumulative Trauma Injury (CTI), thus lowing productivity, quality and workers' satisfaction. Also, the HIWT (2009) contends that apart from working in hot climates, welders are sometimes required to weld on, or inside, preheated weldments. It argues that the preheat temperatures required for welding special materials can be quite high and the welder must be protected from coming into contact with the hot metal. The heat produced through welding and cutting processes poses a serious fire hazard as fragments of metal at high temperature are produced and if these hot metal fragments come into contact with a combustible material they may act as an ignition source and start a fire (Davison, 1999)

In a study to determine the prevalence of radiation-related ocular diseases among welders in the Kumasi metropolis, Kumah, Cobbinah, and Duodu (2011) contend that welding arc emits a wide spectrum of radiations ranging between 200nm-1400nm. They indicate that these radiations include ultraviolet (UV) rays (200-400nm), visible light (400-700nm) and infrared rays (700-1400nm).

Ultraviolet radiation and far infra-red (IR) are absorbed by the cornea and lens whereas visible light and near infra-red penetrate to the retina. This may cause eye infections. They found that a total of 308 (65.5%) welders and 76 (16.9%) non-welders (control group) had one or more ocular conditions. The repeated exposure of the eyes to UV radiation (UVR) causes both short-term eye complaints and permanent eye damage. Short-term complaints include mild irritations such as excessive blinking, swelling or difficulty looking at strong light (Cains, 1992). Exposure to UV radiation over long periods can result in more serious damage to the eyes, including cataracts, pterygium, solar keratopathy (cloudiness of the cornea), cancer of the conjunctiva and skin cancer of the eyelids and around the eyes. They concluded that the ocular symptoms and ailments prevalent among the welders were most likely due to the radiations they are exposed to in their work environment.

The AFSCME Research & Collective Bargaining Department (2011) indicated that many of the substances in welding smoke, such as chromium, nickel, arsenic, asbestos, manganese, silica, beryllium, cadmium, nitrogen oxides, phosgene, acrolein, fluorine compounds, carbon monoxide, cobalt, copper, lead, ozone, selenium and zinc, can be extremely toxic with severe health implications. It states that the individual components of welding smoke can affect any part of the body, including the lungs, heart, kidneys and central nervous system and may cause health complications such as irritating of eyes; nose; chest; and respiratory tract, coughing, wheezing, shortness of breath, bronchitis, pulmonary edema (fluid in the lungs) and pneumonitis (inflammation of the lungs). Also, exposure to metal fumes (such as zinc, magnesium, copper, and copper oxide) can cause metal fume fever. Again, it has been found that gastrointestinal effects, such as nausea, loss of appetite, vomiting, cramps, and slow digestion, are associated with welding.

The AFSCME report found that welders have an increased risk of lung cancer, and, possibly cancer of the larynx (voice box) and urinary tract as a result of the large quantity of toxic substances in welding smoke, including cancer-causing agents such as cadmium, nickel, beryllium, chromium, and arsenic. Furthermore, welders may also experience a variety of chronic respiratory (lung) problems, including bronchitis, asthma, pneumonia, emphysema, pneumoconiosis (refers to dust-related diseases), decreased lung capacity, silicosis (caused by silica exposure) and siderosis (a dust related disease caused by iron oxide dust in the lungs). In addition, it was revealed that exposure to loud noise can permanently damage welders' hearing whilst work postures (especially welding overhead, vibration, and heavy lifting) could contribute to musculoskeletal disorders such as back injuries, shoulder pain, tendinitis, reduced muscle strength, carpal tunnel syndrome, white finger, and knee joint diseases. Other health problems related to welding include: heart disease, skin diseases, hearing loss and chronic gastritis (inflammation of the stomach), gastroduodenitis (inflammation of the stomach and small intestine), ulcers of the stomach and small intestine, as well as reproductive risks such as poorer sperm quality (AFSCME Research & Collective Bargaining Department, 2011).

Welding and cutting pose a serious fire hazard as fragments of metal at high temperature are produced and if these hot metal fragments come into contact with a combustible material they may act as an ignition source and start a fire (Davison, 1999). Also, excessive exposure to heat can result in heat stress or heat stroke. According Health and Safety Executive (2012), the main hazards associated with oxyacetylene gas welding are: fire caused by heat, sparks, molten metal or direct contact with the flame; explosion when cutting up or repairing tanks or drums which contain or may have contained flammable materials; fire/explosion caused by gas leaks, backfires and flashbacks; fumes created during flame cutting; fire/burns resulting from misuse of oxygen; burns from contact with the flame or hot metal; crushing or impact injuries when handling and transporting cylinders.

The Occupational Safety and Health Branch (OSHB) of the Labour Department of Hong Kong in its 1999 guidebook entitled "A guide to safety and health at work for gas welding and flame cutting" opines that fire and explosion hazards of gas welding and flame cutting are mainly due to problems with the gas supply system, or due to the high temperature of the flame used or the hot slag produced in the process. Among the fire and explosion hazards listed by OSHB (1999, p.2) in its guidebook were:

- Fires and explosions resulted from the release of flammable fuel gases or oxygen into the atmosphere from leaks at joints, hose connections or fittings of the gas supply system;
- Fires and explosions in the gas supply system caused by flashback from the blowpipe due to gas lines not completely purged before lighting up, or back-feeding of fuel gas into the oxygen line or vice versa; decomposition or detonation of acetylene in the absence of oxygen or air due to flashback at the blowpipe or overheating of gas cylinder; high-pressure oxygen (without fuel gas) which promotes combustion of materials such as oil, grease, organic compounds, aluminium metal and its alloys, and elastomers used in valve seats and seals;
- Explosions from over-pressurization of the gas supply system;

- Fires from the ignition of flammable or combustible materials in the vicinity by the flame of the blowpipe, hot surfaces of the work-piece or hot slag from the process

In addition, OSHB (1999, p.3) indicated that the health hazards of gas welding and flame cutting were mainly due to the radiation and toxic fumes or gases emitted during the process. These hazards include:

- Eye injuries: heat cataract caused by infra-red radiation from molten metal, resulted in not able to see things clearly; arc eye caused by ultra-violet radiation emitted during the process, resulted in very painful and watery eyes; other injuries such as corneal ulcer and conjunctivitis from foreign particles e.g. slag and cutting sparks;
- Skin irritation and reddening due to over exposure to radiation; inhalation of fumes or gases produced during the process: metal fume fever which is a febrile illness due to freshly formed metal oxide fumes; toxic fumes of metals such as lead, cadmium, beryllium; toxic gases such as oxides of nitrogen, fluorides resulted in bronchial and pulmonary irritation;
- Burns from the blowpipe flame, hot slag or hot surfaces of the work-piece;
- Personal injuries due to handling gas cylinders or large work-pieces.

2.9 Safety Measures in Welding Operations

According to Singh and Anand (2013), an important aspect in welding safety is the awareness about the hazards and the risk assessment. They argue that awareness creation among welders about health and safety risks associated with their operations is very important because it unveils the potential risks and hazards associated with welding and cutting processes such as: physical hazards: electricity, radiation, heat, flames, fire, explosion, noise and magnetic fields; chemical hazards: welding fumes, fuel gases, inert gases, gas mixtures and solvents; and general safety hazards: movement of machinery, falling objects, forklift trucks, mobile cranes, overhead cranes, site transport and other related hazards which may creep in during manual handling of gas cylinders, tools, materials, equipment, consumables, etc. Singh and Anand opine that though welders may not be aware of all the aforementioned risks and hazards some of which may creep in during the process of welding, it is appropriate that they take precautions when engaging in welding processes in order to avoid such potential risks and hazards.

