University of Education,Winneba http://ir.uew.edu.gh

UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION-KUMASI

AN INVESTIGATION INTO THE ASSET INTEGRITY MANAGEMENT SYSTEM OF GHANA'S OIL INDUSTRY. AT THE ATUABO GAS COMPANY IN GHANA

EDGAR KPAKPO ADDO

JULY, 2015

University of Education,Winneba http://ir.uew.edu.gh

UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION-KUMASI

AN INVESTIGATION INTO THE ASSET INTEGRITY MANAGEMENT SYSTEM OF GHANA'S OIL INDUSTRY. AT THE ATUABO GAS COMPANY IN GHANA

EDGAR KPAKPO ADDO

(7131220011)

A Dissertation in the Department of **MECHANICAL TECHNOLOGY EDUCATION**. Faculty OF **TECHANICAL EDUCATION**, submitted to the school of Graduate Studies, university of Education, Winneba in partial fulfilment of the requirements for the award of Master of Mechanical Technology (Mechanical) degree**.**

JULY, 2015

University of Education,Winneba http://ir.uew.edu.gh

DECLARATION

I, Edgar Kpakpo Addo declare that this dissertation, with the exception of quotations and references contained in published works which have all been identified and acknowledged, is entirely my original work, and it has not been submitted, either in part or whole for another DEGREE ELSEWHERE.

Signature …………………………………………………..

Date ……………………………………………….............

SUPERVISOR'S DECLARATION

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

Name ……………………………………………………………………

Signature…………………………………………………….................

Date………………………………………………………….....................

University of Education,Winneba http://ir.uew.edu.gh

ACKNOWLEDGEMENT

Many individuals have contributed to the creation of this dissertation in various ways, including offering moral support and providing extensive feedback on some or all of the text.

Producing this dissertation has been extraordinarily complicated, and I thank Ing. Professor N. Kyei-Baffour, supervisor for his fatherly advice, guidance, great cooperation, useful suggestions and criticisms, all of which contributed to the success of the study.

Secondly, I wish to acknowledge my head of department Marine Engineering RMU Mr. J. F. Tetteh, the project engineer, project supervisors and QAQC department of Ghana Gas Company for their immersed support in helping to investigate into the asset integrity management system of Ghana's oil industry records necessary for the reports. I especially thank the following for their numerous and varied contributions; Emmanuel Adjei Larty, Eunice Oduraa Ansu, Mr Edukoh, my In –laws on campus Yaa Adutwumwaa, Adwoa, Cynthia Dumasi, Mr. Gabriel Akpako and Mr. Fareed Amoah.

A very special thanks goes to Edward Ewusi Essoun, who read each chapter in detail, and made numerousvaluable suggestions and contributions.

Finally, I extend my profound gratitude to all lecturers in the Department of Mechanical Technology of the University of Education, Winneba-Kumasi Campus for their efforts in imparting the required knowledge to me which served as the bases for this dissertation.

University of Education,Winneba http://ir.uew.edu.gh

DEDICATION

This dissertation is dedicated to my lovely wife Mrs. Lydia Achiaa Addo and children Nii Adotey Addo, Naa Dromo Adoley Addo and Nyameye Nii Adoteye Addo.

University of Education,Winneba http://ir.uew.edu.gh

TABLE OF CONTENTS

CONTENT **PAGE**

University of Education,Winneba http://ir.uew.edu.gh

University of Education,Winneba http://ir.uew.edu.gh

University of Education,Winneba http://ir.uew.edu.gh

University of Education,Winneba http://ir.uew.edu.gh

University of Education,Winneba http://ir.uew.edu.gh

LIST OF TABLES

TABLE **PAGE**

University of Education,Winneba http://ir.uew.edu.gh

LIST OF FIGURES

FIGURE **PAGE**

University of Education,Winneba http://ir.uew.edu.gh

University of Education,Winneba http://ir.uew.edu.gh

ABSTRACT

The purpose of the study was to investigate into the asset integrity management system of Ghana's oil industry. The study adopted descriptive research design for the study. Qualitative and quantitative research methods were used for the study. The researcher used questionnaire surveys and interviews to collect primary data**.** The populations for the study were personnel of Ghana Gas Company, Ghana National Petroleum Company and the Ministry of Energy and their supervisors in industry. The population for the study was seven hundred (700). A sample of 151 respondents from the Ghana Gas company at Atuabo was randomly selected. This was made up of 50 supervisors and 101 practicing engineers and operators. SPSS software version 18 was used to analyse data. The findings of the study concluded that the asset integrity management (AIM) addresses corrosion management inspection and repair, safety of critical elements, instrumented protective functions, The asset integrity management(AIM) delegates duties, responsibilities, authorities and accountabilities with respect to its development and implementation. All relevant personnel do not have access to relevant AIM documentation and records. The AIM incorporates or links to a quality management system as a mechanism for assisting in meeting the asset integrity management (AIM) performance standards or key indicators. Key Performance Indicators (KPIs) are regularly reviewed by supervisors and managers. The researcher recommended that, the managers of the organization must ensure that AIM addresses corrosion management inspection and repair, safety of critical elements, instrumented protective functions, the AIM must delegate duties and responsibilities to improve Assets Integrity Management Strategy of the Ghana Gas Company, Atuabo.

University of Education,Winneba http://ir.uew.edu.gh

CHAPTER ONE

INTRODUCTION

1.1 General Introduction

Safe and reliable production is the cornerstone to efficient and profitable oil and gas production operations. As majority of the offshore oil and gas installations in the Ghana oil and gas sector are operating beyond their design life, management and prevention of unwanted incident especially those involving hydrocarbons, is essential to achieving this desired safety and reliability. This sort of events can lead to multiple fatalities with respect to people, contamination of the environment, economic loss and reputational damage for example, the Texas City refinery disaster in 2005 and The Gulf of Mexico Oil Spill in 2010 (Ciaraldi, 2009). The effective Asset Integrity Management (AIM) is critical in preventing major accidents, improve availability, business and operational efficiency and increase reliability in oil and gas production operations. To achieve this, it is necessary that an aware workforce deploy quality practices to sound facilities(Rao, Sharma, and Krishna, 2012).

1.2 Asset Integrity Management (AIM)

Management of asset integrity in modern oil and gas industry is a complex and a cross-functional activity made up of many components covering many disciplines, and it is a birth to death journey for an asset. The United Kingdom Health, Safety and Environment, (HSE, 2007), defined Asset Integrity as "the ability of an asset to perform its required function effectively and efficiently whilst protecting health, safety and the environment and AIM as the means of ensuring that the people, systems, processes and

University of Education,Winneba http://ir.uew.edu.gh

resources that deliver integrity are in place, in use and will perform when required over the whole lifecycle of the asset" Health, Safety and Environment (HSE, 2007).

According to Sutton (2010), Asset Integrity Management (AIM) should be a core element in companies' total management systems, strategies and activities. It seeks to ensure that all equipment, piping, instrumentation, electrical systems, and other physical items in a unit are designed, constructed, operated, inspected, and maintained to the appropriate standards. AIM is built on the philosophy that prevention of major accident is reliant on the following principles. The Plant or equipment are designed and continually assessed to ensure it is fitness for purpose (i.e. Mechanical integrity). The Process (including programme and procedures) are in place, in use, up to date and adhere to Operational integrity of the organization. The People are trained and competent with regards to their safety critical duties (i.e. Personnel integrity) (Sutton, 2010).

For an effective integrity management of an asset, the people, plant and process needs to remain fit for purpose over the life cycle of the asset. Asset integrity is a major concern in high risk and capital intensive business such as oil and gas (O&G) industry. The industry basic infrastructure such as platforms, Mobile Offshore Production Unit (MOPU), Semisubmersible, Floating, Production Storage and Offloading vessel (FPSO) require an effective asset management to ensure organization'slong term economic and business sustainability. In deep water and in marginally profitable fields, a vessel typed facility like FPSO is the preferred alternative and cost effective ways for extracting oil reserves compared to a fixed structure. The FPSO which is often complex and operate at a fixed location require a comprehensive set of asset integrity indicators for monitoring its integrity performance (Sutton, 2010).

University of Education,Winneba http://ir.uew.edu.gh

Asset integrity refers to the strategies and activities aimed for maintaining assets or equipment to ensure that they continue to operate in safe, remain available and reliable manner. It includes characteristics such as design, operations, maintenance, and inspection to maximize return from operating assets. Asset integrity management, on the other hand, ensures that the people, processes and plant and resources which deliver the integrity are in place and fit for purpose over the whole life cycle of the asset. The asset integrity is a crucial factor in asset‘s performance and, in turn, can affect all parties including owner, client and operations and maintenance (O&M) company‘s revenue (Sutton, 2010).

History shows that inadequate monitoring of asset's health conditions have not only resulted in facility interruption but have led to huge economic losses, environmental pollution and disastrous incidents. In the offshore, O&G industry, some of the example of the major incidents include; Alexander Kielland, Piper Alpha, Petrobras P-36, West Atlas, and Deepwater Horizon. The similarities between the blowout in Montara field, West Atlas jack-up rig incident and the Deepwater Horizon tragedy are quite striking. From that viewpoint, asset's health conditions have to be monitored and assessed continuously to maintain minimum risk to humans, the environment, and financial status. It has thus become important for asset owners, operations and maintenance, contractors a duty to have asset integrity management system in place to maintain the assets, in such that, it continues to operate as a variable in assuring, safe, reliable and environment-friendly manner.

For instance, recognizing the importance of effective asset integrity, the Offshore Division, Health, Safety and Environment, HSE (2007), has initiated the KP3-Asset

University of Education,Winneba http://ir.uew.edu.gh

integrity program for the offshore installations of United Kingdom UK offshore programmes. Monitoring the performance of asset integrity is one of the most vital and challenging issues in the asset integrity management program, especially with the increasing of assets. Integrity monitoring should be factbased, rather than judgment based, and may include the following strategies pointed out by (OGP 2008): Key performance indicators (KPI), or simply performance indicators, Barrier performance standard verification, Audit findings, Incident and accident investigations and Benchmarking and lessons learned from external events.

In delivering the asset integrity management during O&M stage, there should be a striking balance between lack of maintenance, over-maintenance and improper operation. Thus, a good framework with KPIs to measure asset performance of critical asset such as the offshore floating facilities is of vital importance.

1.3 Statement of the Problem

Offshore floating production facilities are mix between production platform and marine facility operations. There are fundamental differences in the way offshore floating facilities are operated compared to conventional O&G production platforms and marine tankers. The differences in the form of inspection, repair and maintenance, equipment type, and competency required for personnel, etc. will require different approach of asset integrity management compare to other O&G facility. The efficient management of these assets during their operational phase is important to ensure fitness-for-service with optimum financial return on investment is an important duty for field client, asset owners and operators. As most of the FPSOs are converted ocean-going oil tankers, of various

University of Education,Winneba http://ir.uew.edu.gh

ages, to operate in a fixed location, it is desirable to have more flexible and thorough inspection approaches as compared to the vessels (ship) which are designed to more relaxed safety criteria with five yearly routine dry-docking procedure (Moan, 2005). To achieve effective asset integrity, the organization requires a set of comprehensive key performance indicators which covers all aspects of asset integrity needed for decision-making. Therefore, this study is aiming to find a way to achieve sustainable asset integrity of the FPSOs by implementing an asset integrity performance measurement which will comply with the increasing demands of managing ageing structures and equipment in terms of safety, environmentally friendly operations and business aspects.

1.4 Objectives of the study

The main objective of the study was to investigate the asset integrity management system of Ghana's oil industry. To achieve the aim of this work, the specific objectives were as follows:

1. To review various asset integrity management techniques at Ghana Gas Company (Atuabo).

2. To assess the theoretical concepts of asset integrity performance framework in the oil and gas domain and practical implementation of framework for offshore floating facilities operated by Ghana's oil and gas industry.
3. To assess the current implementation of the AIM techniques at Ghana Gas Company (Atuabo).
4. To map the current status and elaborate on the future innovation trends of AIM products and services on the Ghana Gas Company (Atuabo).

University of Education,Winneba http://ir.uew.edu.gh

1.5 Research questions

The study was guided by the following research questions:

1. What are the various asset integrity management techniques at Ghana Gas Company (Atuabo)?

2. What are the theoretical concepts of asset integrity performance framework in the oil and gas domain and practical implementation of framework for offshore floating facilities operated by Ghana's oil and gas industry?
3. What is the current implementation of the AIM techniques at Ghana Gas Company (Atuabo)?
4. What is the current status and the future innovation trends of AIM products and services on the Ghana Gas Company (Atuabo)?

1.6 Scope of Work

This thesis report covers the following scope of work,a comprehensive literature survey on Asset Integrity Management (AIM) within the Global and local O&G industry. A market survey of available innovative AIM products and services offered by Ghana Gas Company (Atuabo) and to review the status quo. Highlights of the status and gaps through a thorough analysis of theory and what is currently available in AIM of oil and gas assets. Highlights of the potential challenges of human, technical and organizational issues related to innovating these AIM products and services.

University of Education,Winneba http://ir.uew.edu.gh

1.7 Significance of the Study

The study will provide useful information for the oil and gas industry to assist them revamp their Asset Integrity Management (AIM) techniques to handle frequent accidents and improve the welfare of workers through the eradication of huge economic losses, environmental pollution and catastrophe safety incidents. It will also provide useful information for policy framers in the oil and gas industry. The conclusions and recommendations drawn will provide the Ghana Gas Company (Atuabo) with essential information that will help them enhance their AIM Techniques.

1.8 Limitations of the Study

The results that will be analyzed in this study are limited to Ghana Gas Company (Atuabo) in Ghana. This is as a result of time constraints and slow responses from the respondents. Moreover, AIM is a very wide subject which covers design, technical and operational integrity but this thesis report is limited to the area of technical and operational integrity of O&G assets within the Ghana Gas Company (Atuabo).

1.9 Delimitation of the Study

The study covered the technical and operational integrity of oil and gas assets within the Ghana Gas Company (Atuabo) in Ghana. However, it is assumed that Ghana Gas Company (Atuabo) can provide information that can be used to generalize all Gas companies and energy provision companies in Ghana. This is because; it has all the type of assets one can think of in terms of size and sophisticated storage facilities.

University of Education,Winneba http://ir.uew.edu.gh

1.10 Organization of the Study

This thesis consists of six chapters, Chapter One deals with the background of the study, the statement of the problem, research questions and purpose of the study, significance and organization of the study. Chapter Two focuses on the review of related literature whiles Chapter Three deals with the methodology used in the study, research design, the population sample and sample procedures, data gathering instruments and data collection procedures of the study. Also in the chapter are methods of data analysis. Chapter Four presents the research findings. The Chapter Five discusses the main findings.Chapter Six presents the summary of the findings, conclusions and recommendations and suggestions for further research.

University of Education,Winneba http://ir.uew.edu.gh

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

To achieve effective asset integrity, the organization requires a set of comprehensive key performance indicators which covers all aspects of asset integrity needed for decision-making. Therefore, this study is aiming to find a way to achieve sustainable asset integrity of the FPSOs by implementing an asset integrity performance measurement which will comply with the increasing demands of managing ageing structures and equipment in terms of safety, environmentally friendly operations and business aspects. The researcher used the following objectives to review literature. The specific objectives used to review literature are as follows;

1. To review various asset integrity management techniques at Ghana Gas Company (Atuabo).

2. To assess the theoretical concepts of asset integrity performance framework in the oil and gas domain and practical implementation of framework for offshore floating facilities operated by Ghana's oil and gas industry.
3. To assess the current implementation of the AIM techniques at Ghana Gas Company (Atuabo).
4. To map the current status and elaborate on the future innovation trends of AIM products and services on the Ghana Gas Company (Atuabo).

University of Education,Winneba http://ir.uew.edu.gh

2.2 Theoretical Literature

2.2.1 Asset Integrity Management Definitions

Assets for an oil and gas facility such as engineering structures, equipment, safety systems, and components play vital roles in fulfilling business objectives. BSI PAS 55-1 (2008), defined asset as "Plant, machinery, property, buildings, vehicles and other items that have a distinct value to the organization". These capital intensive and complex assets are exposed to and affected by a set of internal and external elements such as; fatigue, corrosion, extreme weather, modifications, geotechnical and geological hazards, accidental damage, lifetime extension of ageing installations (de Jong, 2008). Thus, assets require a constant focus on integrity at all stages of its assets life cycle for the performance and growth of the industry. CCPS-RBPS (2007), describes that the primary objective of the asset integrity element is to ensure reliable performance of equipment designed to contain, prevent, or mitigate the consequences of a release of hazardous materials or energy. Reviewing the literature and various regulatory organizations' guidelines lead to identification of few meaning of asset integrity, defined as follows:

Health, Safety and Environment, (HSE, 2007), defined "asset integrity as the ability of an asset to perform its required function effectively and efficiently whilst protecting health, safety and the environment." On the other hand CCPS- RBPS (2007), also defined asset integrity in the same way: "The asset integrity element is the systematic implementation of activities, such as inspections and tests necessary to ensure that important equipment will be suitable for its intended application throughout its life." OGP (2008), described that "asset integrity is related to the prevention of major incidents. It is an outcome of good design, construction and operating practices. It is achieved when

University of Education,Winneba http://ir.uew.edu.gh

facilities are structurally and mechanically sound and perform the process and produce the products for which they were designed."

The CCPS (2010), guideline for process safety metrics explained asset integrity as "work activities that help ensure that equipment is properly designed is installed in accordance with specifications, and remains fit for purpose over its life cycle."

Pirie (2007), outlined asset integrity as a "continuous process of knowledge and experience applied throughout the lifecycle to manage the risk of failures and events in design, construction, and during operation of facilities to ensure optimal production without compromising safety, health and environmental requirements."

