

**Effective Compliance Audit Model for Managing Process Safety in
Process Industries**

by

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CERTIFICATION OF APPROVAL

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Approved by,

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May 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

EDMUND SOON BOON THIAM

ABSTRACT

US Occupational Safety and Health Administration (OSHA) developed a program called Process Safety Management (PSM) due to the increasing major accidents in the process industries which has resulted in the loss of life, pollution to the environment and also monetary and asset losses. The purpose of process safety management or commonly known as PSM is to prevent unwanted release of highly hazardous chemicals to reduce exposure to employees and other potential hazards to the environmental, property and other living organisms. The PSM program is being used in the US, Europe and other countries which have any related process industries such as Malaysia. PSM covers 14 elements which comply with the OSHA Act. One of the elements in discussion of this research is Compliance Audit. Compliance audit is a technique to verify that the implementation of the PSM program is in compliance with OSHA standards. Besides that, compliance audit is performed to determine potential weakness or deficiencies in the PSM program used. Thus, by performing compliance audit, the implementation of the PSM program can be improved and can reduce the potential occurrence of accidents while working. The main goal of the research is to develop a comprehensive and effective compliance audit model according to OSHA PSM Standards which includes the six essential components of a compliance audit; planning, staffing, format, conducting the audit, evaluation and corrective and documentation. Prior to development of model, a framework is drafted as a guidance. The compliance audit model is a computer database to capture data and analyse the data. The model utilizes the Piping and Instrumentation Diagram (P&ID) as a basis to conduct the audit. Case study based on Operating Procedure and Training elements is performed to verify the effectiveness and also to ensure model compliance with OSHA PSM standards. The implementation of the model in the near future can assist auditors to conduct a systematic and efficient work flow of the audit. The compliance audit model is also beneficial to the employee as the weaknesses in the PSM program can be identified and rectified to prevent any major accidents such as in Bhopal or Flixborough.

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ABBREVIATIONS & NOMENCLATURES

OSHA	Occupational Safety and Health Administration
PSM	Process Safety Management
CCPS	Center for Chemical Process Safety
P&ID	Piping and Instrumentation Diagram

CHAPTER 1.0

INTRODUCTION

1.0 INTRODUCTION

1.1 Background

A number of major disasters in the process industries such Flixborough, England (1974), Bhopal, India (1984), Phillips Petroleum Company, Pasadena, Texas (1989) and BASF, Cincinnati, Ohio (1990); has increase the need of introduction of stringent process safety aspect((OSHA), 1992; Joseph, Kaszniak, & Long, 2005). Any kind of unexpected release of highly toxic, reactive and flammable in gaseous or liquid form in the process can cause a possibility of a major disaster to occur((OSHA), 2000; Hendershot, 2009). The unplanned releases of hazardous chemicals have been around for years in the process industries and cause the occurrence of various incidents to happen. The incidents result in the loss of life, monetary and also potential impact to the environment((OSHA), 1992, 2000).

Although there is a significant knowledge on the potential hazards of the chemicals that are used in the industries, there are no proper guidelines on ways to manage the chemicals. Therefore, there is an urge for the responsible authorities to develop legislation and regulations to manage or minimize the potential threat of the highly hazardous chemicals. The aim of the proposed legislation is to develop a mechanism, to report on the presence of hazardous chemicals and to incorporate the

knowledge of the hazardous chemicals in preparedness of emergency plans((OSHA), 1992, 2000; Mason, 2001a).

In 1992, US Occupational Safety and Health Administration (OSHA) issued the “Process Safety Management of Highly Hazardous Chemicals” (29 CFR 1910.119) standard to help ensure a safe and healthy workplace. In the standard, it contains the requirements for the management of hazards associated with processes using highly hazardous chemicals in the process industries that also integrate technologies, procedures and management practices ((OSHA), 1992).

Under this standard, process safety management of highly hazardous chemicals can prevent or minimize the reoccurrence of disaster such as Flixborough and Bhopal. OSHA 29 CFR 1910.119 sets the rules around the use and storage of highly hazardous chemicals and flammables above established threshold quantities ((OSHA), 1992). Process safety management (PSM) is a life-cycle approach to reduce the risk with the storage and use of highly hazardous chemicals and flammables. The approach provides measures to ensure that process is in control, chemicals and flammables are properly contained, thus protecting people, property, assets and also environment from potential disasters (Inc., 2004).

OSHA PSM 29 CFR 1910.119 comprises of 14 elements that is implemented in process industries to manage highly hazardous chemicals which is listed as Appendix A in 29 CFR 1910.119((OSHA), 1992). The 14 elements of PSM are employee participation, process safety information, process hazard analysis, operating procedures, training, contractors, pre-startup safety review, mechanical integrity, hot work permit, management of change, incident investigation, emergency planning and response, compliance audit and trade secrets(Mason, 2001a, 2001b).