The WHO/CEC/DWI/IARC (1985) opine that in order to avoid or reduce the established and potential health risks due to welding fumes and gases, sufficient stringent measures should be introduced and enforced immediately to prevent these effects. They explain the stringent measures to include: identification of high exposure situations and their immediate reduction; development of appropriate monitoring programmes using simple and rapid response indicators of ambient air concentrations; development of a worker education programme and active participation of the workers in their own protection; and the establishment of necessary health assessment programmes and evaluation of the effectiveness of the existing ones. In addition, for non-respiratory health and safety problems related to welding, it is recommended that exposure reduction strategies should consider in particular: the possibility of using the flexibility of welding technology to provide for minimum fume exposures from the use of old and new processes; a better use of mechanical ventilation appropriate for each process and application; and the enabling and encouraging of workers to make effective use of available ventilation. Also, in electric-arc welding operations more or less hazardous particles are generated.

Thus there is a need for actions against health effects such as changes of welding techniques and welding parameters, changes of joining technique, local exhausts, respiratory protective equipment, job rotation and robotization (WHO/CEC/DWI/IARC, 1985).

Davison (1999) opines that ideally welding should be carried out in specially designated areas of a workshop. Davison recommends that to reduce any fire hazard, these areas should have: concrete floors; fire extinguishers; arc filter screens; protective drapes or curtains; adequate ventilation. He adds that whenever any welding/cutting operation is carried out, the area should be free from any combustible material that may fuel a fire. Also, welding hazards such as electric shock, burns, fire and explosions, radiation, heat, noise, fumes and gases can be minimized by using an effective combination of control measures (Singh & Anand, 2013).

In welding processes, the preheat temperatures required for welding special materials can be quite high and the welder must be protected from coming into contact with the hot metal (HIWT (2009). The HIWT (2009) recommends that when welders are exposed to excessive heat, they should be supplied with sufficient cool air to avoid breathing excessively hot air. Special precautions must be taken and special procedures must be adopted to protect the welder from the heat. Protective clothing should be worn which helps insulate the welder from excessive heat. Consultation with safety experts and just plain common sense is required in these situations.

2.9.1 Safety Precautions for Arc Welding and Cutting

The HIWT (2009) outlines the following precautionary measures to be followed when performing arc welding and cutting:

- Make sure your arc welding equipment is installed properly and grounded and is in good working condition. This will help prevent fatal electric shocks.
- Always wear protective clothing suitable for the welding to be done. This will help prevent injuries and burns.
- Always wear proper eye protection, when welding, cutting, or grinding. Do not look at the arc without proper eye protection. This will prevent eye injuries and "arc flash."
- Avoid breathing the air in the fume plume directly above the arc. This will prevent illness due to overexposure to hazardous materials in the fume plume.
- Keep your work area clean and free of hazards. Make sure that no flammable, volatile, or explosive materials are in or near the work area. Good housekeeping will help prevent accidents.
- Handle all compressed gas cylinders with extreme care. Keep caps on when not in use. Damaged cylinders can rupture with explosive violence.
- Make sure that compressed gas cylinders are secured to the wall or to other structural supports. The impact of a fall can cause cylinder rupture or valve failure.
- When compressed gas cylinders are empty close the valve and mark the cylinder "empty". This will prevent contamination from entering the cylinder.
- Do not weld in a confined space without special precautions. Poor ventilation can lead to asphyxiation. Accumulation of flammable gases can explode.

Always practice "confined space" safety.

- Do not weld on containers that have held combustibles without taking special precautions. The heat of welding can ignite residual gases and cause an explosion. The heat can cause the release of hazardous fumes. Always assure a container is clean and safe for welding.
- Do not weld on sealed containers or compartments without providing vents and taking special precautions. The heat of welding can cause gases to expand. The increased pressure can lead to an explosion.
- Use mechanical exhaust at the point of welding when welding lead, cadmium, chromium, manganese, brass, bronze, zinc, or galvanized steel, and when welding in a confined space. These "low allowable-limit materials" can cause serious injury. Ventilation will prevent overexposure.
- When it is necessary to weld in a damp or wet area, wear rubber boots and stand on a dry insulated platform. This will minimize the chance of electric shocks.
- Do not use cables with frayed, cracked, or bare spots in the insulation. This will prevent stray arcs between the bare cable and the ground. It will prevent electric shocks.
- When the electrode holder is not in use, hang it on brackets provided. Never let it touch a compressed gas cylinder. This will help prevent damage to the holder. An energized holder can arc to a grounded cylinder and cause an explosion.
- Dispose of electrode stubs in proper container since stubs on the floor are a safety hazard. Hot stubs can ignite fires or can cause trips and falls.
- Shield others from the light rays produced by your welding arc.

Ultraviolet arc rays can cause "arc flash" to the eyes of nearby people.

- Do not weld near degreasing operations. Arc rays can inter- act with fumes of some cleaning agents and produce hazardous gases. Some of these gases can kill.
- When working above ground make sure that scaffold, ladder, or work surface is solid. Falls from elevated positions can cause injury or even death.
- When welding in high places, use safety belt or lifeline. Falls from high places are more likely to cause serious injury or death.

Source: Hobart Institute of Welding Technology [HIWT], (2009, p.6)

2.9.2 Safety Precautions for Oxyacetylene Welding and Cutting

Too ensure safety when performing oxyacetylene welding and cutting, HIWT (2009) outlies the following safety precautionary measures to be adhered to:

- Make sure that all gas apparatus shows UL or FM approval, is installed properly and is in good working condition.
- Make sure that all connections are tight before lighting the torch. Do not use a flame to inspect for tight joints. Use soap solution to detect leaks. This will minimize the chance of fuel gas leaks. Always wear protective clothing suitable for welding or flame cutting. This will prevent injuries and burns.
- Keep work area clean and free from hazardous materials. When flame cutting sparks can travel up to 35 feet (10.7m). Do not allow flame cut sparks to hit hoses, regulators, or cylinders. Good housekeeping will help prevent fires and explosions.
- Handle all compressed gas cylinders with extreme care. Keep cylinder caps on when not in use. Damaged cylinders can rupture with explosive violence.

- Make sure that all compressed gas cylinders are secured to the wall or to other structural supports. Keep acetylene cylinders in the vertical position. The impact of a fall can cause cylinder rupture or valve failure. With horizontal acetylene cylinders, acetone will be mixed in with the delivered gas.
- Store compressed gas cylinders in a safe place with good ventilation. Acetylene cylinders and oxygen cylinders should be kept apart. This will prevent the accumulation of leaking gases and possible fires and explosions.
- When compressed gas cylinders or fuel gas cylinders are empty, close the valve and mark the cylinder "empty". This will prevent contamination from entering the cylinder.
- Use oxygen and acetylene or other fuel gases with the appropriate torches and only for the purpose intended. This will minimize the chance of sustained backfires and flash-backs.
- Avoid breathing the air in the fume plume directly above the flame. This will prevent illness due to overexposure to hazardous materials in the fume plume. 10. Never use acetylene at a pressure in excess of 15 psi (103.4k Pa). Higher pressure can cause an explosion. The high pressure can cause acetylene to detonate spontaneously.
- Never use oil, grease or any material on any apparatus or threaded fittings in the oxyacetylene or oxyfuel system. Oil and grease in contact with oxygen may cause spontaneous combustion
- Do not weld or flame cut in a confined space without taking special precautions. Poor ventilation can lead to asphyxiation.