No matter how the definition various, these definitions explicitly highlight the important role that asset integrity plays in ensuring a sustainable business performance by means of ensuring that the people, systems, processes and resources that deliver integrity are in place, in use, and will perform as required over the whole lifecycle of the asset. This characterization of asset integrity will ultimately highlight the need of asset performance measurement.

The complexity of integrating the concept of sustainable development and the reality of asset integrity management (AIM) practices has been argued. It is important for establishing and consummating an AIM system with practical application value as a whole over the integrity management system. Identifying and prioritizing asset performance through identified risk, detecting and assessing data, resulting in saved costs in the areas of design, operation, and technology application are addressed through sustainability lenses.

University of Education,Winneba http://ir.uew.edu.gh

The research study surfaced over a project initiated to develop governing documents for a major operator company for assessing asset integrity (AI), focusing particularly on design, operational, and technical integrity. The introduction of a conceptual framework for AIM knowledge along with coupled tools and methodologies is vital, as it relates to sustainable development regardless of whether the particular industry belongs to the public or private sector. The subsequent conceptual framework for sustainable asset performance reveals how sustainability aspects may be measured effectively as part of AIM practices. Emerging AIM practices that relate to sustainable development do emphasize design, technology, and operational integrity issues for splitting the problem into manageable segments and alternatively, measure organizational alignment for sustainable performance.

The model uses the analytic hierarchy process (AHP), a multi-criteria analysis technique that provides an appropriate tool to accommodate the conflicting views of various stakeholder groups. The AHP allows the users to assess the relative importance of multiple criteria (or multiple alternatives against a given criterion) in an intuitive manner. This holistic approach to managing AI provides improvement initiatives rather than a seemingly *ad hoc* decision making. The information in this chapter will benefit plant personnel interested in implementing an integrated AIM program or advancing their current AIM program to the next level.

University of Education,Winneba http://ir.uew.edu.gh

2.3 History of AIM System

The decade of the 1970s was a watershed year for International Environmentalism. Alternatively, the first US Earth day was held in 1970, the same year as the US Environmental Protection Agency (EPA) was created. The first United Nations (UN) conference on Human Environment was held in Stockholm in 1972, which led to the formation of the United Nations Environmental Program (UNEP). The UN then set up the World Commission on Environment and Development, also called the Brundtland commission, that defined sustainable development in their 1987 report, "Our common future" (Ratnayake and Liyanage, 2009) as "meets needs of the present generation without compromising the ability of the future generations to meet their own needs." Since then the influence of the concept has increased and it features increasingly as a core element in policy documents of governments and international agencies (Mebratu, 1998).

For an instance, in the same decade, governments reacted to the public concern about the environment by enacting a raft of legislation. For example, the US Congress enacted the seminal legislation for clean water, clean air, and the management of waste. The hard work of activists and writers such as Rachael Carson with her 1962 book, *Silent Spring* (Carson 1962), had started to pay off. The response by industry to the call for regulation and public concern was to design and implement management systems for health, safety, and environment (HSE) to assure management, shareholders, customers, communities, and governments that industrial operations were in compliance with the letter and the spirit of the new laws and regulations. Corporate environment was comprehensively incorporated into corporate policies and procedures during the late 1980s and early 1990s. These management systems grew during the 1990s, there was

University of Education,Winneba http://ir.uew.edu.gh

growing recognition of the interrelationship between economic prosperity, environmental quality, and social justice. The phrase "sustainable development" became the catchword in government and corporate circles to include these three pillars of human development.

A more recent definition of the concept of sustainability was presented by John Elkington in his book, *Cannibals with Forks*. Elkington describes triple bottom line ("TBL", "3BL", or "People, Planet, Profit") concept, which balances over an expanded spectrum of values and criteria for measuring organizational success through economic, environmental and societal conditions (Elkington, 1997; Ratnayake and Liyanage, 2007, 2008). For an example, the development of innovative technologies has played an important role in increasing the global competitive advantage of high-tech companies (Ma andWang, 2006). On the other hand "Who can resist the argument that all assets of business should contribute to preserving the quality of the societal and ecological environment for future generations"? The need to incorporate the concept of sustainable development into decision-making, combined with the World Bank's three-pillar approach to sustainable development, resulted in the popular business term "triple-bottom-line decision making" (World Bank, 2008).

The World Summit on Sustainable Development (WSSD) in 2002 highlighted the growing recognition of the concept by governments as well as businesses at a global level Labuschagne and Brent (2005), and demonstrated very clearly that it is not practical to consider environmental issues separate from socioeconomic issues such as health and safety, poverty, etc. The term "sustainable development" is therefore used in the sense of sustaining human existence, including the natural world, in the midst of constant change. It would be a mistake to use the term to mean no change or to assume that we can freeze

University of Education,Winneba http://ir.uew.edu.gh

the status quo of the natural world. However, the rate of change is an important consideration. Perhaps the challenge to the modern business world should be more properly named “management of change” instead of “sustainable development.”

2.4 Sustainability in Industrial Asset Performance

The term “sustainable development” in the context of asset integrity management (AIM) is not used to mean sustaining the exploiting of an asset indefinitely. Rather, it means meeting the needs of the global society for producing a product at a reasonable cost, safely, and with minimal impact on the environment. The traditional industrial model focused on labor productivity as the road block toward local and global industrial sustainability, while assuming nature would allow exploiting the resources available indefinitely. On the contrary, most industrial minds are reluctant to change their mindset to get the benefit of resources productivity. Consequently, many companies have not paid enough attention quantifying the link between sustainability actions, sustainability performance and financial gain, and on making the “business case” for corporate social responsibility.

Instead, they act in socially responsible ways because they believe it is “the right thing to do.” The identification and measurement of societal and environmental strategies is particularly difficult as they are usually linked to long-time horizons, a high level of uncertainty, and impacts that are often difficult to quantify. This clearly signifies as per the first EPA administrator William Ruckelshaus: “Sustainability is as foreign a concept to managers in capitalist societies as profits are to managers in the former Soviet Union.” (Hart and Milstein, 2003). That is, for some managers, sustainability is a moral mandate

University of Education,Winneba http://ir.uew.edu.gh

and for others, a legal requirement. Yet others view sustainability as a cost of doing business — a necessary evil to maintain legitimacy and right to operate. A few firms such as HP, Toyota, etc. have begun to frame sustainability as a business opportunity, offering avenues for lowering cost and risk, or even growing revenues and market share through innovation (Holliday, 2001).

The detection of enterprise sustainability remains difficult for most firms due to maturing assets, misalignments within the organization, no mechanism to recognize present alignment of sustainability concerns to realize gaps, etc., which in turn may be reconciled with the objective of increasing value for the firm itself, as well as its stakeholders. On these grounds, AIM was initially conceived to focus on industries related to hazardous type operations such as oil and gas, nuclear power, etc. For example, the offshore oil and gas industry on the UK Continental Shelf (UKCS) is a mature production area. Much of the offshore infrastructure is at, or has exceeded, its intended design life. This is due to an apparent general decline in the condition of the plant's installations, scheduled to run Key Program 3 (KP3) focusing on AI during the period of 2004–2007.

According to Lord Kelvin, "When you can measure what you are talking about and express it in numbers you know something about it, but when you cannot measure it, when you cannot express it in numbers, your knowledge is a meager and unsatisfactory kind: it may be the beginning of knowledge, but you have scarcely in your thoughts, advanced to the stage of science" (Ratnayake and Liyanage, 2009). For managing industrial assets, there must be a way to measure the assets' performance. The late Peter Drucker has influenced generations of managers with his admonition: "If you can't

University of Education,Winneba http://ir.uew.edu.gh

measure it, you can't manage it". That is, while it is necessary to manage an organization—be it a nuclear installation, an O&G plant, or a child welfare agency — the managers have to be able to measure what they are doing (Bhen, 2005) to manage as desired.

To achieve the so-called sustainability in a commercial organization, it has to design and then adopt their asset management structure, policies, and procedures to guide and regulate its internal practices. Asset upholding is seen as a cost center according to classical economic theories. Nevertheless, in some of leading companies like Toyota, HP, Shell, etc., managers have begun to realize the importance of intangibles and to reexamine industrial operations through value-added lens. Hence, asset upholding is now seen not only as a cost, but also as a process with significant potential to add value for long-time survival in a competitive business world. More recent publications that have brought this issue into open discussion include Liyanage (2003), Liyanage and Kumar (2003), Jawahir and Wanigaratne (2004), Liyanage (2007), and (Ratnayake and Liyanage, 2007). One of the critical elements of sustainability in the industrial world lies in understanding the role that industrial assets play in this process.

Because industrial assets often drive the way in which they consume resources, create waste, and structure society, their role is not insignificant. In fact, some neoclassical economists believe that many pessimistic views of resource scarcity are driven by a misunderstanding of the powerful substitutability between industrial assets (technology related) and natural resources (Stiglitz, 1979). It is recognized that right priorities are critical ingredients in the operationalizing sustainability concerns in the AIM recipe.

University of Education,Winneba http://ir.uew.edu.gh

2.5 What Is Asset Management (AM)

According to Xerox Corporation, "Asset management is the process of reusing an asset (machine, subassembly, piece part and packing material either by remanufacturing to its original state, converting to a different state or dismantling to retrieve the original components" (Esakul and Al-Adsani, 2006). The new British Standard, PAS 55, endorses the need for primary, performance accountable asset (or business) units, with secondary "horizontal" coordination and efficiency aids through asset-type specializations, common service providers, standards, etc. However, not many managers involved with AM can really claim to have such a structure in place yet. PAS provides a holistic definition for AM: "Systematic & coordinated activities and practices through which an organization optimally manages its physical assets and their associated performance, risks and expenditures over their lifecycles for the purpose of achieving its organizational strategic plan." Hence, AM can be considered as the optimum way of managing assets to achieve a desired and sustainable outcome" (PASS-55-1, 2004). Consequently, it can also be concluded that "AM is the art and science of making the right decisions and optimizing the related processes."

The management of "physical assets" (for instance, design, selection, maintenance, inspection, renewal, etc.) plays a key role in determining the operational performance and profitability of industries that operate assets as part of their core business. For AM to live to these key roles, it has to meet a number of challenges. Some of challenges are (Wenzler, 2005).

1. Alignment of strategy and operations with stakeholder values and objectives
2. Balancing of reliability, safety, and financial considerations

University of Education,Winneba http://ir.uew.edu.gh

3. Benefiting from performance-based rates

4. Living with the output-based penalty regime, etc.

2.6 Empirical Framework of the Study

2.6.1 Asset Integrity Elements

The asset integrity major elements are, Mechanical (technical) integrity, operational integrity and personnel integrity

The elements above show the relation between asset integrity and its major elements, as well as the interrelation between the elements. The way each of the elements performs has effect on the others. The range for mechanical integrity is defined by the operations and both of these elements depend on the personnel involved in dealing with them. This enforces the requirement of personnel integrity to define asset integrity comprehensively. Mechanical integrity is an important contributor to asset integrity, it ensures that equipment are designed, constructed, installed and maintained to minimise risk. The other two elements also have a potential influence on the integrity of an asset(Hassan, 2012).

These elements are discussed below;

2.6.2 Mechanical Integrity

Mechanical integrity is the ability of the asset to withstand the design load (i.e. design pressure/stress, design temperature, etc.). It is primarily concerned with the structural integrity, pressure containment and leak tightness, and focuses on pressurized equipment, piping systems and major structure (Laskar, 2013). According to Smallwood,

University of Education,Winneba http://ir.uew.edu.gh

(2004), to achieve optimum mechanical integrity for process fixed equipment, the following tasks must be used as applicable:

Effective management of plant's operation, engineering and maintenance to achieve mechanical integrity

Design mechanical integrity into a process plant during the design stage

Know and understand equipment's type/condition e.g. degradation or failure mechanism

Operate equipment within acceptable operating envelope

Use secondary containment or other methods to diminish the effects of loss of containment.

2.6.3 Operational Integrity

Operational integrity is the ability of the asset to perform its required functions effectively and safely. It is primarily concerns with the reliability of SCE such as Emergency Shutdown systems (ESD), critical process control systems, and hazard mitigation system (e.g. Fire/gas detection system, High Integrity Pressure Protection System (HIPPS), Safety valves etc.), Ciaraldi (2005). Operational Integrity is about making sure the operating basis are in place, understood, supported and adhere to.

2.6.4 Personnel Integrity

Personnel integrity is the ability of the asset personnel to operate the asset safely and effectively. It is primarily concerned with human factors issues such as operators training, competency management systems, reporting systems, anomaly management, etc (Adair, et al., 2008). The AIM program is intended to be applicable at all stages/phases of an asset life from design and construction to operation and decommissioning. It is a

University of Education,Winneba http://ir.uew.edu.gh

cradle-to-grave program that covers the full life cycle of an operational facility and is based on a continuous process of identification of potential hazards associated with such facility and the risk management and mitigation programs developed to control the hazard(Lawson, 2012).For a facility to perform its required function effectively and efficiently whilst protecting health, safety and the environment, the Mechanical, Operational and Personnel Integrity should be maintained throughout the life cycle of the operational facility.

Listed below are the selected AIM elements to ensure that the Mechanical, Operational and Personnel Integrity are maintained over the life cycle of the asset (Esakuland Al-Adsani, 2006).

2.6.5 Description of the Elements and the Intended Purposes

2.6.5.1 Management of Change

In AIM and major accident prevention, Management of Change (MOC) is one of the most important elements which are employed throughout the life cycle of the asset. It is simply about understanding changes and trying to control them. One of the major threats to MOC is that a change might not be recognized in the first place, and this can be followed by the failure to identify the impacts of the change and implement appropriate actions that allow transition to the change (Julaihi, 2010).

This is evident from a number of globally reported major incidents, where it was revealed that failure to manage change was the root cause or a significant contributor. For example, Failure to manage temporary change led to the loss of containment, explosion, fire and fatalities at the Nypro plant at flixborough in 1974 (Ritchie, 2011).

University of Education,Winneba http://ir.uew.edu.gh

In most cases, MOC is applied well to permanent visible physical changes to an asset. However, temporary or insidious changes are sometimes overlooked or not noticed. In addition, issues such as operations outside of acceptable operating envelops, chemical addition modifications, change in physical properties etc. are often missed. According to Ciaraldi (2005), understanding what constitute a change and how different types of change are governed is important for an asset operator to establish an effective MOC process. To further improve the effectiveness of MOC, an audit procedure which feeds back into process modifications and clarifications should be employed (Ciaraldi,2005).

2.6.5.2 Assessment and Continuous Improvements

Another important element in AIM is the assessment or evaluation of the changing condition of an asset and the continuous assurance and verification of its integrity. This can be achieved if performance measures are in place to monitor progress and determine if effective systems and procedures are in place (Esakluland Al-Adsani, 2006). The preservation of safety critical function of SCE to achieve the required level of asset integrity is achieved by a programme of planned inspection, testing and maintenance activities. This is supported by timely/focused repairs, replacements and restoration of asset condition so that the asset remains fit for its operational purposes. Without this, asset will deteriorate, leading to degradation of performance, ageing and unreliability of its SCE.

University of Education,Winneba http://ir.uew.edu.gh

2.7 Ownership and Accountability

If the accountability is not defined, the ownership of any task or initiatives is diluted and progress will not be recorded. As such, for any integrity management plan or initiative to succeed, the responsibility for identifying the loop holes in the integrity of the asset, the necessary actions required closing these identified gaps, monitoring of progress made in the corrective actions and maintaining of the desired level of performance must be defined (Esaklul et al, 2006).

2.8 Asset Register

Palmer (2011), explained that, data availability, accuracy and continued update are necessary for the implementation of AIM initiatives and measure of progress towards meeting the preset objectives. Without integrity management data, it will be difficult for asset management to monitor or to assert with any level of confidence that the plant or asset is in a safe condition or to complete meaningful predictive work that will ensure the long term reliability of the facilities. All supporting inspection, testing, investigative findings, modifications and maintenance database should be aligned with the asset register. Therefore, periodic reviews are required to ensure the asset register and supporting databases are maintained and always up to date (Daoud, Mohammed, Drahib and Badyab, 2012).

2.9 Risk Management and Hazard Evaluation

The core of AIM is risk and hazards evaluation. These involves the process of planning, identifying, estimating, evaluating, selecting and implementing actions to

University of Education,Winneba http://ir.uew.edu.gh

prevent, minimize, control or eliminate harm to personnel, environment and assets (Khalaf, Abu and Ela, 2008). This emphasizes the need for continuous process that establishes and progressively updates the understanding of the hazards and their management through the life cycle of each asset. The hazard analysis should produce a hazard register and SCE list (for prevention, control and mitigation of the hazards) that includes the level of criticality based on the likelihood and consequences of their failure in service (Esaklul et al, 2006).

2.10 Protective Systems

This are safety critical systems which contribute to preventing, detecting, controlling or mitigate a major accident and ensuring the survival of people and protection of assets. To ensure AIM, these systems should always be reliable, available and operational and their operational functions continually verified to ensure they meet the performance criteria. These systems include, Pressure Safety Valves (PSV), Gas detectors and fire alarms and Process Safety Devices (PSD) etc.

2.11 Facilities Design and Construction

This means ensuring integrity of the assets during design in order to operate within acceptable safety margins and to ensure optimized economy throughout operational life. This is achieved by adopting inherent safe design, developing a safe layout integrating ergonomics (human factor) requirements right from design stage, selection of an appropriate material for sustained operations and carrying out Reliability, Availability and Maintainability (RAM) studies (Baby, 2008).