PSM, as a structured program, has become the model for general process safety management systems worldwide whereby implementation of PSM programs have been active in the process industries. The implementation provides a safe workplace, and provides process industries with the tools and methods to meet or exceed the requirements of global and local government regulatory compliance((CCPS), 2011; Consulting, 2002).

Compliance audit, which is one of the PSM elements, has become an integral part of development of process safety management implementation in industries(Nivolianitou & Papazoglou, 1998) . Verification of best practices and procedures are essential in compliance audit. The audit can determine missing gaps in the process safety management system and determine whether the other 13 elements of PSM implemented in the system comply with the regulations of OSHA PSM CFR 1910.119. Compliance audit is important because it protects employees, property, assets and the environment by establishing procedures to prevent or minimize the consequences of accidents caused by the use of highly hazardous chemicals in industries((CCPS), 2011; (OSHA), 1994; Forest, 2010).

1.2 Problem Statement

Compliance audit in OSHA PSM CFR 1910.119 intends to ensure that the PSM program of the other 13 elements of PSM is operating in an integrated and effective manner. Audit acts as a tool to help in identifying gaps in PSM program and develop recommendations to further improve on the effectiveness of PSM program. However, there is a lack of proper model to conduct the audit in the industry. Unclear modeling of the audit deters the industry to perform compliance audit. Furthermore, there is no simple implementation method for the process of conducting compliance audit for managing process safety management in process industries. The available compliance audit model available did not conform to the six essential components of a compliance audit based on OSHA PSM. Thus, development of an efficient compliance audit model is recommended to manage process safety management in process industries. The model of the compliance audit will be based on the OSHA Instruction CPL 2-2.45A CH-1 and OSHA PSM CFR

1910.119. The model should be able to provide guidance on the planning of the audit, flow of the execution of the audit and also documentation of the audit.

1.3 Objective

The objective of this research study is as follows:

- i) To develop a systematic and comprehensive compliance audit model of PSM elements based on OSHA Instruction CPL 2-2.45A CH-1 in compliance with other OSHA PSM Standard which includes the six essential components and with proper guidance based on the framework developed.

1.4 Scope of Study

The scope of study for this research revolves around the development of effective compliance audit model to manage process safety management. Compliance audit is usually performed on the other 13 PSM elements, but for this research two elements which are Operating Procedure and Training is chosen. The two compliance audit model will have the same design framework to the other elements but only differs in the area of study to comply with PSM standards. A case study will be performed for the model of the two elements. The case study is to test the model developed for effectiveness and suitability of implementation. The scope of study includes the following:

- a) Analyze OSHA PSM Standard and Compliance Guideline Standard.
- b) Establish a framework for compliance audit element.
- c) Develop the compliance audit model based on the framework.
- d) Conduct case study on two PSM element which is the Operating Procedure and Training element.

CHAPTER 2.0

LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 Auditing

Decisions are made every day in our life, the decisions are made based on information available at the time of the decision is made. Thus, the information obtained must be reliable. The inconsistency of the information can cause inaccurate decision to be made and will cause detrimental effect one the wrong decision is made(Broberg, Umans, & Gerlofstig, 2013). For example, if there is an error in the financial statement of the borrower, the bank might lose money as the borrower might not be able to repay the loan obtained. The unreliable information or data are due to a few reasons such as remoteness of information, huge amount of data size, and the existence of complex data exchange between sources. (van der Aalst, van Hee, van der Werf, Kumar, & Verdonk, 2011)

The inconsistency of the data received, a method is needed to assure that the information or data received is sufficiently reliable in making decision especially in business. Thus, the development of a process called auditing or known as verification. The audit is performed by an independent party with no bias towards the business or decision made. Initially the objective of auditing is to detect and prevent any errors eventually the objective shifted towards to verify that the data or information is true and fair(van der Aalst et al., 2011). There are different types of

auditing in the industry such as accounting audit known as financial audit, quality assessment, project management, operations audit and energy audit. The audits are different in their own industry, for example in accounting, financial audit is carried out to seek for assurance whether the accounts books is in a balance state, true and fair while in project management, audit is conducted to assess whether the project is following the schedule planned and whether the project is carried out within the budget. (Francis, 2004)

Generally, auditing is used in every industry, be it in the manufacturing industry, finance industry and the process industry. Commonly audit is used in the business or finance industry to assess their operating effectiveness within their business boundaries. Boundaries in this context means rules and regulations set by the law, authorities and the business stakeholders. Audit is a mean of evaluating the execution of the business and whether the business adheres to the boundaries set. For example, in the banking industry, financial audit is performed by qualified auditors (CPA – Certified Public Accountants), where verification of the financial statements of the organization is evaluated in accordance to the legislation of the banking industry. The audit is carried out to check whether any violation of the law occurs and also identification of gaps to improve efficiency and effectiveness of the said industry (Sarens, De Beelde, & Everaert, 2009; Zhou, 2007).