Accumulation of fuel gas can explode. Always practice “confined space” safety.

- When assembling apparatus, crack gas cylinder valve before attaching regulators (cracking means opening the valve on a cylinder slightly, then closing). This blows out any accumulated foreign material. Make sure that all threaded fittings are clean and tight. The impact of foreign material can cause regulators to explode, when they are pressurized upon opening of the cylinder valve.
- Always follow the torch manufacturer’s instructions when lighting the torch. This will prevent damage and the release of excess gases.
- Always follow the torch manufacturer’s instructions when shutting down a torch. This will prevent damage and re-verse gas flows in the hoses.
- Use mechanical exhaust when welding or cutting lead, cadmium, chromium, manganese, brass, bronze, zinc, or galvanized steel. These “low allowable-limit materials” can cause serious injury.
- If you must weld or flame cut with combustible or volatile materials present, take extra precautions, make out a hot work permit, and provide for a lookout, etc. This will minimize the chance of fires.
- Do not weld or flame cut on containers that have held combustibles without taking special precautions. The heat of the flame can ignite residual gases and cause an explosion. The heat can cause the release of hazardous fumes. Always assure a container is clean and safe for welding or cutting.
- Do not weld or flame cut into a sealed container or compartment without providing vents and taking special precautions. The heat of the flame can cause gases to expand. The increased pressure can lead to an explosion.

- Do not repair damaged hoses with tape. Only trained persons should repair hoses. Gas leaks can cause fires and explosions and, in some cases, asphyxiation.

Source: Hobart Institute of Welding Technology [HIWT], (2009, p.6)

According too Occupational Safety and Health Branch (1999). In gas welding and flame cutting, fires may arise from ignition of flammable or combustible materials not only by direct contact with the flame, but also by contact with the hot slag or work-piece which may take a considerable time to cool down. Therefore, the following precautions were recommended to prevent fires:

- Move all flammable or combustible materials to a safe place away from the work area.
- Use suitable means to protect combustible materials that cannot be moved from close contact with flame, heat, hot slag or sparks such as covering with fire resistant materials.
- Use suitable means to prevent slag or spark from reaching combustible materials along or down ducts, channels and through holes in walls and floors, such as covering the openings by fire resistant materials.
- Prevent equipment for gas welding and flame cutting from being contaminated with oil or grease.
- Before starting welding or cutting work on used containers, ensure that the container is free from any substance that may emit flammable or toxic vapours upon heating by washing with suitable solvents and purging with inert gas.
- Provide suitable fire-fighting equipment such as fire extinguishers, buckets of sand near by the work area.

- Ensure that sparks and slag from the work are extinguished and cooled before leaving the work area.

For Eye protection, the OSHB (1999) asserts that welding and cutting of metals by means of oxy-acetylene could affect the eye and cause severe eye problem. Therefore, it is recommended that welders should protect their eyes by using approved eye protectors such as goggles, visors, spectacles, face screens; approved shield such as helmet, hand shield; and approved fixed shield such as screen. Welders should also wear protective clothing to protect themselves against burns by the flame of the blowpipe, the hot slag or workpiece. Thus, appropriate protective clothing such as facemasks, aprons, gloves, safety shoes and spats, should be selected according to the nature, volume and location of the welding or cutting work. Again, in order to prevent respiratory related problems, OSHB recommends that welders should use a respirator. The provides additional protection to the worker from inhalation of toxic fumes, and should be used in supplement to, but not in lieu of, the use of an efficient ventilation system. Moreover, it is recommended that when welding and cutting is performed in a confined space, workers should be provided with supply air type respirators in addition to provision of efficient ventilation.

The HSE (2012) recommends that the following precautionary measures should be adhered to when using oxyacetylene gas welding in order to help prevent fire:

- move the workpiece to a safe location for carrying out hot work;
- remove nearby combustible materials (such as flammable liquids, wood, paper, textiles, packaging or plastics);
- protect nearby combustible materials that cannot be moved. Use suitable guards or covers such as metal sheeting, mineral fibre boards or fire-retardant blankets;

- check that there are no combustible materials hidden behind walls or in partitions, particularly if the welding or cutting will go on for some time. Some wall panels contain flammable insulation materials, e.g. polystyrene;
- use flame-resistant sheets or covers to prevent hot particles passing through openings in floors and walls (doorways, windows, cable runs, etc.);
- if the consequences of a fire are severe, e.g. work inside ships, you may need to appoint a fire watch during and after the work finishes. It is normal to maintain fire watch for 30 minutes after hot work finishes;
- prevent flame, heat, sparks or hot spatter from landing on the hoses;

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The chapter presents the methodology employed for the study. It describes the research design adopted and presents the population and sample size for the study. Also, the chapter explains the data collection instruments and procedures used as well as the data analysis techniques adopted. In addition, issue relating to the validity and reliability of the instruments used for data collection were discussed in the chapter.

3.2 Research Design

According to Kothari (2004), research design is the advance planning of the methods to be adopted for collecting relevant data and the techniques to be used in their analysis, keeping in view the objective of the research and the availability of staff, time and money. It sets out "the guidelines that linkup the elements of methodology adopted for a study namely; relating the paradigm to the research strategy and then the strategy to methods for collecting empirical data" (Denzin & Lincoln, 2000 p.22). Thus, a research design is a general plan of how a researcher intends to go about answering the research questions, specifying the sources from which to collect data, and considering the constraints that (e.g. access to data, time, location and money) that are likely to affect data collection as well as discussing ethical issues (Saunders, Lewis, & Thornhill, 2009). Saunders, et al. contend that the main research designs used in social science research are experiment, survey, case study, action research, grounded theory, ethnography and archival research.

According to Kothari (2004), a research design appropriate for a particular research problem, usually involves the consideration of the following factors: (i) the means of obtaining information; (ii) the availability and skills of the researcher and his staff, if any; (iii) the objective of the problem to be studied; (iv) the nature of the problem to be studied; and (v) the availability of time and money for the research work. Therefore, with regards to the purpose and specific objectives of the study as well as the data collection methods to be employed, a survey was deemed the most appropriate research design for the study. Creswell (2012) defines a survey as the type of a descriptive research whereby investigators administer a survey to a sample or to the entire population of people to describe the attitudes, opinions, behaviours or characteristics of the population. He posits that in this procedure, survey researchers collect quantitative, numbered data using questionnaires (e.g., mailed questionnaires) and statistically analyze the data to describe trends about responses to questions and to test research questions or hypotheses. Therefore, considering the nature of the study, the survey design was deemed appropriate in terms of collecting data from a large group of respondents within a relatively short period of time.