University of Education,Winneba http://ir.uew.edu.gh

Laskar (2013), explained that, the mechanical integrity of the asset is assured by construction and fabrication to a suitable design using appropriate materials, good workmanship and quality assurance in accordance with;

- ✓ Recognized codes and standards
- ✓ Good industry practices
- ✓ Regulatory requirements

2.12 Operation and Maintenance

This element addresses the need to operate assets within the safe operating envelope and define the limits beyond which system integrity may be jeopardized. Mechanical integrity can be maintained by adhering to operating procedures and processes (Esaklul, 2006).

Asset integrity can be maintained when assets are;

Operated within the original design parameters or through parameters defined through a MOC process that evolves as the facility moves through different phases of its life cycle.

Inspected, maintained and repaired to a condition which is consistent with the original design or fitness for service criteria. Audited to provide assurance of conformance and identification of non-conformance for corrective action and this corrective action is assigned ownership and target date to ensure it is carried out.

Atherton (2008), explains that a successful AIM programme requires comprehensive knowledge of the asset, including its actual condition, all operations and activities conducted in the life of the asset. Rahim, Refsdal and Kenett (2010), also added that the core element in managing an asset or operations is based on a good

University of Education,Winneba http://ir.uew.edu.gh

Maintenance Management System (MMS). Proper asset maintenance requires proactively planned maintenance programmes and this can significantly reduce the overall operating cost and increase the efficiency and productivity of the asset.

2.13 Incident/Accident Investigation and Prevention

The thorough investigation and analysis of incidents and accidents (both actual events and near misses), along with the appropriate follow-up to prevent recurrence, provides one of the most effective means of improving the safety and reliability of an asset (Sutton, 2010).

Every unexpected asset failure or damage present an opportunity to learn about the integrity of the assets, determine the root cause of the failure, developing action plan to prevent recurrence, track the progress of these actions and communicate lessons learned throughout the asset (Esaklul, 2006).

2.14 Leadership

Leadership at all level of an organization is a necessary start to good AIM. The senior leadership has the key function of improving understanding, simplification, challenge and learning in major hazard control and ultimately in performance(Rahim et al, 2010).

When the leadership visibly and openly display passion for integrity management, this will pervade through the organization and promote the development of a similar zeal within the workforce (Ciaraldi, 2005).

University of Education,Winneba http://ir.uew.edu.gh

2.15 Competency/Skills Assurance

According to Esaklul (2006), one of the most overlooked requirements for integrity management is the assurance that all personnel are trained and competent for their job. It is a dangerous assumption to believe that an operator is competent to operate a unit because he/she has operated a similar unit in another plant. It should be noted that, competency is not about training, intelligence or education level, but it is about the specific skills required to properly do a particular job and the individual's level of expertise. Managing people's competence is a critical part of managing overall safety and integrity of an asset. Wherever people interface with complex work systems, skilled knowledge and skilled performance are vital to operational integrity (Sandra,2013).

A proper competency assurance program defines the skills required for each job and the minimum level of competency necessary to carry out the job. Additionally, there must be a means in place to continually assess the individual skills of a worker so that deficiencies may be identified and corrected with targeted training and testing (Oliver, 2002).

2.16 Emergency Management

Tveiten, Albrechtsen, Waero, Wahl (2012), defines emergency management "as the total activities (both administrative routines and informal processes) conducted in a more or less coordinated way to control emergencies before, during and after an event. This includes analysis, planning, training, handling, learning, anticipation and monitoring". This is the last line of defense in an AIM plan, the ability to reduce the effect or mitigate the consequences of an accident. It is essential that assets are reliable

University of Education,Winneba http://ir.uew.edu.gh

and available and can respond quickly to mitigate the effect of an undesired event by having robust emergency management plan. In addition to having the plans in place, they should be regularly reviewed to be able to adapt to changes in the identified hazards, be fully understood by all those likely to be impacted and regularly exercised and tested through drills (Jones, 2007)

2.17 Risk based approach

Risk based approach provides a detailed evaluation of failure modes and the assessment of their corresponding likelihood and consequences if the failure eventually occurs. Leading and lagging indicators are then developed to monitor the performance of the asset to prevent potential incidents (Sepeda, 2009). Two types of risk based approach are discussed below.

2.18 Risk Base Inspection (RBI)

Risk Based Inspection (RBI) methodologies are becoming standard industrial practice for the management and planning of in-service inspection activities. According to Horrocks and Adair (2010), these methodologies seek to define and manage the risk associated with individual equipment, such that items that constitute the highest risk receive the greatest attention from a planned inspection program. RBI provides detailed evaluations of the mode of failure, the barriers to prevent, control or mitigate these failures, and results in an inspection programme to effectively identify potential failure before they occur at reduced cost (Kapusta, 2008).

University of Education,Winneba http://ir.uew.edu.gh

2.19 Reliability Based Maintenance (RBM)

The oil and gas process plants and facilities require essential targeted continuous maintenance to ensure high levels of reliability and safety. A Risk Based Maintenance (RBM) strategy is a useful tool to plan and design a cost effective maintenance schedule (Wang, 2012). The unexpected failures, the down time associated with such failures, the loss of production and, the higher maintenance costs are major problems in any process plant. RBM approach helps in designing an alternative strategy to minimize the risk resulting from breakdowns or failures (Willcocks,2000).

The RBM methodology is comprised of four modules, Identification of the scope of maintenance, Risk assessment, Risk evaluation and Maintenance planning.

Krishnasamy, Khan and Haddara (2005), explained that, using this methodology, one is able to estimate risk caused by the unexpected failure as a function of its probability and consequence. Critical equipment can be identified based on the level of risk and a pre-selected acceptable level of risk. Maintenance of equipment is prioritized based on the risk, which helps in reducing the overall risk of an asset.

2.20 Safety Critical Element (SCE)

SCEs as defined earlier are those systems and components (including computer programmes, hardware, procedures etc.) designed for the purpose of preventing, controlling or to mitigate major accident hazards (MAHs) and the failure of which could cause or contribute substantially to a major accident. These include SIS, structures, fire and gas detection, and ESD, blow down, temporary refuge etc. According to HSE (2007), the term “contribute substantially to a major accident” is intended to include within the

University of Education,Winneba http://ir.uew.edu.gh

category of SCE those parts whose failure would not directly initiate a major accident but would make a significant contribution to the chain of events which would result in a major accident.

As assets age, it is very important to ensure that the SCEs are still capable of performing their intended functions efficiently and effectively whilst protecting health, safety and the environment. Marty, Theys, Bucherie, Bolsover and Cambos (2010), explained that in AIM, duty holders must ensure that the SCE lifecycle management should involve identification of the MAH, selection of the SCEs by identifying structures and plant which can cause, contribute to, prevent or mitigate a major accident event and develop Performance Standards (PS) for the identified SCEs.

This management plan should involve alignment of planned targeted maintenance, inspection and testing etc. required to ensure the SCE meet its required PS. Unnikrishnan (2006), added that managing deviations or changes and impacts on MOC is also a critical part of the lifecycle management of SCEs. The continual monitoring of the status of the hardware barriers and performance assurance task (using a feedback loop) enable management and operators to analyze the ongoing conformance of the SCEs with their PS. This provides opportunity for improvement and possibilities for further risk reduction.

2.21 Risk Based Inspections (RBI)

The scope of an inspection and frequencies has traditionally been time based and driven by statutory regulation or insurance requirements and industry practices. Major shutdowns were planned to take place at particular fixed intervals, and it was normal

University of Education,Winneba http://ir.uew.edu.gh

practice to open, clean and inspect all equipment irrespective of its condition or necessity. The inspections when completed were often unfocused and indiscriminate, resulting in large amounts of data which are in most cases irrelevant. These practices, although inflexible, have to an extent, provided adequate safety and reliability. They just have not been cost effective or efficient(Peterson and Jablouski, 2003).

The Risk Based Inspection (RBI) approach is an effective inspection planning tool supporting the engineers in their quest to focus the inspection and maintenance efforts into the high risk operating assets, while assigning an appropriate effort to the lower risk equipment. The end deliverable of RBI is a comprehensive inspection plan developed through a risk management process that aims at ensuring the integrity of an asset in the most cost effective manner(Dos Santos, 2000).

RBI is an integrated methodology that factors risk into inspection and maintenance decision making. It is a systematic and structured approach for developing inspection plans using risk management techniques that identify the probability/likelihood of failure and the consequences of such failure from the human, environmental, assets and reputational viewpoints(Reynolds, 2000). Overall, since a relatively large percentage of risk is associated with a small percentage of equipment, the RBI methods improve the management of risk through closely focusing on the critical areas of the asset, and reducing efforts on the non-critical areas i.e. inspection effort is proportional to the criticality of the operating asset(Al-Mithin, Sardesai, Alharbi, Murthy and Hannan, 2011).The RBI methodology provides a logical, documented and repeatable system for making informed decisions on inspection frequencies, details of inspection, inspection scope etc.

University of Education,Winneba http://ir.uew.edu.gh

2.21 RBI Process

According to Peterson et al (2003), The RBI process consists of Carrying out a Risk assessment on the asset, Using the results of the assessment to determine the inspection frequencies and scopes, Before performing a criticality risk assessment, three basic questions should be asked, this are, What can go wrong or what are the potential failures?, What are the probabilities or likelihood of the failure events occurring? And what are the possible consequences of these failures?

2.21.1 Risk Assessment Process

Risk assessments are fundamental tools in the safety community. They help make and implement decisions regarding safety, which in effect prevent accidents, improve safety performance, and reduce Operational Expenditure OPEX by systematically identifying and evaluating hazards concerning the design and potential failures (Hassenzahl and Finkel, 2008).

To conduct a risk assessment, the following process has been developed; identify the hazards, Frequency assessment, Consequence assessment, Risk evaluation and Action forward.

2.21.2 Hazard Identification

The first and most important step in any risk management program is to identify any possible hazards associated with your activities. Unless hazards are identified, consequence and likelihood reduction cannot be implemented. Hazards identification is

University of Education,Winneba http://ir.uew.edu.gh

the act of recognizing the failure conditions or threats, which could lead to undesirable events. The main item to determine the hazards is the amount of information which is known about the equipment or conversely the identification of where there is a lack of information. Even when information appears to be known, the risk based approach requires the quality and accuracy of the information be tested and validated. Risk increases when there is a lack of, or uncertainty in the information required to assess the equipment integrity (Peterson, and Jablonski, 2003).

Information about the asset can be gathered from the design specifications, fabrication records, operational experience, maintenance records, inspection records, the knowledge of material degradation methods and the rates at which material degradation will, or has occurred.

2.21.3 Frequency Assessment

This is the likelihood of the undesired event occurring and the rate at which these specified events would be expected to occur in a specified period of time.

2.21.4 Consequence Assessment

According to Bae and Lee (2012), this can involve the use of analytical models to predict the effects of different scenarios or consequence of a failure event. Information exists describing the effects of hazardous materials on humans, fire and blast effects on buildings and structures, dispersion and environmental effects, etc.

University of Education,Winneba http://ir.uew.edu.gh

2.21.5 Risk Evaluation

Risk evaluation is used to determine the significance of a risk to the organization and whether each specific risk should be accepted. The value indicating a risk and its associated implications are arguably subjective but are nonetheless important for assessing the risk status (Bae and Lee, 2012). For a given risk event (e.g. accidental hydrocarbon release), each of the release criteria is evaluated based on the likelihood and consequence. Likelihood is the probability of occurrence and Consequence is the severity of impact. In quantitative risk assessment, the risk is the product of the numerical consequence and the probability of occurrence(Clare and Armstrong, 2006).According to Clare et al. (2006), sequence and likelihood can each be assessed using various methods of varying complexity, ranging from qualitative to quantitative.

2.21.6 Action Forward

The underlying implicit assumption is that in a competent organization, findings from the RBI will be followed by proper actions that will actually reduce equipment risk and ensures the integrity of the asset (Peterson and Jablonski, 2003). The action plan may include one or a combination of the following activities (Peterson et al, 2003). Follow up inspection, Asset monitoring, Asset replacement, Operational procedure changes, Use of upgraded materials and Instrumentation upgrade

2.22 Major Accident Hazards (MAH)

Major Accident can be thought of as an occurrence such as major emissions, spill, fire or explosion resulting from uncontrolled developments in the course of operations

University of Education,Winneba http://ir.uew.edu.gh

and can lead to multiple fatalities or serious danger to the environment. MAH are hazard that has the potential of resulting to a major accident e.g. hydrocarbon releases (Peball and Dragan, 2011). Craddock (2004), explains that, major accident occurs because of failure to identify or recognize MAH and take adequate steps to manage the associated risks. Major accidents are low frequency very high consequence events requiring careful management. This needs to be supported by a safety culture that has all levels of an asset organization engaged in the common goal of major accident prevention. This starts with committed leadership. Leadership that is complacent about low frequency high consequence events will be leading an organization that is closer to triggering a major incident than a leadership that is mindful about such events.

It is important to recognize that for this class of failures, the primary risk control measures are built into the system at the planning selection, design, construction, and installation phases (i.e. ensuring the integrity of the asset in all phases). Major incidents are not driven by operational considerations i.e. they do not necessarily require operational failures to be realize, and may occur even if a system is operated within its design envelop (Smith and Zijlker, 2005).

Picture 1. A fire outbreak

University of Education,Winneba http://ir.uew.edu.gh

2.23 Performance Standard (PS)

PS are statements which can be expressed in quantitative or qualitative terms, of the performance required of a system, item or equipment, person or procedure, and which is used as the basis of managing the hazard e.g. planning, measuring, control or audit through the life cycle of the asset (SCE). Or, they are documents describing the criteria for the assessment of the asset (SCE) for compliance with minimum requirement to asset operations and characterizing its performance criteria (Derevyakin, 2010).

Marty et al (2010), explains that, The PS standard defines the following criteria for each of the SCE;

- ✓ Functionality of the SCE i.e. response time of the SCE
- ✓ Availability of the SCE i.e. the handiness of the SCE
- ✓ Reliability i.e. the ability of the system to perform its required functions when it's needed.
- ✓ Survivability i.e. the ability of the element to deliver its function if exposed to an undesired event e.g. fire, blast, vibrations, etc.
- ✓ Interdependency i.e. other systems necessary for the function of the SCE to perform adequately e.g. emergency power supply for SIS (Marty et al, 2010).

2.23 Integrity Assurance

These are assurance activities performed to confirm that the asset meets the required PS during design and throughout the operational lifetime of the asset. At the

University of Education,Winneba http://ir.uew.edu.gh

design stage, such assurance is undertaken through the use of appropriate design codes and standards, best practice, risk based approach, design review etc. by suitable qualified, experience and competent persons (Marty et al, 2010). Assurance activities during operational stage include inspection, test and maintenance.

The activities mentioned above are required in other to enable;

2.24 Verification

`Verification tasks are carried out in order to verify that the previously defined PS for the SCE is achieved. According to Dhar (2011), this is system of independent and competent scrutiny of the suitability of SCE throughout its life cycle. The process of identifying SCEs, producing PS and performing Assurance is monitored and verified by an Independent Competent Person (ICP). Verification is a sampling process and includes document review, checks using calculation, physical examination, testing or witnessing of tests, audit, and confirmation of records during the operational life of the asset.

2.25 Guideline for Asset Integrity Management

Several regulatory organizations such as Oil & Gas Producers (OGP) and Health & Safety Executive (HSE), UK, have provided guidelines on maintaining asset integrity. These guidelines are mostly concerned with the ageing installations in offshore facilities that focus on the asset integrity management strategy to decrease major incident risks.

University of Education,Winneba http://ir.uew.edu.gh

2.26 OGP Guideline on Asset Integrity

International Association of Oil & Gas Producers (OGP) provided a guideline to facilitate the organizations in reducing major incident risk by focusing on asset integrity management. For the purpose of collecting information and evaluating the risks of major incidents, OGP (2008), points out the need for a common key performance indicator (KPI) which can be used as a direct measure of major incident risk within the oil and gas exploration and production (E&P) industry. OGP has adopted different approaches towards identifying major incident KPIs.

Several examples of KPIs based on HSE -UK, guideline, which are of leading and lagging category were used to monitor and review the asset integrity performance. These indicators mostly cover the operation, maintenance, and staff performance. At the same time, OGP has given a guideline on how to use these KPIs to evaluate the asset integrity performance against the stated goal. This guideline basically summarizes the ways to control major incident risk throughout the operation period of E&P activity.

2.27 Health, Safety and Environment (UK) on Asset Integrity

In 2004 the Offshore Division of the HSE, UK, started Key Program 3 (KP3)-AssetIntegrity (HSE, 2007). The objective was to ensure that offshore duty-holders adequately maintained safety-critical elements (SCEs) of their installations. SCEs classified system are parts of an installation, the purpose of which is to prevent, control or mitigate major accident hazards, and the failure of which could cause or contribute substantially to a major accident. HSE have deliberated "Asset Integrity" as the third

University of Education,Winneba http://ir.uew.edu.gh

pillar in the Step Change in Safety temple model strategy together with recognizing hazard and reducing risk, and personal ownership for safety.

The group responsible in developing an Asset Integrity toolkit covering comprehensive guidance with reference to good industry practice documents for effective safety critical plant and equipment maintenance management. HSE have developed three potential key performance indicators, which are: KPI1, loss of containment i.e. reportable hydrocarbon releases; KPI2, verification of significant compliance issues; and KPI3, production losses associated with deficiency in maintaining safety.Finally, after having a detailed study and observation, the KPI3 were replaced with safety-critical maintenance backlog for monitoring the cross industry asset integrity.

University of Education,Winneba http://ir.uew.edu.gh

CHAPTER THREE

RESEARCH METHODOLOGY

This chapter covers the research methods that were adopted by the researcher in arriving at the findings. It describes the research design, the population, sampling and sample procedures, data gathering instruments and data collection measures.