Auditing can be carried by an internal or external party, where the internal party is usually sourced within the company itself and external auditors is the engagement of service provided by an external party (Barua, Rama, & Sharma, 2010). Most importantly, the auditors should be independent during their auditing process and judgement. An auditor should be proficient in the field he or she is auditing and have to be knowledgeable in the auditing process. The auditor should also possess traits of integrity, patience, honesty, and fair. He or she who is auditing should have a thorough knowledge of the law principles in the industry before conducting the audit. ((CCPS), 1993; van der Aalst et al., 2011)

Normal auditing will have to comply with rules and regulations of the business of the auditing. The laws vary from business to business. For example, in financial audits, the auditing will have to comply with The International Accounting Standards Committee and the Accounting Standard Board of the Institute of Chartered Accountants where rules will be available from the standards available on the standards of auditing (Funnell & Wade, 2012; Sarens et al., 2009). For auditing in a manufacturing business various laws will be considered, such as Health and Safety Act, quality and performance act. Certain businesses have their own standards to comply as well.

2.2 OSHA PSM Standard – Compliance Audit

In the context of this research, compliance audit is conducted in process industries which use the OSHA PSM Standard. It is an audit process to verify on the efficiency and effectiveness of the system implemented. The OSHA PSM CFR 1910.119 in accordance with the usage of highly hazardous chemicals as listed in Appendix A of OSHA PSM CFR 1910.119, has stated that there are 14 elements to be covered in process safety management ((OSHA), 1992). The elements are employee participation, process safety information, process hazard analysis, operating procedures, training, contractors, pre-startup safety review, mechanical integrity, hot work permit, management of change, incident investigation, emergency planning and response, compliance audit and trade secrets ((OSHA), 1992; Inc., 2004; Mason, 2001a, 2001b). The standard is introduced to aid employers in the process industries to prevent or mitigate potential chemical release that could lead to a catastrophic accident in the workplace which might affect the surrounding community as well. Process safety management (PSM) is the proactive identification, evaluation and mitigation or prevention of chemical releases that could occur as the results of failures in processes, procedures or equipment (Einolf & Menghini, 1999).

Compliance audit is the need to evaluate compliance with the PSM standard particularly the other thirteen (13) elements, the evaluation should be performed at

least every three years. This audit will verify procedures and practices used are adequate and are being executed in compliance with the PSM standard. In addition according to OSHA, there are 6 essential components of compliance audit which is planning, staffing, format, conducting the audit, evaluation and corrective action and lastly documentation ((CCPS), 2011). All of the 6 components are needed to form a good compliance audit ((CCPS), 1993).

In the OSHA PSM CFR 1910.119, it is stated that the audit must be conducted by at least one person knowledgeable in the field process and a report of the findings of the audit must be produced and any deficiencies found should be corrected. The audit must be documented and the two most recent compliance audit reports must be kept on file for future reference((CCPS), 2011; (DEC), 1997; (OSHA), 1994;Energy, 1996).

The PSM standard is known as a performance standard. Compliance is a judgment of the best management practices in the process industries and is usually valid at the current period of time. OSHA stated that an audit with respect to compliance with the PSM standard is an extremely important function. OSHA added that compliance audit acts as a self-evaluation for employers to measure the effectiveness of their process safety management system. In recognizing the problem, OSHA developed a guideline for compliance audit in accordance to OSHA PSM CFR 1910.119 standard. The standard is known as the Process Safety Management of Highly Hazardous Chemicals – Compliance Guidelines and Enforcement Procedures (CPL 2-2.45A CH-1)((OSHA), 1994; Downs, 2005).The guideline is intended to help in evaluating an employer's compliance with the PSM standard whereby it shall be used in conjunction with Appendix B: Clarifications and Interpretations of the PSM Standard (CPL 2-2.45A CH-1) ((OSHA), 1994).

In general, the guideline for compliance audit present a program summary, quality criteria references and a verification checklist for each of the PSM elements.

The verification checklist consists of records review, on-site inspection and interview. Since, compliance audit have to be completed for all 13 elements of PSM, there will be interrelationship of elements. This interrelationship shall be documented and should be crosschecked before completion of audit.