Studies have shown that the two major approaches too research are the quantitative approach and the qualitative approach (Fellows & Liu, 2003). However, Denzin and Lincoln (2000); Collins, Onwuegbuzie and Jiao (2007) contend that since the 1960s, an increasing number of researchers have been advocated a third approach to research which combines the techniques of quantitative and qualitative approaches. This third approach has been referred to as the mixed methods approach and it involves collecting both numeric and text information, either simultaneously or sequentially, so as to best understand research problems, with the final database representing both quantitative and qualitative information (Creswell & Clark, 2007).

However, in line with the research design adopted for the study i.e. a survey, the quantitative approach was employed for the purpose of data collection and analysis. This approach was chosen based on the assertion of Kothari (2004) that the quantitative approach involves the generation of data in quantitative form which can be subjected to rigorous quantitative analysis in a formal and rigid fashion. Furthermore, Boateng (2014) opines that the quantitative method is used to determine the extent of a problem or the existence of a relationship between aspects of a phenomenon by quantifying the variation.

3.3 Population

According to Fraenkel and Warren (2002), the population of a study refers to the complete set of individuals (subjects or events) having common characteristics in which the researcher is interested. In order words, it is "a collection of all possible individuals, objects or measurement that have one or more characteristics in common that are of interest to the researcher" (Arthur, 2012 p.109). Considering the study area used as a case, the Sunyani Municipality, the target population for the study comprised all operators of welding shops within the Sunyani Municipality. Since there is no registered list of all welders in the informal sector in the municipality, the researcher could not quote the exact population size in terms of numbers.

3.4 Sample and Sampling Techniques

The sample size of a study consists of a carefully selected unit of the population for the study or is a sub-group of the population that is an ideal representative of the entire population (Kumar, 2005; Sarantakos, 2005). The sample for the study comprised 65 welders who plied their trade at the within the Sunyani Magazine Area. The sample was selected using the convenience sampling technique.

The Sunyani Magazine Area was chosen as the sample frame because it has been observed that majority of welding shops in the municipality are located within this area and therefore using the convenience sampling technique, it was easy to find a lot of welding shops around than search the whole of the municipality.

3.5 Data Collection Methods

Studies have shown that the choice of data collection instrument(s) for a particular study depends on the research approach adopted, thus whether quantitative, qualitative of mixed methods approach as well as the specific research questions posed (Boateng, 2014). Therefore, based on the quantitative approach adopted for the study, and the pertinent research questions to be answered, a questionnaire was deemed an appropriate data collection tool for the study.

A questionnaire is a data collection tool consisting of a series of question either close-end, open ended or both that requires the respondent to provide brief answers with regards to a description of current events, conditions or attributes of a population at a particular point in time (Burns, 2000). The questionnaire was employed as the main instrument for data collection because it is suitable for collecting data from large group and widespread respondents as well as generate reliable and valid data from a high proportion of a population within a reasonable period and at a minimum cost (Dane, 1990). Also, the questionnaire is an effective instrument for securing factual information about practices and conditions of which the respondents are presumed to have knowledge and opinions on (Cohen, Manion & Morrison, 2005).

One set of questionnaire was designed and self-administered to the respondents in their various welding shops within the Sunyani Magazine Area. The questionnaire was designed based on the research questions in such a way that the response items were appropriate in answering the pertinent research questions. The response items in the questionnaire were developed with reference to issues pertaining to each research question as found in prior literature. The questions were structured as forced-choice response items involving dichotomous or multiple choice and Likert scale type of closed-ended questions. This closed-end structure of questions was adopted because questions of that nature are easy to ask and quick to answer, require no lengthy writing by the respondent and the results are straightforward to analyze (Naoum, 1998).

The questionnaire was in five sections, thus Section A, B, C, D and Section E. The Section A part of the questionnaire was made up of dichotomous response items which captured the demographic data of the respondents such as gender, age, work experience, and educational qualification. Section B comprised of questions relating to the background of the welding operations of the respondents. The rest of the sections consisted of closed-ended response items presented under three subsections according the to the specific research questions they sought to answer. Section C comprised 20 response items on health and safety hazards associated with welding operations. Section D comprised 15 response items unsafe practices of welders. Section E comprised 19 response items on precautionary measures are adopted in ensuring safety in welding operations. The response items in Sections C, D, and E were rated using a five-point Likert scale with response categories of: 1 – Agree, 2 – Not sure, and 3 - Disagree.

3.6 Pilot Test of Instrument

In order to establish that the questionnaire was valid and could be relied upon to generate the appropriate responses for the study, the final administration if the questionnaire was preceded by a pilot test of the questionnaire with 10 welders within the Sunyani Municipality but outside the sample size selected for the study. The pilot test was conducted to measure the face validity of the survey questionnaire to ensure that the items were suitable for the constructs assessed (Saunders et al., 2009). The researcher revised the questionnaire based on the responses received from the pilot test.

3.7 Validity and Reliability of Data Collection Instrument

When conducting a survey and using the questionnaire as a data collection instrument, issues of validity and reliability of the instrument are very important and must be taken into considerations. Mugenda and Mugenda (2003) define validity as the degree to which results obtained from the analysis of the data actually represent the phenomena under study. On the other hand, Carmines and Zeller (1979) assert that the reliability of an instrument concerns the ability of the instrument to reproduce data in a consistent way on repeated trials though there will always be a presence of chance error no matter how reliable the method may be. Thus, while validity is concerned with whether the findings are really about what they appear to be about, reliability refers to the extent to which a data collection technique will yield consistent results (Saunders, et al., 2009).

With regards to issues of validity, the questionnaire was designed based on the purpose and specific objectives of the study and with reference to similar constructs in prior literature. After designing the questionnaire, the researcher submitted a draft copy to his supervisor for perusal and expert advice.

The comments and suggestions from the supervisor assisted the researcher in improving upon the face and content validity of the instrument. In terms of reliability of the instrument, the results from the pilot test were analyzed using the Cronbach's Alpha Reliability Coefficient test for Likert-scale type of questionnaire. The test produced an alpha coefficient of 0.81, which was considered appropriate. This coefficient was deemed appropriate and reliable because according to De Vellis (1991), a reliability coefficient of 0.8 is considered very respectable for determining the appropriateness of an instrument.

3.8 Data Collection Procedures

As part of the processes leading to the administration of the questionnaire to the respondents, the researcher used two weeks to identify 212 welding shops and the owners of these shops within the Sunyani Magazine Area. Through personal interactions with the owners of the welding shops identified, the researcher explained the purpose of the study to them and why he wanted them to participate in the study. After the interactions, 65 of the welders accepted the offer and agreed to participate in the study as respondents. Hence, the researcher concentrated of this number of welders as his sample for the study.

One week after the interactions took place, the researcher went back to the welders one after the other to administer the questionnaire to them. Since majority of the welders could neither read nor write, the researcher took it upon himself to read out the response items to them in the local language (the Twi language) that they undertook. Based on the responses they gave, the researcher ticked or answered the specific response item appropriately. For those who could read and write in English, the questionnaire was handed over to them to answer it by themselves after which the research went round to retrieve them. In all, the data collection process lasted for one month.