3.1 Research design

A research design provides a framework for the collection and analysis of data. A choice of research design reflects decisions about the priority been given to set of dimensions of the research process. The researcher used descriptive research design for the study. This refers to a research which specifies the nature of a given phenomena. It determines and reports the way things are done. Descriptive research thus involves collecting data in order to test hypotheses or answer research questions concerning the current status of the subject of the study (Burns and Grove, 2003).

The researcher used questionnaire surveys and interviews to collect primary data, which promote direct relationship between the researcher and the respondents. Secondary research is a means to reprocess and reuse collected information as an indication for betterments of the research. Both primary and secondary data are useful for the research but both may differ from each other in various aspects. In secondary data, information relates to a past period. Hence, it lacks aptness and therefore, it has unsatisfactory value. Primary data is more accommodating as it shows latest information. Primary data is accumulated by the researcher particularly to meet up the research objective of the project (Burns and Grove, 2003).

University of Education,Winneba http://ir.uew.edu.gh

However, the type of research design employed by the researcher was questionnaire, interview and observations. These types of research were used because it eventually enables the researcher to make judgement about the effectiveness, relevance or desirability of the programme. Research methods can be placed into two basic categories: quantitative or qualitative. Qualitative research gathers information that is not in numerical form. For example, diary accounts, open-ended questionnaires, unstructured interviews and unstructured observations. Qualitative data is typically descriptive data and as such is harder to analyze than quantitative data. Qualitative research is useful for studies at the individual level, and to find out, in depth, the ways in which people think or feel (Burns and Grove, 2003).

Analysis of qualitative data is difficult and requires accurate description of participant responses, for example, sorting responses to open questions and interviews into broad themes. Quotations from interviews might be used to illustrate points of analysis. Expert knowledge of an area is necessary to try to interpret qualitative data and great care must be taken when doing so. However, quantitative research gathers data in numerical form which can be put into categories, or in rank order, or measured in units of measurement.

This type of data can be used to construct graphs and tables of raw data. Experiments typically yield quantitative data, as they are concerned with measuring things. However, other research methods, such as observations and questionnaire can produce both quantitative and qualitative information. For example, a rating scale or closed questions on a questionnaire would generate quantitative data as these produce either numerical data or data that can be put into categories (e.g. “yes”, “no” answers).

University of Education,Winneba http://ir.uew.edu.gh

Whereas open-ended questions would generate qualitative information as they are a descriptive response.

A good example of a qualitative research method would be the case study. Experimental methods limit the possible ways in which a research participant can react to and express appropriate social behavior. Findings are therefore likely to be context-bound and simply a reflection of the assumptions which the researcher brings to the investigation. The researcher used both qualitative and quantitative methods to analyze the research.

3.2 Population, sample size and sampling method

The targeted populations for the study arepersonnel of Ghana Gas Company, Ghana National Petroleum Company and the Ministry of Energy and their supervisors in industry. The targeted population for the study was seven hundred (700). From a review of literature, a survey questionnaire was developed to collect data for the study. Data was collected through use of a written questionnaire hand-delivered to participants. 151 respondents from the Ghana Gas company at Atuabo were randomly selected. The researcher chose the random selection method because of its fairness in terms of not being biased to other department.

3.3 Research instrument

Data were collected using a structured written questionnaire, interviews were conducted and personal observation were also used. The instruments were critically analyzed by the researcher and a pilot study was undertaking to make the instruments valid and reliable.

University of Education,Winneba http://ir.uew.edu.gh

3.4 Questionnaire

The Questionnaire used for the study included alternative questions where the respondent had to choose only from the alternative levels using the Likert scale ranging from 1 for strongly disagree to 5 for strongly agree. The questionnaire was made up of questions related toan investigation into the asset integrity management system of Ghana's oil industry. Supervisor's general opinion was gathered. Questionnaires were distributed to Supervisors and engineers. Closed and open ended questionnaire items were designed to collect primary data; this is because it has proven to be consistent and popular method of data collection. Questionnaires were designed for supervisors and personnel of the Ghana gas company at Atuabo. The questionnaire for supervisors covered items which helped me to get information on how their employees (operators) are practically managing assets at the workplace. The researcher approached the respondents in their workplace, interacted with them and observed their activities. The questionnaires were hand delivered to the respondents in their various workplaces for them to fill them in their leisure time. And the researcher had to pick them after 2 weeks. However, all of the respondents were able to fill the questionnaire. The respondents formed a sample size of One Hundred and fifty one (151) engineers in Ghana gas company Atuabo. This was made up of 50 supervisors and 101 practicing engineers and operators. Out of 151 questionnaires sent out for primary data, 151 questionnaires were retrieved. Therefore, the analysis of the data was made up of 100% response rate.

University of Education,Winneba http://ir.uew.edu.gh

3.5 Data analysis

The data collected was first edited to check contradictions and ensure consistency. The edited responses were recorded and analyzed statistically. The main statistical technique employed was percentages; tables were used to explain certain findings. Percentages of the Respondents – Supervisors and engineers or operators and their respective views on some important issues on the questionnaire would be found. This was used to discuss the collected data.

The research instruments and the methodology used for this research were very successful. Finally, the cooperation of Supervisors and engineers or operators encouraged the researcher to undertake this research project successfully.

University of Education,Winneba http://ir.uew.edu.gh

CHAPTER FOUR

ANALYSIS OF DATA

This chapter presented the analysis of data according to the research objectives of the study includingto review various asset integrity management techniques, to study the practical implementation of framework for offshore floating facilities, to understand the current implementation of the AIM techniques, to map the current status and to elaborate on the future innovation trends of AIM products and services.

4.1 **Asset Integrity Management Technique**

Table 4.1: Demographic Information of Respondents

Biographic Information	Frequency	Percentages
Age		
36-40 years	60	39.7
31-35 years	45	29.8
41-50 years	31	20.5
26-30 years	15	9.9
Total	151	100
Educational level		
Bachelors degree	101	66.9
Masters degree	40	26.5
Diploma	10	6.6
Total	151	100

University of Education,Winneba http://ir.uew.edu.gh

According to Table 4.1, majority 39.7% of the respondents were between the ages 36-40 years, 29.8% were between the ages 31-35 years, 20.5% of the respondents were between the ages 41-50 year and minority 9.9% were between the ages 26-30 years. Majority 66.9% of the respondents were Bachelor's degree holders, 26.5% were Master's degree holders and 6.6% of the respondents were Diploma holders.

According to Figure 4.1, majority 83.4% of the respondents agreed that the AIMS addresses corrosion management inspection and repair, safety of critical elements, instrumented protective functions, planned maintenance inspection and repair equipments,7.3% of the respondents remained neutral and 4.6% disagreed. These are assurance activities performed to confirm that the asset meets the required Performance Standards during design and throughout the operational lifetime of the asset. At the design stage, such assurance is undertaken through the use of appropriate design codes and standards, best practice, risk based approach, design review etc. by suitable qualified, experience and competent persons (Marty et al, 2010). Assurance activities during operational stage include inspection, test and maintenance.

University of Education,Winneba http://ir.uew.edu.gh

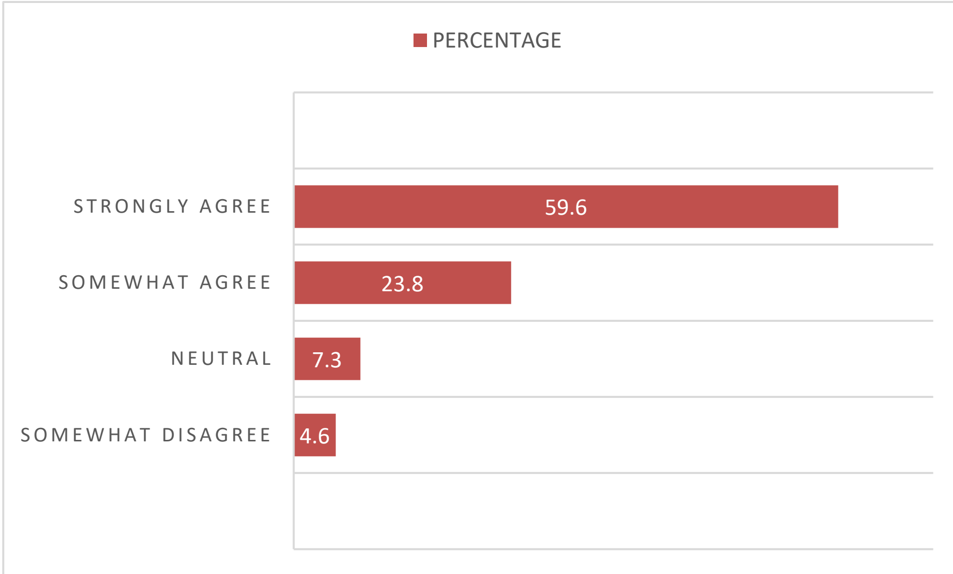

Figure 4.1 the AIMS addresses corrosion management inspection and repair, safety of critical elements, instrumented protective functions, planned maintenance inspection and repair equipment's.

Figure 4.2 indicates that, 93.4% of the respondents strongly agreed that the AIMS delegates duties, responsibilities, authorities and accountabilities with respect to its development and implementation, and 6.6% remained neutral. It is important to recognize that,for this class of failures, the primary risk control measures are built into the system at the planning selection, design, construction, and installation phases (i.e. ensuring the integrity of the asset in all phases). Major incidents are not driven by operational considerations i.e. they do not necessarily require operational failures to be realise, and may occur even if a system is operated within its design envelop (Smith and Zijlker, 2005).

University of Education,Winneba http://ir.uew.edu.gh

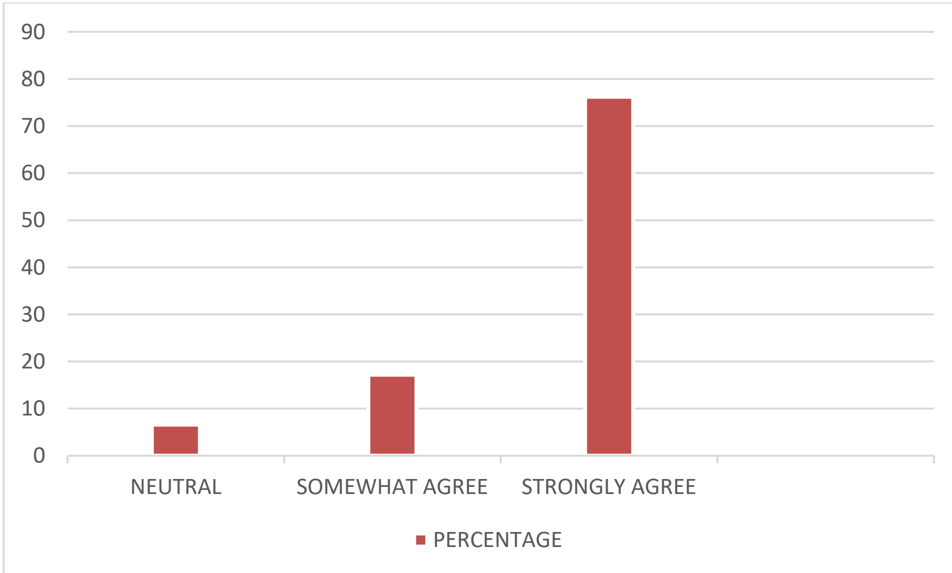

Figure 4.2: The AIMS delegates duties, responsibilities, authorities and accountabilities with respect to its development and implementation.

Figure 4.3 shows that majority 90.1% of the respondents strongly agreed that the AIMS demonstrates that any future development or activities can be addressed and 9.9% remained neutral. `Verification tasks are carried out in order to verify that the previously defined Performance Standard for the Safety Critical Element is achieved. According to Dhar, (2011), this is system of independent and competent scrutiny of the suitability of SCE throughout its life cycle. The process of identifying Safety Critical Elements, producing Performance Standard and performing Assurance is monitored and verified by an Independent Competent Person (ICP). Verification is a sampling process and includes document review, checks using calculation, physical examination, testing or witnessing of tests, audit, and confirmation of records during the operational life of the asset.

University of Education,Winneba http://ir.uew.edu.gh

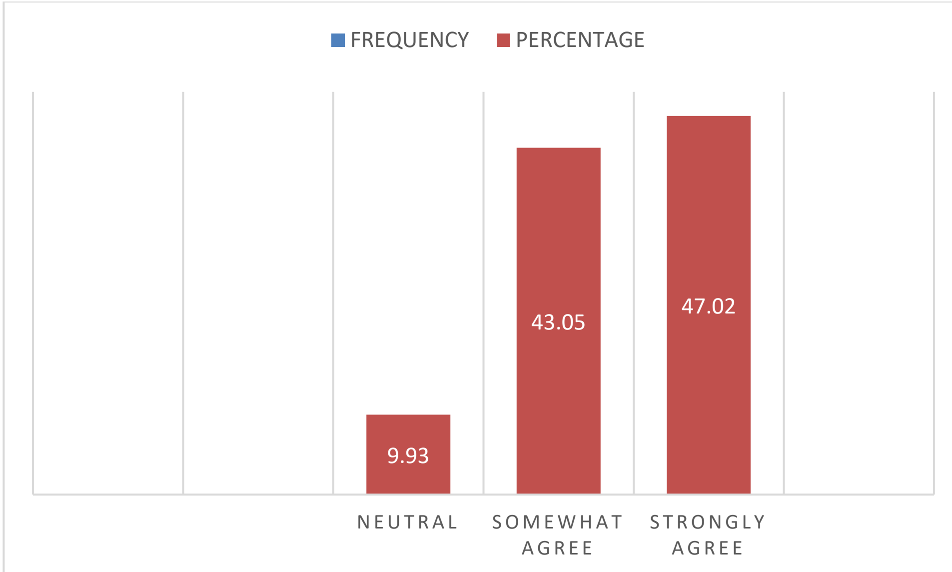

Figure 4.3: The AIMS demonstrates that any future development or activities can be addressed

Figure 4.4 indicates that majority 84.1% of the respondents disagreed that all relevant personnel have access to relevant AIMS documentation and records and minority 15.8% remained neutral. The Risk Based Inspection (RBI) approach is an effective inspection planning tool supporting the engineers in their quest to focus the inspection and maintenance efforts into the high risk operating assets, while assigning an appropriate effort to the lower risk equipment. The end deliverable of Risk Based Inspection (RBI) is a comprehensive inspection plan developed through a risk management process that aims at ensuring the integrity of an asset in the most cost effective manner (Dos Santos, 2000).

Risk Based Inspection (RBI) is an integrated methodology that factors risk into inspection and maintenance decision making. It is a systematic and structured approach for developing inspection plans using risk management techniques that identify the probability/likelihood of failure and the consequences of such failure from the human,

University of Education,Winneba http://ir.uew.edu.gh

environmental, assets and reputational viewpoints (Reynolds, 2000). Overall, since a relatively large percentage of risk is associated with a small percentage of equipment, the RBI methods improve the management of risk through closely focusing on the critical areas of the asset, and reducing efforts on the non-critical areas i.e. inspection effort is proportional to the criticality of the operating asset (Al-Mithin et al., 2011). The RBI methodology provides a logical, documented and repeatable system for making informed decisions on inspection frequencies, details of inspection, inspection scope etc.

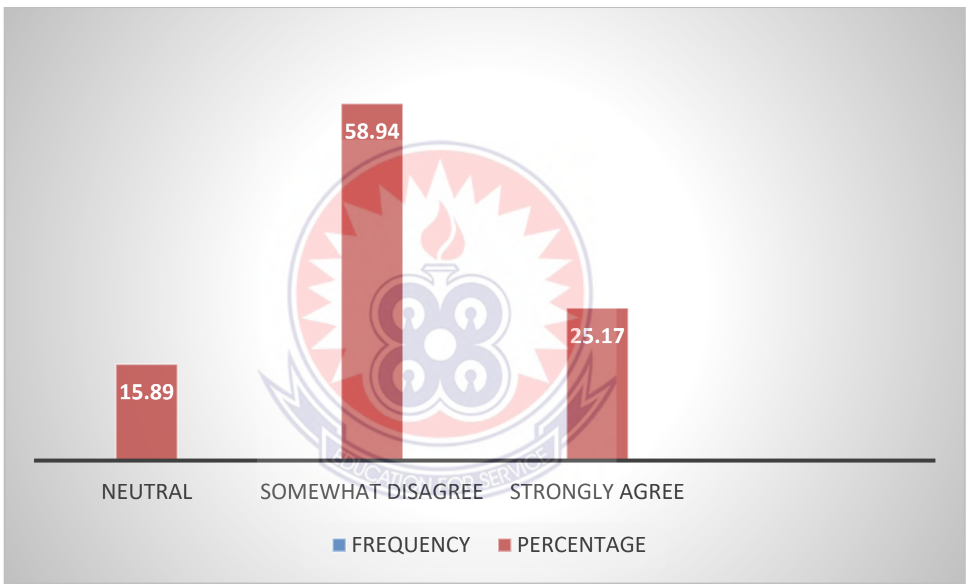

Figure 4.4: All relevant personnel have access to relevant AIMS documentation and records

4.2 Key Performance Indicators

According to Figure 4.5, majority (86.09%) of the respondents strongly agreed that the AIMS incorporates or links to a quality management system as a mechanism for assisting in meeting the AIMS performance standards or key indicators while minority (13.9%) remained neutral. The first and most important step in any risk management

University of Education,Winneba http://ir.uew.edu.gh

program is to identify any possible hazards associated with your activities. Unless hazards are identified, consequence and likelihood reduction cannot be implemented. Hazards identification is the act of recognizing the failure conditions or threats, which could lead to undesirable events. The main item to determine the hazards is the amount of information which is known about the equipment or conversely the identification of where there is a lack of information. Even when information appears to be known, the risk based approach requires the quality and accuracy of the information be tested and validated. Risk increases when there is a lack of, or uncertainty in the information required to assess the equipment integrity (Peterson, and Jablonski, 2003).Information about the asset can be gathered from the design specifications, fabrication records, operational experience, maintenance records, inspection records, the knowledge of material degradation methods and the rates at which material degradation will, or has occurred.