3.9 Data Analysis

Data analysis consists of examining, categorizing, tabulating, or otherwise recombining the evidence to address the initial propositions of the study (Boateng, 2014). For the purpose of data analysis, results from the questionnaire were categorized, coded and entered into the Statistical Package for Service Solutions (SPSS) version 21 and analyzed using frequency counts, percentages and weighted mean scores. Frequencies count indicated the number involved in a particular response item, while percentages showed the number relative to the total involved. Weighted mean scores were used to obtain the average score of the variables for the purpose of ranking.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION OF RESULTS

4.1 Introduction

The chapter presents the results of the study. The responses from the questionnaires were extracted and presented in tables and analyzed quantitatively as shown in the sections that follow. The results were discussed with reference to findings of related literature to establish whether they corroborate or contradict the findings of prior studies.

4.2 Demographic Characteristics of Respondents

In conducting a research that seeks to investigate the attitudes, behaviour, characteristics, or perceptions of people about a particular phenomenon, it is necessary to have an idea about the background characteristics of such people who the researcher intends to use as respondents in the research. It is believed that the specific demographic characteristics of people such as their gender, age, level of educational, profession/trade, work experience among other characteristics can influence their thought patterns, perception, knowledge and understanding of the issues under study.

Studies have shown that gender diversity has an influence on people's reactions, perceptions, and approach to situations and issues. Thus, females approach social phenomenon differently from their male counterparts due to their unique gender characteristics. Over time, behavioural research has established that people of the same age cohort tend to exhibit some common characteristics which are quite different from members of different age cohorts. Also, there is no doubt that education has had a great impact on people's level of knowledge and understanding of issues which hitherto they could not have any idea about if they were illiterate.

The years of work experience in a particular trade or profession puts a person in a better position to acquire more experience about his/her work and thereby make meaning contributions towards helping others understand the issues relating to the work.

From the foregoing, it was deemed necessary to analyze the demographic characteristics of the respondents of the study to establish how such characteristics may influence their views about the issues under discussion. Hence, the bio-data of the 65 respondents used in the study is presented in Table 4.1 as follows:

Table 4.1: Demographic Characteristics of Respondents

Demographic Characteristics	Frequency	Percentage
Gender		
Male	61	93.8
Female	4	6.2
Age		
Below 30 years	22	33.8
30 – 39	18	27.7
40 – 49	19	29.2
50 years and above	6	9.2
Level of Education		
Basic Education	40	61.5
Secondary Education	6	9.2
Vocational/Technical Education	19	29.2
Tertiary	0	0
Work Experience		
Below 5 years	11	16.9
5 – 14	33	50.8
15 years and above	21	32.3

It can be observed from Table 4.1 that majority of the respondents who took part in the study were males as indicated by 93.8% of the gender distribution ratio. The females who participated in the study were less than one-tenth of the sample size as represented by 6.2%. Considering the nature of welding operations and the hazards associated with welding, it is not surprising that the gender distribution of the respondents appears to suggest that majority of welders in the Sunyani Municipality are males.

The age distribution of the respondents shows that slightly over 60.0% of them were below 40 years with slightly below one-tenth representing 9.2% of them were either 50 years or above. Also, 29.2% of the welders who took part in the study indicated that they were within the 40 – 49 years' age bracket. The age distribution of the respondents implies that majority of the welders are in their youthful age which seems to confirm the notion that welding operations involves a lot of energy and therefore suitable for young persons than older persons.

Like other trades, welding operations in Ghana do not require high level of formal education. As revealed by the results, majority of the welders who participated in the study representing 61.5% indicated that their highest level of education was basic education. While none of the respondents have acquired any form of tertiary education with only 9.2% indicating that they have acquired secondary education, 29.2% of them stated that they have attained vocational/technical education. The results on the educational background of the respondents reflects the typical Ghanaian informal sector trade where education is not considered as a major requirement in engaging in such trades.

The study involved owners/managers of welding workshops and for that matter it was expected that the respondents used for the study will exhibit a great deal of experience in welding operations. As confirmed by the results, over 80.0% of the respondents had garnered over five years work experience in the welding trade with just 16.9% indicating that they have acquired less than five years in the trade. The period of work experience stated by majority of the respondents shows that they are very familiar with issues pertaining to welding operations and therefore were in a better position to make meaningful contributions to the study.

4.3 Analysis and Discussion of Results

The questionnaires were designed to solicit for information pertaining to the type of welding techniques adopted by welders in the Sunyani Municipality, the kinds of metal used for welding operations, and the kind of gas used for gas welding activities. In addition, the research instrument sought to collect data on the health and safety hazards associated with welding operations, the unsafe work practices of welders that expose them to various hazards, as well as the precautionary measures adopted to mitigate the potential health and safety hazards. The results of the aforementioned issues are presented and analyzed under specific sub-headings in the sections that follow:

4.3.1 Type of Welding Techniques adopted by Welders

There are various types of welding techniques adopted by welders in joining different kinds of metals together. The type of welding technique employed by a welder may depend on a lot of factors such as cost of operation, welder's knowledge in the use of the particular method, the kind of welding operation to be conducted, the welding environment among other factors.

Considering the fact that the welding workshops used in the study were located within the informal welding sector, the study sought to investigate the type of welding techniques mostly adopted by welders in this sector. Hence, the information in Table 4.2 relates to the types of welding techniques adopted by welders in the Sunyani Municipality.

Table 4.2 Type of Welding Techniques adopted by Welding Workshops

Types of Welding	Yes		No	
	f	%	f	%
Arc Welding	56	86.2	9	13.8
Oxyacetylene Welding	52	80.0	13	20.0
High-Energy Beam Welding	3	3.1	63	96.9
Hot Pressure Welding	6	9.2	59	90.8

Based on the results with regards to the types of welding techniques adopted by welders in the Sunyani Municipality, it appears that the commonest welding techniques adopted by majority of welders is arc welding as indicated by 86.2% of the respondents. Following arc welding is oxyacetylene welding which 80.0% of the respondents indicated that they use for their welding activities with 20.0% of them answering in the negative. While as low as 3.1% of the welders stated that they use high-energy beam welding techniques on few occasions, majority of the respondents representing 96.9% assert that they do not adopt this method of welding. Likewise, 90.8% of the respondents indicated that they do not engage in hot pressure welding though 9.2% answered in the affirmative.

The results of the study revealed that welders in the Sunyani Municipality adopt two main welding techniques for their welding operations.

These are arc welding and oxyacetylene welding techniques. Also, it was found that high-energy beam welding and hot pressure welding techniques were not common techniques used by majority of welders. Thus, just a few number of welders adopted such welding techniques for some special-purpose welding operations. The findings are consistent with the assertion of Singh and Anand (2013) that though there are over 80 different types of welding techniques, the widely used welding techniques are arc welding and oxyacetylene welding.

In the Ghanaian perspective, the study corroborates the findings of Kumah, Cobbina, and Duodu (2011) who reported that 40% of welders at the Suame Magazine use oxyacetylene gas for their welding operations. Also, the results are consistent with that of Gyasi (2013) who revealed that majority of the welding firms in Ghana employ shielded metal arc welding as the commonly used welding method. Again, the results support the findings of Akpakpavi (2015) that the welding processes used in the informal welding sector in Ghana include shielded metal arc welding and oxyacetylene welding.

4.3.2 Kinds of Metal used for Welding

There are a number of metals available for welding processes. While some metals are highly conductible and may respond to heat quickly, melt and make better welds, other metals may not be suitable for some kind of welding processes. Depending on the type of metals to be joined together or welded, welders may use different kinds of metal they deemed suitable for any particular welding activity. In this regard, the study sought to find out the kinds of metal used by welder in the Sunyani Municipality for their welding operations as presented in Table 4.3 as follows:

Table 4.3: Kinds of Metal used for Welding

Types of Metal	Yes		No	
	f	%	f	%
Aluminium	59	90.8	6	9.2
Copper	49	75.4	16	24.6
Stainless steel	44	67.7	21	32.3
Nickel	62	95.4	3	4.6
Beryllium	0	0	0	0
Magnesium	53	81.5	12	18.5

Among the various metals used for welding activities, nickel appeared to be the widely used metal as indicated by 95.4% of the respondents with only 4.6% of them dissenting. Aluminium emerged as the next common metal used for welding after nickel as indicated by 90.8% of the respondents. Magnesium followed aluminium as one of the widely used metal for welding activities as reported by 81.5% of the welders who took part in the study. Copper and stainless steel following in that order as some of the metals mostly used by welders in joining other metals together as indicated by 75.4% and 67.7% of the respondents respectively. However, none of the respondents stated that they use beryllium in their welding activities.

The results show that welders in the Sunyani Municipality use various kinds of metal in their welding operations with the common ones' being nickel, aluminum, copper, and magnesium. The use of nickel, copper and magnesium as metals for welding activities is consistent with the list of metals outlined by the AFSCME Research and Collective Bargaining Department (2011) to be suitable for welding activities.

The use of stainless steel as a welding material confirms the assertion of Smallbone and Kocak (2012) that welders use different kinds of steel to perform their welding activities.

4.3.3 Kinds of Gases used for Welding

Depending on the type of welding technique or method adopted, welders use different kinds of gases to facilitate their welding operations. The kinds of gases used by welders in the Sunyani Municipality for their welding operations are presented in Table 4.4 as follows:

Table 4.4: Kinds of Gases used for Welding

Kinds of Gases	Yes		No	
	f	%	f	%
Argon	65	100	0	0
Helium	44	67.7	21	32.3
Oxygen	65	100	0	0
Carbon dioxide	65	100	0	0

The results as presented in Table 4.4 show that the widely used gases for welding activities are argon, oxygen and carbon dioxide as reported by all the 65 respondents who participated in the study. Also, 67.7% of the respondents indicated that they used helium in their gas welding operations.

4.3.4 Health and Safety Hazards associated with Welding Operations

The purpose of the study required that the study investigate the potential health and safety hazards that welders are exposed to in the course of carrying out their welding operations. Hence, they researcher sought the views of welders in the Sunyani Municipality on the various health and safety challenges they encounter in their welding operations. The responses relating to this issue are presented in Table 4.5 as follows:

Table 4.5: Health and Safety Hazards associated with Welding Operations

Health and Safety Hazards	1		2		3		WM
	f	%	f	%	f	%	
Skin irritation due to excessive radiation and heat	60	92.3	3	4.6	2	3.1	2.89
Personal injuries and accidents	56	86.2	4	6.2	5	7.7	2.78
Eye infections	52	80.0	3	4.6	10	15.4	2.65
Fire explosion	39	60.0	13	20.0	13	20.0	2.55
Respiratory problems	43	66.2	9	13.8	13	20.0	2.46
Suffocation	46	70.8	2	3.1	17	26.2	2.45
Musculoskeletal disorders	46	70.8	0	0	19	29.2	2.42
Lung infections caused by toxic welding gases	41	63.1	0	0	24	36.9	2.26
Electric shock	36	55.4	8	12.3	21	32.3	2.23
Gastrointestinal effects	36	55.4	3	4.6	26	40.0	2.15
Radiation-related ocular diseases	32	49.2	7	10.8	26	40.0	2.09
Noise and vibration causing hearing impairment	34	52.3	3	4.6	28	43.1	2.09

Key: 1 – Agree, 2 – Not sure, 3 – Disagree, f – frequency, WM – Weighted Mean

It can be observed from Table 4.5 that the major health and safety threats that welders are exposed to in the course of performing their welding activities was exposures to excessive heat which leads to skin irritation and radiation. This was attested to by majority of the respondents as revealed by the highest mean score of 2.89. Personal injuries and accidents was reported as the next common health and safety challenge that welders encounter at the workplace as shown by a mean score of 2.78. Eye infections, fire explosion, respiratory disorders and suffocation due to excessive heat were some of the health and safety challenges mostly reported by welders as indicated by the relatively high mean scores of 2.65 to 2.45. In addition, it was revealed by majority of the respondents that welding activities exposed them to health complications such as musculoskeletal disorders, lung infections, electrical shocks, and gastrointestinal effects. However, the least reported health and safety hazards associated with welding as indicated by lowest weighted mean score of 2.09 were radiation-related ocular diseases and hearing impairment caused by excessive noise and vibration from machines.

The study has shown that welders are exposed to various health and safety hazards associated with their welding operations. The most common and prevalent hazards reported by majority of the respondents in the study were skin irritation, body injuries and accidents, eye infections, fire explosion, and respiratory challenges among others. This confirms the assertion of the AFSCME Research and Collective Bargaining Department (2011) that a lot of the substances in welding smoke can be extremely toxic with severe health implications. The report of other safety hazards such as radiation, electric shock, and excessive noise leading to hearing impairment corroborate the position of Singh and Anand (2013) that welders by the nature of their operation are constantly exposed to health and safety threats such as electric shocks, radiation, heat, and excessive noise. Furthermore, the results confirm the assertion of Kumah, Cobbinah, and Duodu (2011) that welding arc emits wide spectrum of radiations which when exposed to the welder over long periods can result in serious damage to the eyes

4.3.5 Unsafe Work Practices of Welders

It is believed that some unsafe and careless behaviour and practices of welders can expose them to serious safety challenges at the workplace. The views of respondents as presented in Table 4.6 were sought on a number of predetermined unsafe practices which prior studies have shown that welders tend to engage in. This was meant to find out if welders in the Sunyani Municipality also engage in such unsafe work practices.

Table 4.6 Unsafe Work Practices of Welders

Unsafe Work Practices	1		2		3		WM
	f	%	f	%	f	%	
Intake of alcohol or hard drugs	61	93.8	2	3.1	2	3.1	2.91
Poor handling of welding equipment	50	76.9	6	9.2	9	13.8	2.63
Failure to wear personal protective equipment	52	80.0	0	0	13	20.0	2.60
Non-compliance with safety rules and guidelines	49	75.4	5	7.7	11	16.9	2.58
Use of faulty equipment and tools	46	70.8	9	13.8	10	15.4	2.55
Unvaried, repetitive movements	49	75.4	0	0	16	24.6	2.51
Using high or sustained force	46	70.8	2	3.1	17	26.2	2.45
Gross negligence during welding operations	41	63.1	7	10.8	17	26.2	2.37
Lack of awareness of welding related health hazards	43	66.2	2	3.1	20	30.8	2.35
Twisted, stooped, awkward asymmetrical postures	37	56.9	4	6.2	24	36.9	2.20
Lack of maintenance culture	36	55.4	4	6.2	15	23.1	2.02

Key: 1 – Agree, 2 – Not sure, 3 – Disagree, f – frequency, WM – Weighted Mean

More often, a lot of accidents and injuries that occur at the workplace are caused by unsafe work practices of workers. In this study, the researcher investigated the practices of welders which were deemed to expose them to safety risks leading to accidents and other safety challenges in the welding workshop. The results show that the practice where welders take too much alcoholic beverages and hard drugs such as heroine before engaging in their daily welding operations expose them to serious safety hazards. This unsafe behaviour on the part of welders was rated as the most dangerous practice among other factors as indicated by a mean score of 2.91. The careless attitude towards handling welding equipment and workers' failure to wear personal protective equipment was noted to be another major causes of injuries and life-threatening accidents in the welding workshop as indicated by a mean score of 2.63 and 2.60 respectively. Also, welders' failure to comply with safety rules and regulations guiding welding activities was deemed as an unacceptable behavior to expose welders to safety hazards as shown by a mean score of 2.58.