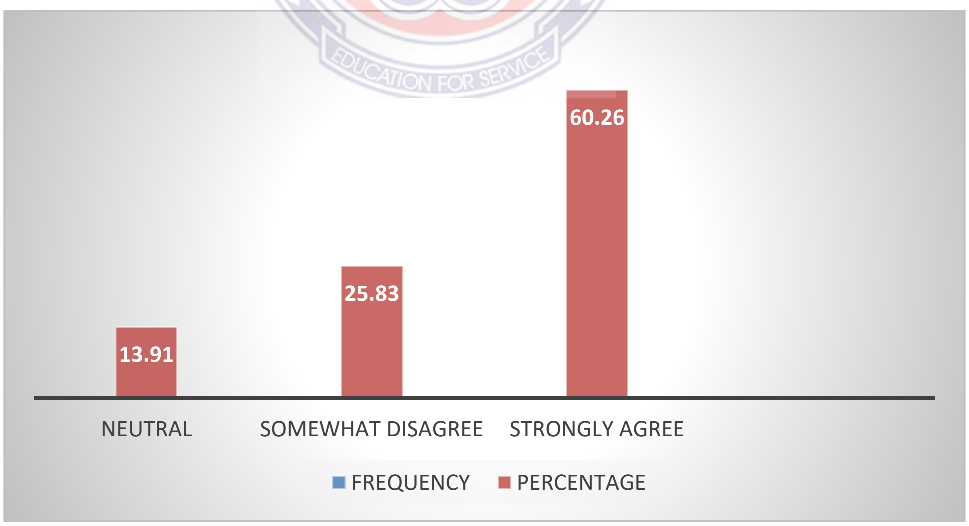

Figure 4.5: The AIMS incorporates or links to a quality management system as a mechanism for assisting in meeting the AIMS performance standards or key indicators

University of Education,Winneba http://ir.uew.edu.gh

Figure 4.6 shows that, majority 53% of the respondents strongly disagreed that Key Performance Indicators (KPIs) are regularly reviewed by supervisors and managers, 21.9% of the respondents somewhat agreed, 12.6% remained neutral and minority 7.9% somewhat disagreed that KPIs are regularly reviewed by supervisors and managers. The group responsible in developing an Asset Integrity toolkit covering comprehensive guidance with reference to good industry practice documents for effective safety critical plant and equipment maintenance management. Health, Safety and Environment (HSE), have developed three potential key performance indicators, which are: Key Performance Indicators (KPI) 1, loss of containment i.e. reportable hydrocarbon releases; Key Performance IndicatorsKPI2, verification of significant compliance issues; and Key Performance IndicatorsKPI3, production losses associated with deficiency in maintaining safety. Finally, after having a detailed study and observation, the KPI3 were replaced with safety-critical maintenance backlog for monitoring the cross industry asset integrity.

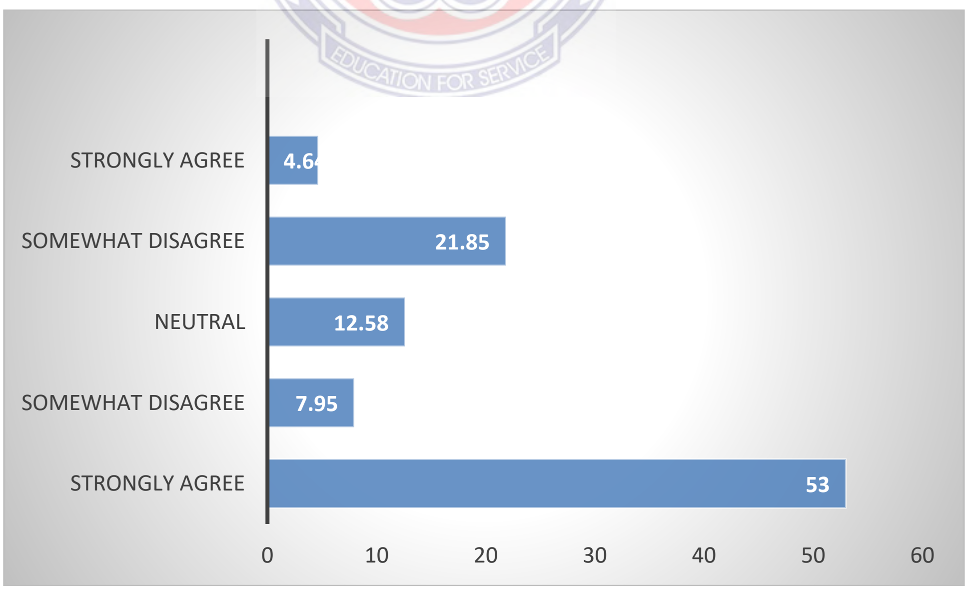

Figure 4.6: KPIs are regularly reviewed by supervisors and managers

University of Education,Winneba http://ir.uew.edu.gh

4.3 Asset Integrity Management Accountability

According to Figure 4.7, majority (74.8%) of the respondents agreed that,mechanisms are in place to ensure the accountability of senior management for the achievement of asset integrity management, 19.2% of the respondents strongly agreed and 6% remained neutral. It is important to recognize that for this class of failures, the primary risk control measures are built into the system at the planning selection, design, construction, and installation phases (i.e. ensuring the integrity of the asset in all phases). Major incidents are not driven by operational considerations i.e. they do not necessarily require operational failures to be realize, and may occur even if a system is operated within its design envelop (Smith and Zijlker, 2005).

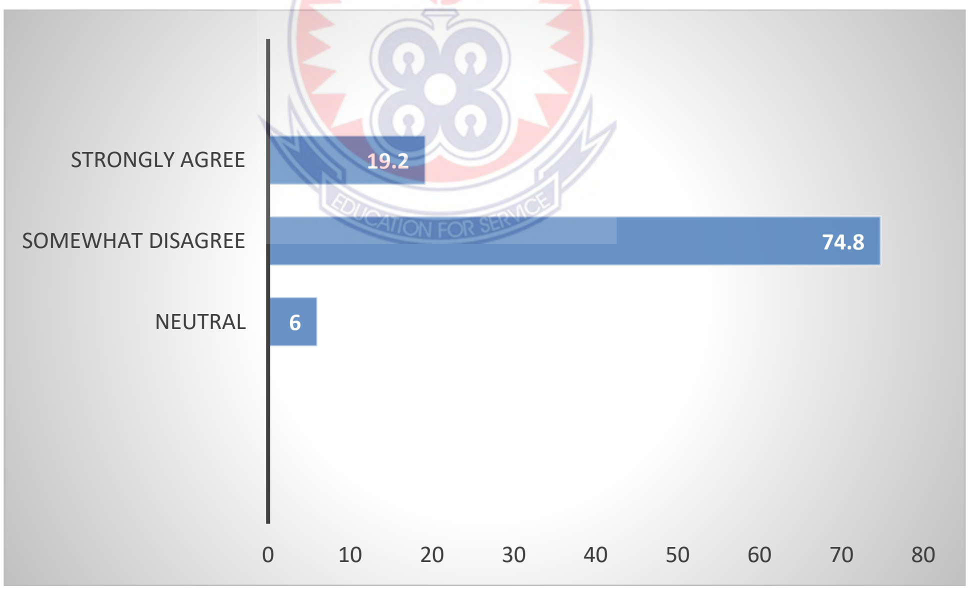

Figure 4.7: Mechanisms are in place to ensure the accountability of senior management for the achievement of asset integrity management

University of Education,Winneba http://ir.uew.edu.gh

According to Figure 4.8, majority 89.41% of the respondents agreed that Integrity assessment procedures and guidelines are in place, such as pipeline integrity management system, structural integrity management system, technical change management system, maintenance management manual etc, while minority 10.6% remained neutral. These are assurance activities performed to confirm that the asset meets the required Personal Standard during design and throughout the operational lifetime of the asset. At the design stage, such assurance is undertaken through the use of appropriate design codes and standards, best practice, risk based approach, design review etc. by suitable qualified, experience and competent persons (Marty et al, 2010). Assurance activities during operational stage include inspection, test and maintenance.

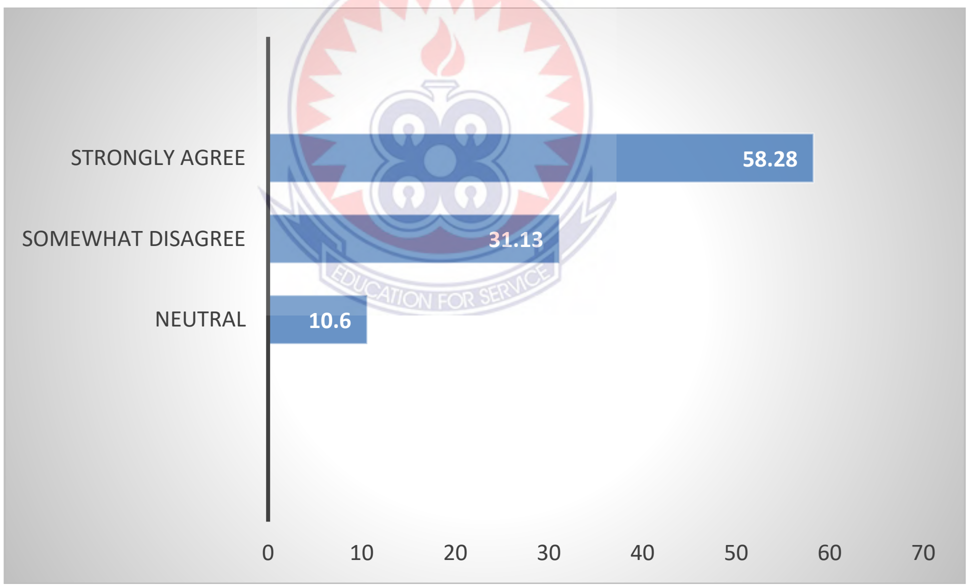

Figure 4.8: Integrity assessment procedures and guidelines are in place, such as pipeline integrity management system, structural integrity management system, technical change management system, maintenance management manual etc

University of Education,Winneba http://ir.uew.edu.gh

Figure 4.9 indicates that majority (75.5%) of the respondents somewhat agreed that the AIMS responsibilities and accountabilities of all personnel align with their skills and training, 15.2% of the respondents remained neutral and minority 9.3% somewhat disagreed that the AIMS responsibilities and accountabilities of all personnel align with their skills and training. `Verification tasks are carried out in order to verify that the previously defined PS for the SCE is achieved. According to Dhar (2011), this is system of independent and competent scrutiny of the suitability of SCE throughout its life cycle. The process of identifying SCEs, producing PS and performing Assurance is monitored and verified by an Independent Competent Person (ICP). Verification is a sampling process and includes document review, checks using calculation, physical examination, testing or witnessing of tests, audit, and confirmation of records during the operational life of the asset.

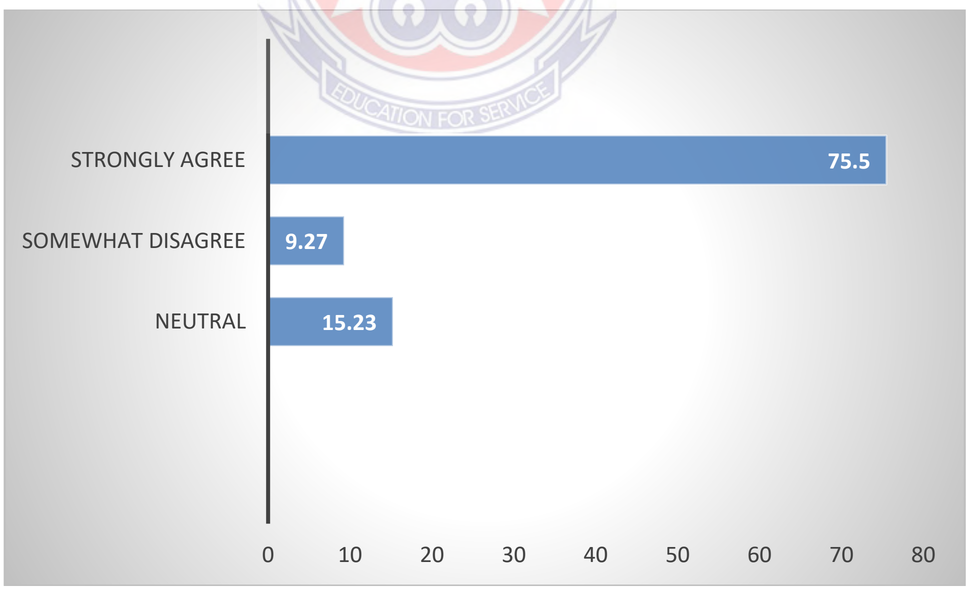

Figure 4.9: The AIMS responsibilities and accountabilities of all personnel align with their skills and training

University of Education,Winneba http://ir.uew.edu.gh

4.4 Employee Involvement and Communication

Figure 4.10 shows that majority (84.1%) of the respondents strongly agreed that Frontline maintenance technicians are consulted when risk, problem solving and devising maintenance work schedules and procedures, 10.6% of the respondents remained neutral and minority 5.3% somewhat agreed that Frontline maintenance technicians are consulted when risk, problem solving and devising maintenance work schedules and procedures. The first and most important step in any risk management program is to identify any possible hazards associated with your activities. Unless hazards are identified, consequence and likelihood reduction cannot be implemented. Hazards identification is the act of recognizing the failure conditions or threats, which could lead to undesirable events. The main item to determine the hazards is the amount of information which is known about the equipment or conversely the identification of where there is a lack of information. Even when information appears to be known, the risk based approach requires the quality and accuracy of the information be tested and validated. Risk increases when there is a lack of, or uncertainty in the information required to assess the equipment integrity (Peterson, and Jablonski, 2003).

Information about the asset can be gathered from the design specifications, fabrication records, operational experience, maintenance records, inspection records, the knowledge of material degradation methods and the rates at which material degradation will, or has occurred.

University of Education,Winneba http://ir.uew.edu.gh

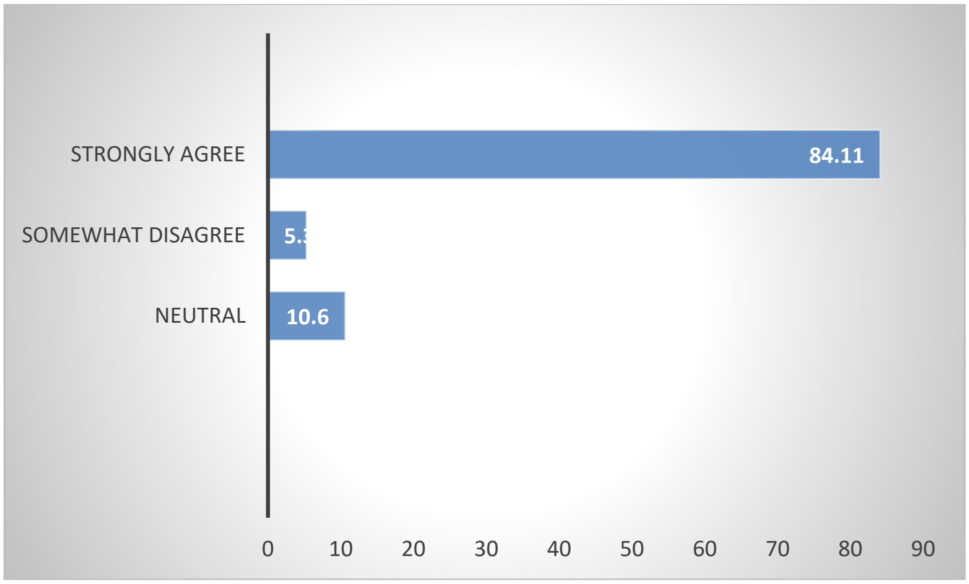

Figure 4.10: Frontline maintenance technicians are consulted when risk, problem solving and devising maintenance work schedules and procedures

4.5 Objectives, Plans and Performance Standards

Figure 4.11 reveals that majority (90.7%) of the respondents agreed that plans are updated to reflect changes in performance standards, or outcomes of appraisals of the AIMS effectiveness while 4.6% somewhat disagreed and remained neutral respectively. PS are statements which can be expressed in quantitative or qualitative terms, of the performance required of a system, item or equipment, person or procedure, and which is used as the basis of managing the hazard e.g. planning, measuring, control or audit through the life cycle of the asset (SCE). Or, they are documents describing the criteria for the assessment of the asset (SCE) for compliance with minimum requirement to asset operations and characterizing its performance criteria (Derevyakin, 2010).

Marty et al (2010), explains that, The PS standard defines the following criteria for each of the SCE;

University of Education,Winneba http://ir.uew.edu.gh

- ✓ Functionality of the SCE i.e. response time of the SCE
- ✓ Availability of the SCE i.e. the handiness of the SCE
- ✓ Reliability i.e. the ability of the system to perform its required functions when it's needed.
- ✓ Survivability i.e. the ability of the element to deliver its function if exposed to an undesired event e.g. fire, blast, vibrations, etc.
- ✓ Interdependency i.e. other systems necessary for the function of the SCE to perform adequately e.g. emergency power supply for SIS (Marty et al, 2010).

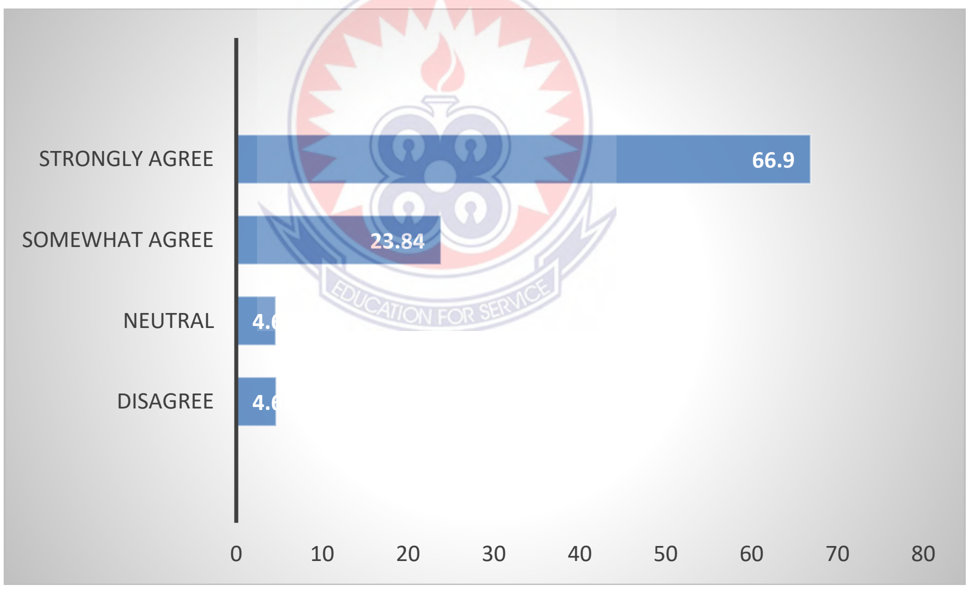

Figure 4.10: Plans are updated to reflect changes in performance standards, or outcomes of appraisals of the AIMS effectiveness

University of Education,Winneba http://ir.uew.edu.gh

4.1.6 Safe Operating Procedures

According to Figure 4.11, majority 66.9% of the respondents somewhat agreed that there are procedures or documentation describing how deferrals are authorized and justified, 16.6% of the respondents remained neutral, 11.3% strongly agreed and minority 5.3% somewhat disagreed that there are procedures or documentation describing how deferrals are authorized and justified.' Verification tasks are carried out in order to verify that the previously defined PS for the SCE is achieved. According to Dhar, (2011), this is system of independent and competent scrutiny of the suitability of SCE throughout its life cycle. The process of identifying SCEs, producing PS and performing Assurance is monitored and verified by an Independent Competent Person (ICP). Verification is a sampling process and includes document review, checks using calculation, physical examination, testing or witnessing of tests, audit, and confirmation of records during the operational life of the asset.

Figure 4.12 shows that majority 99.3% of the respondents strongly agreed that a process is in place to ensure that safety critical elements are identified and maintenance scheduled accordingly whiles 0.7% remained neutral. Risk evaluation is used to determine the significance of a risk to the organization and whether each specific risk should be accepted. The value indicating a risk and its associated implications are arguably subjective but are nonetheless important for assessing the risk status (Bae and Lee, 2012). For a given risk event (e.g. accidental hydrocarbon release), each of the release criteria is evaluated based on the likelihood and consequence. Likelihood is the probability of occurrence and Consequence is the severity of impact. In quantitative risk assessment, the risk is the product of the numerical consequence and the probability of occurrence (Clare

University of Education,Winneba http://ir.uew.edu.gh

and Armstrong, 2006). According to Clare et al. (2006) sequence and likelihood can each be assessed using various methods of varying complexity, ranging from qualitative to quantitative.

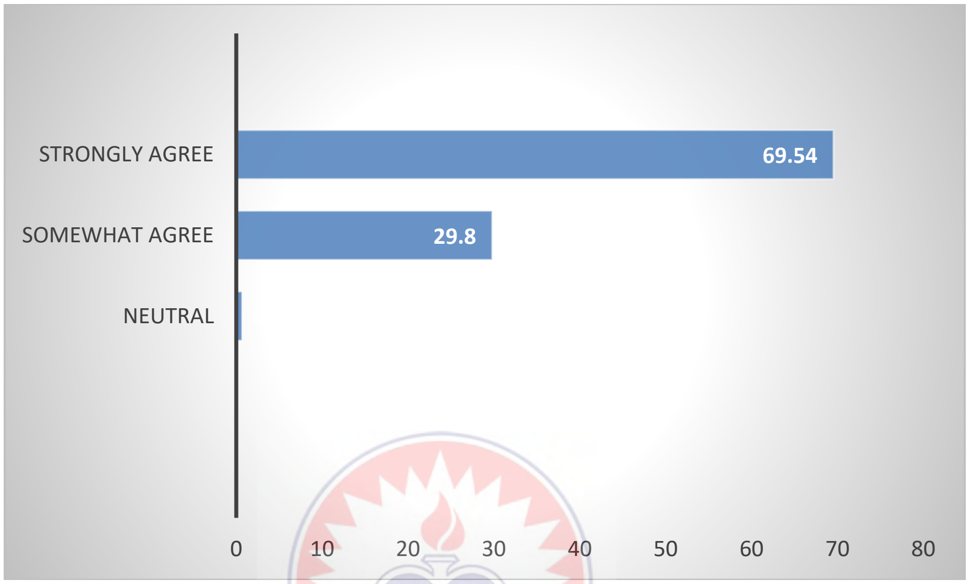

Figure 4.12: A process is in place to ensure that safety critical elements are identified and maintenance scheduled accordingly

Figure 4.13 shows that majority 57.6% of the respondents strongly agreed that procedures are in place for the periodic review of maintenance, 22.5% of the respondents somewhat agreed and 19.9% remained neutral. The first and most important step in any risk management program is to identify any possible hazards associated with your activities. Unless hazards are identified, consequence and likelihood reduction cannot be implemented. Hazards identification is the act of recognizing the failure conditions or threats, which could lead to undesirable events. The main item to determine the hazards is the amount of information which is known about the equipment or conversely the identification of where there is a lack of information. Even when information appears to

University of Education,Winneba http://ir.uew.edu.gh

be known, the risk based approach requires the quality and accuracy of the information be tested and validated. Risk increases when there is a lack of, or uncertainty in the information required to assess the equipment integrity (Peterson, and Jablonski, 2003). Information about the asset can be gathered from the design specifications, fabrication records, operational experience, maintenance records, inspection records, the knowledge of material degradation methods and the rates at which material degradation will, or has occurred.

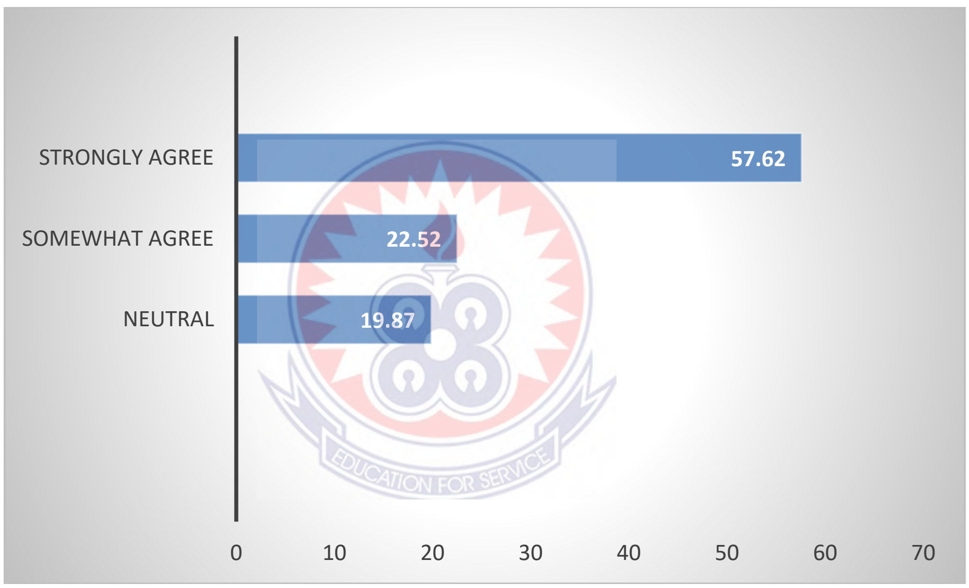

Figure 4.13: Procedures are in place for the periodic review of maintenance

4.7 Promoting Safe Workplace Environment

Figure 4.14 reveals that majority (92.05%) of the respondents somewhat agreed that the project management team has developed the AIMS to ensure and promote a safe working environment whiles minority 7.95% of the respondents remained neutral. Risk evaluation is used to determine the significance of a risk to the organization and whether

University of Education,Winneba http://ir.uew.edu.gh

each specific risk should be accepted. The value indicating a risk and its associated implications are arguably subjective but are nonetheless important for assessing the risk status (Bae and Lee, 2012). For a given risk event (e.g. accidental hydrocarbon release), each of the release criteria is evaluated based on the likelihood and consequence. Likelihood is the probability of occurrence and Consequence is the severity of impact. In quantitative risk assessment, the risk is the product of the numerical consequence and the probability of occurrence (Clare and Armstrong, 2006). According to Clare et al. (2006) sequence and likelihood can each be assessed using various methods of varying complexity, ranging from qualitative to quantitative.

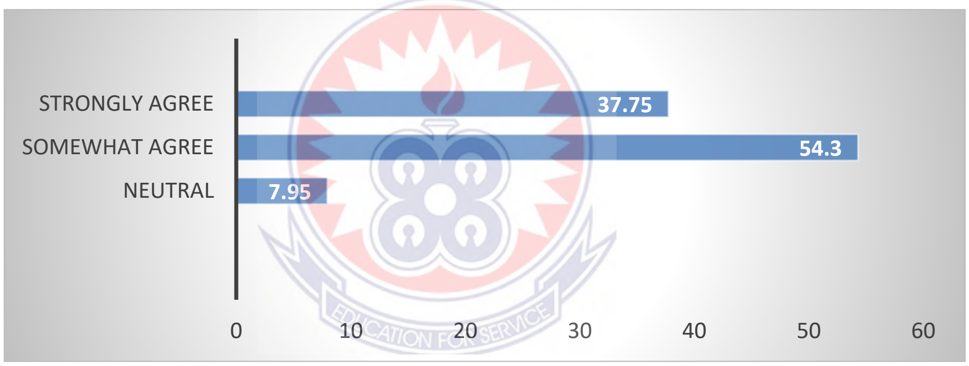

Figure 4.14: The project management team has developed the AIMS to ensure and promote a safe working environment.

4.8 Inspection, Testing, Monitoring and Reporting

According to Figure 4.15 majority 88.7% of the respondents strongly agreed that there are processes covering the inspection, testing and monitoring of site activities, plant and equipment for the operation, whiles minority 11.3% remained neutral. Risk assessments are fundamental tools in the safety community. They help make and implement decisions regarding safety, which in effect prevent accidents, improve safety

University of Education,Winneba http://ir.uew.edu.gh

performance, and reduce Operational Expenditure OPEX by systematically identifying and evaluating hazards concerning the design and potential failures (Hassenzahl et al., 2008).

To conduct a risk assessment, the following process has been developed;

- ✓ Identify the hazards
- ✓ Frequency assessment
- ✓ Consequence assessment
- ✓ Risk evaluation
- ✓ Action forward

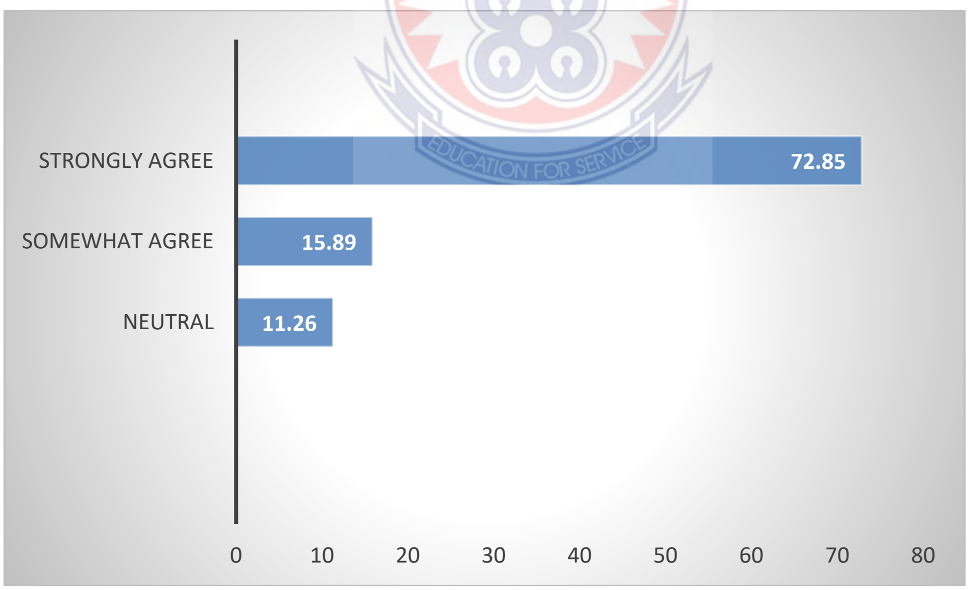

Figure 4.15: There are processes covering the inspection, testing and monitoring of site activities, plant and equipment for the operation

University of Education,Winneba http://ir.uew.edu.gh

Figure 4.16 indicates that majority 92.1% of the respondents strongly agreed that Inspections follow an agreed format and are documented whiles 7.9% remained neutral. Risk assessments are fundamental tools in the safety community. They help make and implement decisions regarding safety, which in effect prevent accidents, improve safety performance, and reduce Operational Expenditure OPEX by systematically identifying and evaluating hazards concerning the design and potential failures (Hassenzahl et al., 2008).

To conduct a risk assessment, the following process has been developed;

- ✓ Identify the hazards
- ✓ Frequency assessment
- ✓ Consequence assessment
- ✓ Risk evaluation
- ✓ Action forward

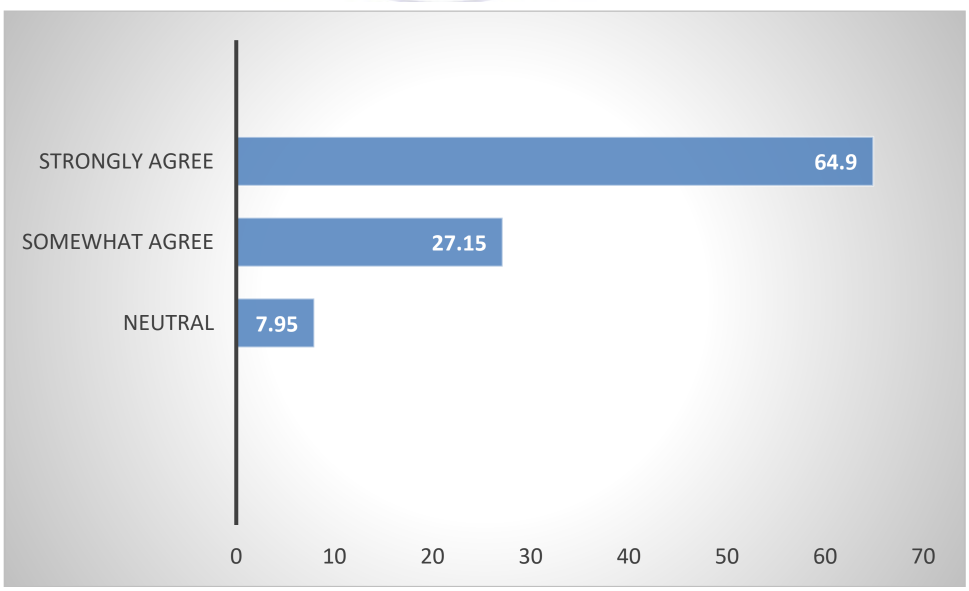

Figure 4.16: Inspections follow an agreed format

University of Education,Winneba http://ir.uew.edu.gh

CHAPTER FIVE

DISCUSSION OF RESULTS

This chapter discussed the results of the study. The discussion of results was done according to the research objectives.

5.1 Asset Integrity Management Techniques (AIMT)

Majority 83.4% of the respondents agreed that the AIMS addresses corrosion management inspection and repair, safety of critical elements, instrumented protective functions, planned maintenance inspection and repair equipments, 7.3% of the respondents remained neutral and 4.6% disagreed. These are assurance activities performed to confirm that the asset meets the required PS during design and throughout the operational lifetime of the asset. At the design stage, such assurance is undertaken through the use of appropriate design codes and standards, best practice, risk based approach, design review etc. by suitable qualified, experience and competent persons (Marty et al, 2010). Assurance activities during operational stage include inspection, test and maintenance.

Majority 93.4% of the respondents agreed that the AIMS delegates duties, responsibilities, authorities and accountabilities with respect to its development and implementation while 6.6% remained neutral. It is important to recognize that for this class of failures, the primary risk control measures are built into the system at the planning selection, design, construction, and installation phases (i.e. ensuring the integrity of the asset in all phases). Major incidents are not driven by operational considerations i.e. they do not necessarily require operational failures to be realize, and

University of Education,Winneba http://ir.uew.edu.gh

may occur even if a system is operated within its design envelop (Smith and Zijlker, 2005).

Majority 91% of the respondents strongly agreed that the AIMS demonstrates that any future development or activities can be addressed and 9.9% remained neutral. `Verification tasks are carried out in order to verify that the previously defined PS for the SCE is achieved. According to Dhar (2011), this is system of independent and competent scrutiny of the suitability of SCE throughout its life cycle. The process of identifying SCEs, producing PS and performing Assurance is monitored and verified by an Independent Competent Person (ICP). Verification is a sampling process and includes document review, checks using calculation, physical examination, testing or witnessing of tests, audit, and confirmation of records during the operational life of the asset.