In addition, the use of faulty welding equipment and the practice where welders engage in repetitive and awkward movements lead to health and safety challenges among welders as revealed by mean scores of 2.55 and 2.51 respectively. Other practices and behaviours such as the use of excessive human force in performing a welding task, gross negligence by welders when welding, and welders' lack of knowledge with regards to the various welding related health and safety hazards can somewhat pose safety challenges to welders as indicated by mean scores 2.45, 2.37, and 2.35 respectively. Though, reported by some welders as amounting to unsafe work practices, situations such the act of posing in rigid and awkward manner for a long time and lack of maintenance culture were not deemed as factors that have high propensity to cause safety threats to welders as shown by their mean scores of 2.20 and 2.02 respectively.

4.3.6 Precautionary Measures for ensuring Safety in Welding Operations

Considering the hazardous nature of welding operations, welders are required to safeguard against their health and safety my adhering to safety measures at the workplace in order to minimize or at best prevent the health and safety challenges they encounter. Presented in

Table 4.7 are the views of respondents with regards to the safety measures adopted at their workplace.

Table 4.7 Precautionary Measures for ensuring Safety in Welding Operations

Precautionary Measures	1		2		3		WM
	f	%	f	%	f	%	
Use ultraviolet radiation filters for eye protection	55	84.6	2	3.1	8	12.3	2.72
Keep your head out of fumes	51	78.5	4	6.2	10	15.4	2.63
Wear appropriate personal protective equipment	51	78.5	2	3.1	12	18.5	2.60
Proper installation of welding equipment	50	76.9	4	6.2	11	16.9	2.60
Strict enforcement of safety rules and guidelines	48	73.8	2	3.1	15	23.1	2.51
Periodic maintenance of welding equipment	47	72.3	4	6.2	14	21.5	2.51
Use exhaust ventilation	44	67.7	4	6.2	17	26.2	2.42
Handle compressed gas cylinders with extreme care	42	64.6	4	6.2	19	29.2	2.35
Keep work area clean and free of scrap	39	60.0	7	10.8	19	29.2	2.31
Do not weld on sealed containers without vents	39	60.0	4	6.2	22	33.8	2.26

Key: 1 – Agree, 2 – Not sure, 3 – Disagree, f – frequency, WM – Weighted Mean

The hazardous nature of welding operations require that welders adhere to safety measures to help prevent or minimize the risks associated with welding. The lighting and ultraviolet radiations produced during welding exposes the welders serious eye defects. Therefore, majority of the respondents opined that the use of ultraviolet radiation filters to protect the eye should be encouraged among welders. This practice was rated as the most important safety measure as indicated by the highest mean score of 2.72. Majority of the respondents indicated that they keep their heads out of the fumes generated during welding to avoid inhaling the harmful substances in such flames.

Another important precautionary measures adopted by welders involved the wearing of personal protective equipment and the proper installation of welding equipment to prevent any possible accidents. This measures were rated very high by the respondents with mean scores of 2.60 each. Furthermore, it was revealed that as part of measures to ensure safety in welding workshops owners of the workshops ensured strict adherence to safety rules and regulations, and conduct regular maintenance of welding equipment as shown by mean scores of 2.51 each. To avoid suffocation and skin irritation as a result of excessive heat from welding activities it was required that welding workshops are constructed with proper ventilation facilities. This issue taken into serious consideration my majority of the welders to participated in the study as shown by a mean score of 2.42.

Other precautionary measures adopted by welders in the Sunyani Municipality involved the handling of compressed gas cylinders with extreme care, keeping workshops and work areas clean and free from scrap metals as indicated by their relative low mean scores of 2.35 and 2.31 respectively. Though majority of the welders claimed that they do not weld on sealed containers without vents, this practice was deemed to be a normal practice and therefore do not constitute a serious precautionary measure that should be given great attention as indicated by the lowest mean score of 2.26.

The precautionary measures adopted by welders in the Sunyani Municipality as a means of preventing work-related injuries and accidents include the use of ultraviolet radiation filters to protect their eyes from the toxic emissions and radiations from welding processes. Also, welders wear personal protective equipment to protect themselves from safety hazards.

Based on the results with regards to how welders protect themselves from the safety hazards during welding, it emerged that majority of them were very cautions of the dire consequences of engaging in unsafe welding practices. Hence, they took the necessary steps and measures to ensure that welding is conducted in a safe atmosphere by adhering to various safety measures and regulations. The results are consistent with the assertion of Hobart Institute of Welding Technology [HIWT], (2009), that despite the numerous hazards that welders are continually exposed to during welding operation, when correct precautionary measures are followed, welding will be a safe occupation. Again, the study supports the recommendation of Singh and Anand (2013) that preventive measures such as avoiding eye injury, respiratory protection, and ventilation of the work area, wearing protective clothing, and having safe equipment to use among others should be adopted by welders at the workplace.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

The chapter presents that summary of key findings of the study and the conclusions drawn. It also contains the recommendations made on the findings of the study and the suggestions made for further research.

5.2 Summary of Key Findings

The study sought to investigate safety considerations in welding operations in the Sunyani Municipality. Specifically, the study investigated the health and safety hazards associated with welding operations, identified the unsafe work practices of welders that expose them to health and safety threats, as well as examined the precautionary measures adopted in ensuring safety in welding operations in the Sunyani Municipality. The key findings of the study were presented under relevant subheadings based on the pertinent objectives as follows:

Health and Safety Hazards Associated with Welding Operations

The study revealed that welders are exposed to various kinds of health and safety challenges in the course of undertaking their welding operations. As such it was necessary to identify these hazards for appropriate safety measure to be taken to avert the situation. The common health and safety hazards associated with welding operations as reported by majority of welders in the Sunyani Municipality are: skin irritation caused by excessive heat from welding flames, eye infections caused by ultraviolet rays and other toxic substances emitted during welding, lung infections and other respiratory complications caused by fumes and toxic gases, injuries and accidents such as body cuts and burns, as well as suffocation caused by excessive heat in enclosed welding workshop.

Other safety hazards reported by the welders include musculosketal disorders caused by repetitive actions and awkward postures during welding, electric shock caused by electrical sockets and naked cables, excessive noise produced by welding equipment leading to hearing impairment, and fire explosion which may lead to fatal injuries and loss of life.

Unsafe Work Practices of Welders

The numerous health and safety hazards associated with welding operations may be caused by gross negligence on the part of welders and deliberate disregard for safety rules and regulations. Most often welder who encounter safety challenges are those engaged in unsafe work practices which have the potential of exposing them to safety hazards. It was reported by majority of the welders that the excessive intake of alcoholic beverages and hard drugs such as heroine, careless handling of welding equipment, failure to wear personal protective clothing, and non-compliance with welding safety rules and regulations were the most common unsafe work practices engaged in by majority of welders.