Majority 84.1% of the respondents somewhat disagreed that all relevant personnel have access to relevant AIMS documentation and records whiles minority 15.8% remained neutral. The Risk Based Inspection (RBI) approach is an effective inspection planning tool supporting the engineers in their quest to focus the inspection and maintenance efforts into the high risk operating assets, while assigning an appropriate effort to the lower risk equipment. The end deliverable of RBI is a comprehensive inspection plan developed through a risk management process that aims at ensuring the integrity of an asset in the most cost effective manner (Dos Santos, 2000).

RBI is an integrated methodology that factors risk into inspection and maintenance decision making. It is a systematic and structured approach for developing inspection plans using risk management techniques that identify the probability/likelihood of failure and the consequences of such failure from the human,

University of Education,Winneba http://ir.uew.edu.gh

environmental, assets and reputational viewpoints (Reynolds, 2000). Overall, since a relatively large percentage of risk is associated with a small percentage of equipment, the RBI methods improve the management of risk through closely focusing on the critical areas of the asset, and reducing efforts on the non-critical areas i.e. inspection effort is proportional to the criticality of the operating asset (Al-Mithin et al., 2011). The RBI methodology provides a logical, documented and repeatable system for making informed decisions on inspection frequencies, details of inspection, inspection scope etc.

5.2 Key Performance Indicators

Majority 86.1% of the respondents strongly agreed that the AIMS incorporates or links to a quality management system as a mechanism for assisting in meeting the AIMS performance standards or key indicators whiles minority 13.9% remained neutral. The first and most important step in any risk management program is to identify any possible hazards associated with your activities. Unless hazards are identified, consequence and likelihood reduction cannot be implemented. Hazards identification is the act of recognizing the failure conditions or threats, which could lead to undesirable events. The main item to determine the hazards is the amount of information which is known about the equipment or conversely the identification of where there is a lack of information. Even when information appears to be known, the risk based approach requires the quality and accuracy of the information be tested and validated. Risk increases when there is a lack of, or uncertainty in the information required to assess the equipment integrity (Peterson, and Jablonski, 2003). Information about the asset can be gathered from the design specifications, fabrication records, operational experience, maintenance records,

University of Education,Winneba http://ir.uew.edu.gh

inspection records, the knowledge of material degradation methods and the rates at which material degradation will, or has occurred.

Majority 74.9% of the respondents strongly disagreed that Key Performance Indicators (KPIs) are regularly reviewed by supervisors and managers whiles 12.6% remained neutral and minority 7.9% somewhat disagreed that KPIs are regularly reviewed by supervisors and managers. The group responsible in developing an Asset Integrity toolkit covering comprehensive guidance with reference to good industry practice documents for effective safety critical plant and equipment maintenance management. HSE have developed three potential key performance indicators, which are: KPI1, loss of containment i.e. reportable hydrocarbon releases; KPI2, verification of significant compliance issues; and KPI3, production losses associated with deficiency in maintaining safety. Finally, after having a detailed study and observation, the KPI3 were replaced with safety-critical maintenance backlog for monitoring the cross industry asset integrity.

5.3 Asset Integrity Management Accountability

Majority 94% of the respondents somewhat agreed that mechanisms are in place to ensure the accountability of senior management for the achievement of asset integrity management whiles 6% remained neutral. It is important to recognize that for this class of failures, the primary risk control measures are built into the system at the planning selection, design, construction, and installation phases (i.e. ensuring the integrity of the asset in all phases). Major incidents are not driven by operational considerations i.e. they

University of Education,Winneba http://ir.uew.edu.gh

do not necessarily require operational failures to be realize, and may occur even if a system is operated within its design envelop (Smith and Zijlker, 2005).

Majority 89.4% of the respondents strongly agreed that Integrity assessment procedures and guidelines are in place, such as pipeline integrity management system, structural integrity management system, technical change management system, maintenance management manual etc whiles minority 10.6% remained neutral. These are assurance activities performed to confirm that the asset meets the required PS during design and throughout the operational lifetime of the asset. At the design stage, such assurance is undertaken through the use of appropriate design codes and standards, best practise, risk based approach, design review etc. by suitable qualified, experience and competent persons (Marty et al, 2010). Assurance activities during operational stage include inspection, test and maintenance.

Majority 90.7% of the respondents somewhat agree that the AIMS responsibilities and accountabilities of all personnel align with their skills and training whiles minority 9.3% somewhat disagreed that the AIMS responsibilities and accountabilities of all personnel align with their skills and training. `Verification tasks are carried out in order to verify that the previously defined PS for the SCE is achieved. According to Dhar, (2011), this is system of independent and competent scrutiny of the suitability of SCE throughout its life cycle. The process of identifying SCEs, producing PS and performing Assurance is monitored and verified by an Independent Competent Person (ICP). Verification is a sampling process and includes document review, checks using calculation, physical examination, testing or witnessing of tests, audit, and confirmation of records during the operational life of the asset.

University of Education,Winneba http://ir.uew.edu.gh

5.4 Employee Involvement and Communication

Majority 94.7% of the respondents strongly agreed that Frontline maintenance technicians are consulted when risk, problem solving and devising maintenance work schedules and procedures whiles minority 5.3% somewhat agreed that Frontline maintenance technicians are consulted when risk, problem solving and devising maintenance work schedules and procedures. The first and most important step in any risk management program is to identify any possible hazards associated with your activities. Unless hazards are identified, consequence and likelihood reduction cannot be implemented. Hazards identification is the act of recognizing the failure conditions or threats, which could lead to undesirable events. The main item to determine the hazards is the amount of information which is known about the equipment or conversely the identification of where there is a lack of information. Even when information appears to be known, the risk based approach requires the quality and accuracy of the information be tested and validated. Risk increases when there is a lack of, or uncertainty in the information required to assess the equipment integrity (Peterson, and Jablonski, 2003).

Information about the asset can be gathered from the design specifications, fabrication records, operational experience, maintenance records, inspection records, the knowledge of material degradation methods and the rates at which material degradation will, or has occurred.

University of Education,Winneba http://ir.uew.edu.gh

5.5 Objectives, Plans and Performance Standards

Majority 90.7% of the respondents strongly agreed that plans are updated to reflect changes in performance standards, or outcomes of appraisals of the AIMS effectiveness whiles 4.6% somewhat disagreed and remained neutral respectively. PS are statements which can be expressed in quantitative or qualitative terms, of the performance required of a system, item or equipment, person or procedure, and which is used as the basis of managing the hazard e.g. planning, measuring, control or audit through the life cycle of the asset (SCE). Or, they are documents describing the criteria for the assessment of the asset (SCE) for compliance with minimum requirement to asset operations and characterizing its performance criteria (Derevyakin, 2010).

Marty et al (2010), explains that, The PS standard defines the following criteria for each of the SCE;

- ✓ Functionality of the SCE i.e. response time of the SCE
- ✓ Availability of the SCE i.e. the handiness of the SCE
- ✓ Reliability i.e. the ability of the system to perform its required functions when it's needed.
- ✓ Survivability i.e. the ability of the element to deliver its function if exposed to an undesired event e.g. fire, blast, vibrations, etc.
- ✓ Interdependency i.e. other systems necessary for the function of the SCE to perform adequately e.g. emergency power supply for SIS (Marty et al, 2010).

University of Education,Winneba http://ir.uew.edu.gh

5.6 Safe Operating Procedures

Majority 94.8% of the respondents agreed that there are procedures or documentation describing how deferrals are authorized and justified whiles minority 5.3% disagree that there are procedures or documentation describing how deferrals are authorized and justified. `Verification tasks are carried out in order to verify that the previously defined PS for the SCE is achieved. According to Dhar (2011), this is system of independent and competent scrutiny of the suitability of SCE throughout its life cycle. The process of identifying SCEs, producing PS and performing Assurance is monitored and verified by an Independent Competent Person (ICP). Verification is a sampling process and includes document review, checks using calculation, physical examination, testing or witnessing of tests, audit, and confirmation of records during the operational life of the asset.

Majority 99.3% of the respondents strongly agreed that a process is in place to ensure that safety critical elements are identified and maintenance scheduled accordingly whiles 0.7% remained neutral. Risk evaluation is used to determine the significance of a risk to the organization and whether each specific risk should be accepted. The value indicating a risk and its associated implications are arguably subjective but are nonetheless important for assessing the risk status (Bae and Lee, 2012). For a given risk event (e.g. accidental hydrocarbon release), each of the release criteria is evaluated based on the likelihood and consequence. Likelihood is the probability of occurrence and Consequence is the severity of impact. In quantitative risk assessment, the risk is the product of the numerical consequence and the probability of occurrence (Clare and Armstrong, 2006). According to Clare et al. (2006), sequence and likelihood can each be

University of Education,Winneba http://ir.uew.edu.gh

assessed using various methods of varying complexity, ranging from qualitative to quantitative.

Majority 80.1% of the respondents strongly agreed that procedures are in place for the periodic review of maintenance whiles 19.9% remained neutral. The first and most important step in any risk management program is to identify any possible hazards associated with your activities. Unless hazards are identified, consequence and likelihood reduction cannot be implemented. Hazards identification is the act of recognizing the failure conditions or threats, which could lead to undesirable events. The main item to determine the hazards is the amount of information which is known about the equipment or conversely the identification of where there is a lack of information. Even when information appears to be known, the risk based approach requires the quality and accuracy of the information be tested and validated. Risk increases when there is a lack of, or uncertainty in the information required to assess the equipment integrity (Peterson, and Jablonski, 2003).

Information about the asset can be gathered from the design specifications, fabrication records, operational experience, maintenance records, inspection records, the knowledge of material degradation methods and the rates at which material degradation will, or has occurred.

5.7 Promoting Safe Workplace Environment

Majority 92% of the respondents somewhat agreed that the project management team has developed the AIMS to ensure and promote a safe working environment whiles minority 7.9% of the respondents remained neutral. Risk evaluation is used to determine

University of Education,Winneba http://ir.uew.edu.gh

the significance of a risk to the organization and whether each specific risk should be accepted. The value indicating a risk and its associated implications are arguably subjective but are nonetheless important for assessing the risk status (Bae and Lee, 2012). For a given risk event (e.g. accidental hydrocarbon release), each of the release criteria is evaluated based on the likelihood and consequence. Likelihood is the probability of occurrence and Consequence is the severity of impact. In quantitative risk assessment, the risk is the product of the numerical consequence and the probability of occurrence (Clare and Armstrong, 2006). According to Clare et al. (2006) sequence and likelihood can each be assessed using various methods of varying complexity, ranging from qualitative to quantitative.

5.8 Inspection, Testing, Monitoring and Reporting

Majority 89.7% of the respondents strongly agreed that there are processes covering the inspection, testing and monitoring of site activities, plant and equipment for the operation whiles minority 11.3% remained neutral. Risk assessments are fundamental tools in the safety community. They help make and implement decisions regarding safety, which in effect prevent accidents, improve safety performance, and reduce Operational Expenditure OPEX by systematically identifying and evaluating hazards concerning the design and potential failures (Hassenzahl et al., 2008).

To conduct a risk assessment, the following process has been developed;

- ✓ Identify the hazards
- ✓ Frequency assessment
- ✓ Consequence assessment

University of Education,Winneba http://ir.uew.edu.gh

- ✓ Risk evaluation
- ✓ Action forward

Majority 92.1% of the respondents strongly agreed that Inspections follow an agreed format and are documented whiles 7.9% remained neutral. Risk assessments are fundamental tools in the safety community. They help make and implement decisions regarding safety, which in effect prevent accidents, improve safety performance, and reduce Operational Expenditure OPEX by systematically identifying and evaluating hazards concerning the design and potential failures (Hassenzahl et al., 2008).

To conduct a risk assessment, the following process has been developed;

- ✓ Identify the hazards
- ✓ Frequency assessment
- ✓ Consequence assessment
- ✓ Risk evaluation
- ✓ Action forward

University of Education,Winneba http://ir.uew.edu.gh

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

This chapter contains the summary, conclusion, recommendations and suggestions for further studies. The chapter was based on the research objectives.

6.1 Summary

The main purpose of the study was to investigate into the asset integrity management system of Ghana's oil industry. However, in an attempt to fully achieve the aim of this work, the specific objectives were used including to review various asset integrity management techniques, to study the asset integrity performance framework in the oil and gas domain and practical implementation of framework for offshore floating facilities operated by Ghana's oil and gas industry, to understand the current implementation of the AIM techniques at Atuabo Gas Company and to map the current status and to elaborate on the future innovation trends of AIM products and services on the Atuabo Gas Company and to draw conclusions and make recommendations based on my findings. Qualitative and quantitative research methods were used for the study. The researcher used questionnaire surveys and interviews to collect primary data**.** The targeted populations for the study were personnel of Ghana Gas Company, Ghana National Petroleum Company and the Ministry of Energy and their supervisors in industry. The targeted population for the study was seven hundred (700). A sample of 151 respondents from the Ghana Gas company at Atuabo were randomly selected. This was made up of 50 supervisors and 101 practicing engineers and operators. Out of 151 questionnaires sent out for primary data, 151 questionnaires were retrieved. Therefore, the analysis of the data was made up of 100% response rate.

University of Education,Winneba http://ir.uew.edu.gh

6.2 Major Findings

Majority 83.4% of the respondents agreed that the AIMS addresses corrosion management inspection and repair, safety of critical elements, instrumented protective functions. Majority 93.4% of the respondents agreed that the AIMS delegates duties, responsibilities, authorities and accountabilities with respect to its development and implementation. Majority 91% of the respondents strongly agreed that the AIMS demonstrates that any future development or activities can be addressed.

Majority 84.1% of the respondents somewhat disagreed that all relevant personnel have access to relevant AIMS documentation and records.Majority 86.1% of the respondents strongly agreed that the AIMS incorporates or links to a quality management system as a mechanism for assisting in meeting the AIMS performance standards or key indicators.Majority 74.9% of the respondents strongly disagreed that Key Performance Indicators (KPIs) are regularly reviewed by supervisors and managers. Majority 94% of the respondents somewhat agreed that mechanisms are in place to ensure the accountability of senior management for the achievement of asset integrity management.

Majority 89.4% of the respondents strongly agreed that Integrity assessment procedures and guidelines are in place, such as pipeline integrity management system, structural integrity management system, technical change management system, maintenance management manual etc.Majority 90.7% of the respondents somewhat agree that the AIMS responsibilities and accountabilities of all personnel align with their skills and training. Majority 94.7% of the respondents strongly agreed that Frontline maintenance technicians are consulted when risk, problem solving and devising maintenance work schedules and procedures.

University of Education,Winneba http://ir.uew.edu.gh

Majority 90.7% of the respondents strongly agreed that plans are updated to reflect changes in performance standards, or outcomes of appraisals of the AIMS effectiveness.Majority 94.8% of the respondents agreed that there are procedures or documentation describing how deferrals are authorized and justified. Majority 99.3% of the respondents strongly agreed that a process is in place to ensure that safety critical elements are identified and maintenance scheduled accordingly.Majority 80.1% of the respondents strongly agreed that procedures are in place for the periodic review of maintenance.Majority 92% of the respondents somewhat agreed that the project management team has developed the AIMS to ensure and promote a safe working environment whiles.Majority 89.7% of the respondents strongly agreed that there are processes covering the inspection, testing and monitoring of site activities, plant and equipment for the operation.Majority 92.1% of the respondents strongly agreed that Inspections follow an agreed format and are documented.

6.3 Conclusions

The AIMS addresses corrosion management inspection and repair, safety of critical elements, instrumented protective functions. The AIMS delegates duties, responsibilities, authorities and accountabilities with respect to its development and implementation. That the AIMS demonstrates that any future development or activities can be addressed.All relevant personnel do not have access to relevant AIMS documentation and records. The AIMS incorporates or links to a quality management system as a mechanism for assisting in meeting the AIMS performance standards or key indicators.Key Performance Indicators (KPIs) are regularly reviewed by supervisors and

University of Education,Winneba http://ir.uew.edu.gh

managers. Mechanisms are in place to ensure the accountability of senior management for the achievement of asset integrity management.

Integrity assessment procedures and guidelines are in place, such as pipeline integrity management system, structural integrity management system, technical change management system, maintenance management manual etc.The AIMS responsibilities and accountabilities of all personnel align with their skills and training.Frontline maintenance technicians are consulted when risk, problem solving and devising maintenance work schedules and procedures.

Plans are updated to reflect changes in performance standards, or outcomes of appraisals of the AIMS effectiveness.There are procedures or documentation describing how deferrals are authorized and justified. A process is in place to ensure that safety critical elements are identified and maintenance scheduled accordingly. Procedures are in place for the periodic review of maintenance.The project management team has developed the AIMS to ensure and promote a safe working environment. There are processes covering the inspection, testing and monitoring of site activities, plant and equipment for the operation.Inspections follow an agreed format and are documented

6.4 Recommendations

The managers of the organization must ensure that AIMS addresses corrosion management inspection and repair, safety of critical elements, instrumented protective functions. The AIMS must delegate duties, responsibilities, authorities and accountabilities with respect to its development and implementation. The AIMS must demonstrate that any future development or activities can be addressed.All relevant

University of Education,Winneba http://ir.uew.edu.gh

personnel must have access to relevant AIMS documentation and records. The AIMS must incorporate or links to a quality management system as a mechanism for assisting in meeting the AIMS performance standards or key indicators.Key Performance Indicators (KPIs) must be are regularly reviewed by supervisors and managers.

Mechanisms must be put in place to ensure the accountability of senior management for the achievement of asset integrity management. Integrity assessment procedures and guidelines must be put in place, such as pipeline integrity management system, structural integrity management system, technical change management system, and maintenance management manual.The AIMS responsibilities and accountabilities of all personnel must be aligned with their skills and training.Frontline maintenance technicians must be consulted when risk, problem solving and devising maintenance work schedules and procedures.Plans must be updated to reflect changes in performance standards, or outcomes of appraisals of the AIMS effectiveness. Procedures must be put in place for the periodic review of maintenance.The project management team must develop the AIMS to ensure and promote a safe working environment.

6.5 Suggestions for Further Studies

Based on the conclusion remarks and the recommendations made, the researcher suggested that asimilar research should be undertaken to investigate the impact of training and developments on AIMS using the Atuabo Gas Company as a case study.

University of Education,Winneba http://ir.uew.edu.gh

REFERENCES

Adair, S., Filmalter, E. and Mahlangu, F. (2008). Asset integrity management in the digital age, *Energy Institute - 19th World Petroleum Congress 2008: A World in Transition: Delivering Energy for Sustainable Growth*. P. 89

Atherton, J. (2008).*Incidents that define process safety.* Hoboken, N.J.: Wiley, Hoboken, N.J. p. 76

Al-Mithin, A. W., Sardesai, V., Al-Harbi, B., Murthy, H. S. and Hannan, A. S. A. (2011). Risk Based Inspection (RBI) of Aboveground Storage Tanks to Improve Asset Integrity, *International Petroleum Technology Conference, Bangkok, Thailand,* 7th-9th February 2012. International Petroleum Technology Conference.

Baby, R. (2008). Integrity management during design stage, *Society of Petroleum Engineers - 13th Abu Dhabi International Petroleum Exhibition and Conference, ADIPEC 2008*. P. 53

Ciaraldi, S. W. (2005). The essence of effective integrity management-People, process and plant, *2005 SPE Asia Pacific Health, Safety and Environment Conference and Exhibition -Proceedings*. P. 90

Ciaraldi, S. W. (2009). Practical aspects of integrity management for large oil and gas production infrastructures, *Society of Petroleum Engineers - SPE/IATMI Asia Pacific Health Safety, Security and Environment Conference and Exhibition 2009, APHSSEC 09*. P. 54

Craddock, R. J. (2004). Avoiding a major accident event, *International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production*. P. 78

University of Education,Winneba http://ir.uew.edu.gh

Daoud, M. Mohamed, A. Drahib, S.and Badyab, A. (2012). ADCO's assets integrity requirements during projects execution, *Society of Petroleum Engineers - Abu Dhabi International Petroleum Exhibition and Conference 2012, ADIPEC 2012 - Sustainable Energy Growth: People, Responsibility, and Innovation*. P. 109

Derevyakin, E. M. (2010). Systematic Approach Ensuring Asset Integrity, Equipment Reliability and Process Safety, *SPE Russian Oil and Gas Conference and Exhibition, Moscow, Russia,* 26th-28th October 2010. Society of Petroleum Engineers. P. 91

Dhar, R. (2011). Performance standards for safety critical elements - Are we doing enough? *Society of Petroleum Engineers - SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production 2011*. P. 221

Dos Santos, A.and Al Hajri, A. (2000). Risk Based Inspection - A Valuable Approach, *Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, United Arab Emirates,* 13th-15th October 2000. Society of Petroleum Engineers.

Esaklul, K. A.and Al-Adsani, A. M. (2006). Integrity management in KOC, *8th SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production 2006*.

HSE. (2007). Key Programme 3-Asset Integrity Programme, *A report by the Offshore Division of HSE's Hazardous Installations Directorate,* 5-10.

Hassan, J.and Khan, F. (2012). Risk-based asset integrity indicators, *J Loss Prev Process Ind,* 25. (3): 544-554.

University of Education,Winneba http://ir.uew.edu.gh

Horrocks, P.and Adair, S. (2010). 4.34 - Risk Based Inspection. In: Editor-in-Chief: Tony J.A. Richardson, editor. , *Shreir's Corrosion,* pp. 3084-3101, Elsevier, Oxford, UK.

Hassenzahl, D. M.and Finkel, A. M. (2008). Risk Assessment, Environmental/Occupational. In: Editor-in-Chief: Kris Heggenhougen, editor, *International Encyclopedia of Public Health,* pp. 590-600, Academic Press, Oxford, UK.

Jones, D. S. (2007). Occupational health aspects of emergency preparedness and response, *Society of Petroleum Engineers - Asia Pacific Health, Safety, Security and Environment Conference and Exhibition 2007 - "Responsible Performance: Are We Doing the Best We Can".*

Julaihi, S. Jaafar, A. T., and Bakar, N. A. A. (2010). Management of change, key component of an effective HSE management system, *Society of Petroleum Engineers - SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production 2010.*

Kapusta, S. D.and Reynolds, J. W. (2008). Plant integrity and reliability are the keys to improving profitability, *International Petroleum Technology Conference, IPTC 2008.*

Krishnasamy, L. Khan, F. and Haddara, M. (2005). Development of a risk-based maintenance (RBM) strategy for a power-generating plant, *J Loss Prev Process Ind,* 18. (2) 69-81.

Khalaf, F. and Abu El Ela, M. (2008). The risk management Process - An overview, *Society of Petroleum Engineers - 9th International Conference on Health, Safety*

University of Education,Winneba http://ir.uew.edu.gh

and Environment in Oil and Gas Exploration and Production 2008 - "In Search of Sustainable Excellence".

Laskar, L. (2013). A Novel Methodology for Maintaining Mechanical Integrity of High Pressure Relief Systems, *6th International Petroleum Technology Conference, 2013, Beijing, China,* 26th - 28th March 2013. International Petroleum Technology Conference.

Lawson, B. (2012). Managing asset integrity in the UK continental shelf.

Marty, J. Theys, S. Bucherie, C., Bolsover, A., & Cambos, P. (2010). Independent verification of safety critical elements, *Society of Petroleum Engineers - SPE Russian Oil and Gas Technical Conference and Exhibition 2010, RO and G 10.*

Oliver, M. H. (2002). Plant Integrity Management Reviews, *Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, United Arab Emirates,* 13th-16th October 2002. Society of Petroleum Engineers.

Palmer, G. A. (2011). Confidence in data aids improved asset value, *Society of Petroleum Engineers - SPE Asia Pacific Oil and Gas Conference and Exhibition 2011.*

Peterson, R., and Jablonski, R. (2003). Risk Based Inspection - As Part of an Overall Inspection Management Program, *CORROSION 2003, San Diego Ca,* March 2003. NACE International.

Peball, U., and Dragan, S. (2011). Addressing MAH (major accident hazards) - From assessment to actions, *Society of Petroleum Engineers - SPE International*

University of Education,Winneba http://ir.uew.edu.gh

Conference on Health, Safety and Environment in Oil and Gas Exploration and Production 2011.

Ritchie, D. M. (2011). The role of asset integrity and life extension in major accident prevention, *Society of Petroleum Engineers - Offshore Europe Oil and Gas Conference and Exhibition 2011, OE 2011*.

Reynolds, J. T. (2000). Risk Based Inspection - Where Are We Today? *CORROSION 2000, Orlando, Fl,* 26th - 31st March 2000. NACE International.

Rao, A. R., Rao, S. S., Sharma, T.,& Krishna, K. R. (2012). Asset integrity management in onshore & offshore-enhancing reliability at KGD6, *Society of Petroleum Engineers - SPE Oil and Gas India Conference and Exhibition 2012, OGIC - Further, Deeper, Tougher: The Quest Continues.*

Rahim, Y., Refsdal, I., & Kenett, R. S. (2010). The 5C model: A new approach to asset integrity management, *Int J Pressure Vessels Piping,* 87. (2–3) 88-93.

Sutton, I. (2010). CHAPTER 6 - Asset integrity. *Process Risk and Reliability Management,* pp. 301-346, William Andrew Publishing, Oxford, UK.

Smallwood, R. E. (2004). Equipment Integrity In The New Millennium, *CORROSION 2004, New Orleans, La,* 28th March - 1st April 2004. NACE International.

Smith, D., & Zijlker, V. (2005). Managing major incident risks, *2005 SPE Asia Pacific Health, Safety and Environment Conference and Exhibition - Proceedings*.

Sutton, I. (2010). Chapter 12 - Incident investigation and root cause analysis. *Process Risk and Reliability Management*. pp. 575-654, William Andrew Publishing, Oxford, UK.

University of Education,Winneba http://ir.uew.edu.gh

Tveiten, C. K., Albrechtsen, E., Wærø, I., and Wahl, A. M. (2012). Building resilience into emergency management, *SafSci,* 50. (10) 1960-1966.

Sandra, L. (2013). The Competence Part of a High Integrity Process, ERM, Peter Hill, Warwickshire Oil Storage Ltd.

Sepeda, A. L. (2009). A risk based maintenance approach (for facilities complying with the US OSHA PSM regulation), *J Loss Prev Process Ind,* 22. (6): 680-684.

Unnikrishnan, G. (2006). Management of change - Systems approach with applications, *8th SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production 2006*.

Wang, Y., Cheng, G., Hu, H., andWu, W. (2012). Development of a risk-based maintenance strategy using FMEA for a continuous catalytic reforming plant, *J Loss Prev Process Ind,* 25. (6): 958-965.

Willcocks, J. (2000). Risk-Based Inspection and Integrity Management of Pipeline Systems, *The Tenth International Offshore and Polar Engineering Conference,* 28 May-2 June. The International Society of Offshore and Polar Engineers, Washington, USA.

University of Education,Winneba http://ir.uew.edu.gh

APPENDIX A: THE QUESTIONNAIRE FOR THE RESPONDENTS

Dear respondents,

The researcher is a product of UEW, Winneba, Kumasi Campus conducting a piece of research on investigating into the asset integrity management system of Ghana's oil industry, using the Atuabo Gas as a case study. I respectively request that you form part of this research by completing the attached questionnaire. This is seeking to solicit your opinion on the asset Integrity Management Strategies. Anonymity and non-traceability are assured. It is my fervent hope that you will be exonerated to participate in the study. May I thank you for your valuable cooperation.

1. Name (optional)

……………………………………………………………………………………………..

2.

Department………………………………………………………………………………

…

3. Age

18-25 [ ]   26-30 [ ]   31-35 [ ]   36 - 40 [ ]   41 -50 [ ]   above 50 [ ]

4. Educational level

MSLC [ ]   SSSCE [ ]   DIPLOMA [ ]   BSC [ ]   MSC [ ]   PHD [ ]

University of Education,Winneba http://ir.uew.edu.gh

REVIEWING VARIOUS ASSET INTEGRITY MANAGEMENT TECHNIQUES

5. The AIMS addresses the following main elements:

- corrosion management inspection and repair (e.g. vessels, pipelines, instrumentation)
- safety critical elements (e.g. emergency shut down and isolation equipment, fire protection and detection for plant and equipment)
- instrumented protective functions
- planned maintenance inspection and repair, and fitness-for-purpose (e.g. mobile plant)
- well head and subsurface well integrity

Strongly disagree ☐	**Somewhat disagree ☐**	**Neutral ☐**	**Somewhat agree ☐**	**Strongly agree ☐**

6. The AIMS delegates duties, responsibilities, authorities and accountabilities with respect to its development and **implementation**.

Strongly disagree ☐	**Somewhat disagree ☐**	**Neutral ☐**	**Somewhat agree ☐**	**Strongly agree ☐**

7. The AIMS demonstrates that any future development or activities can be addressed

Strongly disagree ☐	**Somewhat disagree ☐**	**Neutral ☐**	**Somewhat agree ☐**	**Strongly agree ☐**

8. All relevant personnel have access to relevant AIMS documentation and records

Strongly disagree ☐	**Somewhat disagree ☐**	**Neutral ☐**	**Somewhat agree ☐**	**Strongly agree ☐**

University of Education,Winneba http://ir.uew.edu.gh

KEY PERFORMANCE INDICATORS

9. The AIMS incorporates or links to a quality management system as a mechanism for assisting in meeting the AIMS performance standards or key performance indicators (KPIs). KPIs are readily available from the AIMS, such as:

• percentage of programme completed • months of backlog • backlog of critical items • percentage emergency work • weekly schedule compliance

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

10. KPIs are regularly reviewed by supervisors and managers. Reports of outstanding critical maintenance and other exception reports are approved by the manager responsible for facility integrity.

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

ASSET INTEGRITY MANAGEMENT ACCOUNTABILITY

11. Mechanisms are in place to ensure the accountability of senior management for the achievement of asset integrity management, such as: • facility integrity is part of operator's overall business management system • top management regularly reviews the technical health of the facility and effectiveness of its monitoring • every level of workforce has access to relevant integrity information and regular briefings by management

University of Education,Winneba http://ir.uew.edu.gh

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

12. Integrity assessment procedures and guidelines are in place, such as pipeline integrity management system structural integrity management system technical change management system maintenance management manual inspection and corrosion engineering manual small bore piping integrity manual safety critical function maintenance and testing management system asset information system (documented asset register) well head and subsurface well integrity management

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

13. The AIMT responsibilities and accountabilities of all personnel align with their skills and training: • key personnel involved in safeguarding the facility integrity are identified • there is a procedure for identifying the training needs of these personnel, and a training or skills matrix • there are competency requirements for personnel responsible for specific areas of integrity safeguarding such as corrosion or erosion, pressure system, pipework and safety critical elements • specific skills that are outsourced are identified, and the work output and performance monitoring approach described • external accreditation required for specific skills of personnel (own and contractors) is defined •

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

there is a competency assessment procedure • personnel are trained in root cause analysis, HAZID, HAZOP and risk management • training records are maintained and audited

University of Education,Winneba http://ir.uew.edu.gh

EMPLOYEE INVOLVEMENT AND COMMUNICATION

14. "Front line" maintenance technicians are consulted when assessing risk, problem solving and devising maintenance work schedules and procedures: • they are involved in task risk assessments (e.g. job safety analyses or JSAs) and the provision of feedback to improve procedures • they are involved in devising work schedules as required

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

OBJECTIVES, PLANS AND PERFORMANCE STANDARDS

15. The AIMS objectives, plans and standards are defined and verifiable, such as:

• pipeline integrity management system • structural integrity management system • technical change management system • maintenance management manual • inspection and corrosion engineering manual • small bore piping integrity manual • safety critical function maintenance and testing management system • asset information system • well head and subsurface well integrity management

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

16. Plans are updated to reflect changes in performance standards, or outcomes of appraisals of the AIMS effectiveness

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

University of Education,Winneba http://ir.uew.edu.gh

SAFE OPERATING PROCEDURES

17. There are procedures or documentation describing how deferrals are authorised and justified, and ensuring:

• any deferrals of safety critical items follow the change management system of the SMS • when a deferral is approved, it is stipulated whether that work item is still referenced as a backlog *Note: All work requests that have not been completed are "backlog" by definition*

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

18. A process is in place to ensure that safety critical elements are identified and maintenance scheduled accordingly, and scheduled maintenance is prioritised with consideration for the safety and integrity impact of equipment, such as: • critical function tests based on a checklist with acceptance parameters • safety critical element acceptance criteria laid out in written schemes of examination (WSE) • performance measures in integrity manuals for security critical elements or critical function testing • performance standards defining the minimum acceptable standards for a safety critical element in terms of functionality, reliability or availability, and survivability • failed functions not immediately repaired being the subject of a management-of-change report for sign off by the operation's person in charge, with contingency measures in place for safe operation inclusive of an appropriate risk assessment • separate reports for the backlog of safety critical elements and equipment that is not safety critical

University of Education,Winneba http://ir.uew.edu.gh

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

19. Procedures are in place for the periodic review of maintenance procedures to ensure: • maintenance is being undertaken and equipment is safe and fit for purpose before being returned to service • potential improvements to the maintenance process are identified • work is undertaken in accordance with documented procedures • safety critical procedures include a checklist to be filed on completion • the AIMS maintenance system includes performance monitoring arrangements with agreed performance standards and performance indicators • office support staff analyse, monitor and verify the maintenance performance against appropriate key performance indicators, and these prompt queries and discussion between site- and office-based staff for compliance and continuous improvement

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

PROMOTING SAFE WORKPLACE ENVIRONMENT

20. The project management team has developed the AIMS to ensure and promote a safe working environment

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

INSPECTION, TESTING, MONITORING AND REPORTING

21. There are processes covering the inspection, testing and monitoring of site activities, plant and equipment for the operation, including:

University of Education,Winneba http://ir.uew.edu.gh

• procedures for ensuring plant is checked before use • planned regime of workplace AIMS inspections • work activity observations • pre-operation inspections of vehicles and plant • inspections and testing of electrical equipment • inspections and testing of cranes and lifting equipment • inspections and testing of pressure vessels and pressure testing equipment • inspections and testing of emergency, first aid, fire and spill control equipment • inspections and testing of well integrity

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

22. Inspections follow an agreed format and are documented

A corrective action register prioritizes, tracks and closes-out actions and improvements

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

AUDIT, VERIFICATION, REVIEW AND IMPROVEMENT

ASSET INTEGRITY AUDIT

23. The audit and review approach of the AIMS is demonstrated through:

• key performance indicators used in daily and monthly operations reports • monthly facility integrity reports • monthly facility technical change reports • validation and verification schemes • regular internal and external audits and reviews

University of Education,Winneba http://ir.uew.edu.gh

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

DOCUMENT AND RECORD CONTROL PROCEDURES

24. In general, the AIMS describes whether records are centrally kept and:

• integrity records are maintained to demonstrate achievement of the performance standards of the systems and equipment • records are maintained for non-compliances, deviations, deferrals, corrective actions and remedial measures taken • the validation and verification results of specialist contractors are recorded • records accessible to relevant (i.e. site and office) personnel • the form in which the records are kept and what the retention time is.

Strongly disagree ☐	Somewhat disagree ☐	Neutral ☐	Somewhat agree ☐	Strongly agree ☐

Thanks for your cooperation