Precautionary Measures adopted in Ensuring Safety in Welding Operations

In an effort to curb the health and safety hazards associated with welding operations, welders adopt various precautionary measures to protect themselves from workplace injuries and accidents. Among the major safety measures undertaken by welders in Sunyani Municipality were the use of ultraviolet radiation filters during welding to protect their eyes from the radiations, keeping one's head out of welding fumes to avoid inhaling the fumes, wearing personal protective equipment, and ensuring proper ventilation of welding workshop.

Other measures include the strict enforcement of safety rule and regulations, ensuring the regular maintenance of welding equipment, handling compressed gas cylinders with great extreme, and keeping the workplace very tidy and free from unwanted scrap.

5.3 Conclusions

It was deduced from the study that welding operations are highly hazardous and welders are at risk of being exposed to serious health and safety hazards. Though majority of the welders indicated that they were aware of the hazards associated with welding activities, the effects of some of the hazards on the health of welders is not felt immediately but may result in future eye infections and respiratory complications. Despite the dire effects of hazards associated with welding, it was revealed that some welders still engage in unsafe work practices that expose them to various safety hazards. However, it appears that majority of welders are becoming increasingly conscious of the dire consequences of engaging in improper welding practices which tend to expose them to various health and safety challenges. Hence, owners of welding workshops have adopted the necessary precautionary measures to guard against injuries and accidents at the workplace.

5.4 Recommendations

Based on the findings of the study, the following recommendations were made to help improve upon the safety of welders in Ghana as whole and the Sunyani Municipality in specificity:

i. The dire consequences of failure to adhere to welding safety rules and regulations cannot be overemphasized. The injuries and accidents caused by unsafe work practices are fatal and in some can lead to death. Hence, it is recommended that the relevant authority with oversight responsibility of supervising welding operations in the country should design welding safety standards and regulations to guide welders in performing their welding activities in a safe manner.

ii. Apart from the Factories, Offices and Shops Act (1970) and the Labour Act, 2003 (Act 651) which seem to talk about employee safety at the workplace in general, there is no national policy on Occupational Health and Safety that seeks to protect workers from workplace safety hazards. Therefore, the study recommends a national policy that will provide strict guidelines on how to carry out various manufacturing and industrial processes in a safe manner. The policy should among other things outline the risks and hazard associated with each industrial process or activity and the safety measures to be adopted by workers to avoid exposing themselves to such safety challenges.

iii. With the advent of technology, manual welding seems to be fading away to give way for more modernized automatic welding processes with less human effort. With the emergence of robotic welding in the developed countries, it recommended that welding firms in Ghana consider using this new mode of welding in order to reduce the hazards associated with manual welding.

5.6 Suggestion for Further Research

The focus of the study was to investigate the safety considerations associated with welding operations in the Sunyani Municipality. However, the researcher makes the following suggestions for further studies by future researchers in the area of welding operations:

i. Since, majority of welders in the Sunyani Municipality operate in the informal sector, it is suggested that future studies should look at safety consideration of welding operations in the formal sector with a wider scope of firms.

ii. Further studies should assess the quality of welding apprenticeship training to ascertain whether welding apprentices receive enough training on safety hazards in welding and measures for controlling such hazards.

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APPENDIX

UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

QUESTIONNAIRE FOR WELDERS

Please, you are kindly requested to fill this questionnaire in your capacity as a welder. The questionnaire seeks to investigate the health and safety hazards associated with welding operations in the Sunyani Municipality. This exercise is meant to collect data for my dissertation for the degree of Master of Technology (Mechanical Technology) degree at the University of Education, Winneba. You are being informed that the responses you give will be used for academic purposes only.

Instruction: Please tick (√) what you think is the right answer from the alternatives given and state briefly where necessary.

SECTION A: Demographic Characteristics of Respondents

1. Gender

Male [ ] Female [ ]

2. Age group

Below 30 years [ ] 30 – 39 years [ ]

40 – 49 years [ ] 50 years and above [ ]

3. Level of Education

Basic [ ] Secondary [ ]

Vocational/Technical [ ] Tertiary [ ]

4. Please indicate your years of working experience in the construction industry?

Below 5 years [ ] 5 – 14 years [ ] 15 years and above [ ]

Section B: Background of Welding Operations

5. What types of welding processes do you undertake?

Types of Welding	Yes	No
Arc Welding		
Oxyacetylene Welding		
High-Energy Beam Welding		
Hot Pressure Welding		

6. What metals do you use in your welding activities?

Types of Metal	Yes	No
Aluminium		
Copper		
Bronze		
Stainless steel		
Nickel		
Beryllium		
Magnesium		

7. What kind of gases do you use for your welding activities?

Kind of Gases	Yes	No
Argon		
Helium		
Oxygen		
Carbon dioxide		

Section C: Health and Safety Hazards associated with Welding Operations

8. Please indicate whether you agree or disagree with the following health and safety hazards associated with welding Operations. Please rank your responses using: 1 – Agree, 2 – Not sure, 3 - Disagree.

Safety Hazards	**1**	**2**	**3**
Fire explosion			
Electric shock			
Excessive heat			
Radiation-related ocular diseases			
Eye infections			
Lung infections			
Chronic respiratory problems			
Toxic wielding smoke and gases			
Suffocation			
Noise and Vibration causing hearing impairment			
Musculoskeletal disorders			
Gastrointestinal effects			
Skin irritation and reddening due to excessive radiation and heat			
Personal injuries and accidents			

Section D: Unsafe Practices of Welders that expose them to Hazards

9. Please indicate whether you agree or disagree with the following unsafe practices of welders that expose them to risks and hazards in welding operations. Please rank your responses using: 1 – Agree, 2 – Not sure, 3 - Disagree.

Unsafe Practices	1	1	2
Lack of maintenance culture			
Failure to wear appropriate personal protective equipment			
Intake of alcohol or hard drugs (heroin, cocaine, etc.)			
Non-compliance with safety rules and guidelines			
Poor handling of welding equipment			
Lack of awareness on welding related health and safety hazards			
Use of faulty equipment and tools			
Gross negligence during welding operations			
Twisted, stooped, awkward asymmetrical postures			
Fixed, sustained, rigid or prolonged postures			
Unvaried, repetitive movements			
Sudden, uncontrolled or jerky movements			
Using high or sustained force			

Section E: Precautionary Measures for ensuring Safety in Welding Operations

10. Please indicate whether you agree or disagree with the following precautionary measures necessary for ensuring safety in welding operations. Please rank your responses using: 1 – Agree, 2 – Not sure, 3 - Disagree.

Precautionary Measures	1	2	3
Strict enforcement of safety rules and guidelines			
Wear appropriate personal protective equipment			
Use ultraviolet radiation filters for eye protection			
Keep your head out of the fumes			
Periodic maintenance of welding equipment			
Provide protective screens and flash goggles			
Use exhaust ventilation			
Proper installation of welding equipment			
Keep work area clean and free of hazards			

Handle all compressed gas cylinders with extreme care			
Keep caps on when not in use			
Do not weld on sealed containers without vents			