The techniques used to conduct compliance audit varies, either being performed internally, corporate auditors or engaging with third party auditors(Einolf & Menghini, 1999). The audit should be a review of compliance with the overall PSM standards. Despite different techniques available, the common steps in performing compliance audit are the same. Planning stage, implementation of audit and documentation of audit are the phases of compliance audit activity ((CCPS), 2011; (OSHA), 1994;Downs, 2005). In the planning stage, assigning of lead auditor or team, scope of audit, preparation of specific documents for review and facility planning; are among the common jobs. Implementation of audit is more straight forward, usually conducting meetings, perform on-site inspection and conduct interview. The last stage is the documentation stage, whereby deficiencies are recorded and corrective action is taken into action (Safety Resources Co. of Ohio, 2009).

Hilscher-Clarke added that compliance audit is a technique used to gather sufficient facts and information, which includes statistical information, to verify compliance with standards(Safety Resources Co. of Ohio, 2009). Auditing of process safety management is to evaluate the design and effectiveness of the program and also an on-site inspection of the safety and health conditions and also best practices implementation. The essential elements of the audit based on Hillscher-Clarke are Planning, Staffing, Format, Conducting the Audit, Evaluation and Corrective Action(Safety Resources Co. of Ohio, 2009).

There are a few compliance audit system which has being used in the process industries, where various tools have been used such as a checklist, questionnaire and

interview, and the use of software modeling to assist in conducting audit(Birkmire, Lay, & McMahon, 2007; Energy, 1996; Nivolianitou & Papazoglou, 1998). The tools used have its own limitation; some of the results obtained are subjective and has different interpretation. Appendix A shows a sample of compliance audit system implemented by the US Department of Energy (DOE)(Energy, 1996) which implement the questionnaire reporting in the audit of PSM elements based on OSHA Standard. Another example of audit system is developed by EHS Management Partners, Inc. which provides Environmental, Health and Safety services to the industry; the system is model on Microsoft Access to provide a comprehensive database of all the PSM elements for each tracking and documentation (Einolf & Menghini, 1999). Questions regarding each of the elements will be available in the model, and will be assessed and given a score for each element. The system could also produce report to facilitate easy reference. In the model developed by EHS Management Partners, Inc., there is unclear step on how to conduct auditing. The system did not explain on the steps to conduct the audit. Besides that, there are also irregularities of format between the technique used by EHS Management Partners, Inc. and the technique used by Hillscher-Clarke. There is no fixed technique used by everyone, and this will cause confusion among users. A screenshot of the system developed by EHS Management Partners, Inc. is shown in Figure 1 and Figure 2.



Figure 1: Screenshot of EHS Management Partners, Inc. Compliance Audit System (Einolf & Menghini, 1999)

Edit Facility Assessment						
Assessment Data		Pulp and Paper Giant	Southern	Pine City	09/09/1997	?
Question No:	3	Mgmt Cat:	Employee Participati	RegRef:	1910.119 (c) (3)	
Question :	Does the written program provide employees (including contractor employees) and their representatives access to process hazard analyses and all other					
Assessment	Suggested Practices	Implementation Levels	Guidance			
Implem. Level:	3	Key Issue?	<input type="checkbox"/>	Further Investigation?	<input type="checkbox"/>	
Good Practices:	Policy states that employees have access to information.					
Findings :	Contractors and their employees need to be provided with access to process hazard analyses and other information.					
DeleteQuestion			Go To	Close		
Record:	3	of 134				

Figure 2: Screenshot of EHS Management Partners, Inc. Compliance Audit System (Einolf & Menghini, 1999)

CHAPTER 3.0

RESEARCH METHODOLOGY

3.0 RESEARCH METHODOLOGY

3.1 Research Approach

The framework of the compliance audit model will be develop based on the OSHA Instruction CPL 2-2.45A CH-1 entitled Process Safety Management of Highly Hazardous Chemicals – Compliance Guidelines and Enforcement Procedures. The framework will provide a basis on the steps to conduct audit of process safety management. Then, the compliance audit model will be developed based on the framework. Case studies of the model will be conducted to check for effectiveness of the model. Two elements, Operating Procedure and Training are chosen as the case study for the model. The case study will determine whether the compliance audit model develop can be implemented in the near future in process industries. Thus, the process industries can benefit in terms of a successful implementation of process safety management program while preventing major disaster such as fire, explosion and unplanned release of toxic materials. Figure 3 shows the flow chart of the research methodology.

Tools such as Microsoft Access and Excel will be used to develop the framework and eventually the model. The model focuses on being user-friendly and effective in performing auditing. The model developed will be in a form of database whereby the user could input data into the model and could retrieve data if

necessary. Piping and Instrumentation Diagram (P&ID) is used as a basis to conduct the compliance audit, the audit revolves around the P&ID and compliment the database model to ensure a thorough process of audit. (Refer Chapter 4.0 for more detailed discussion on the framework and the use of P&ID)

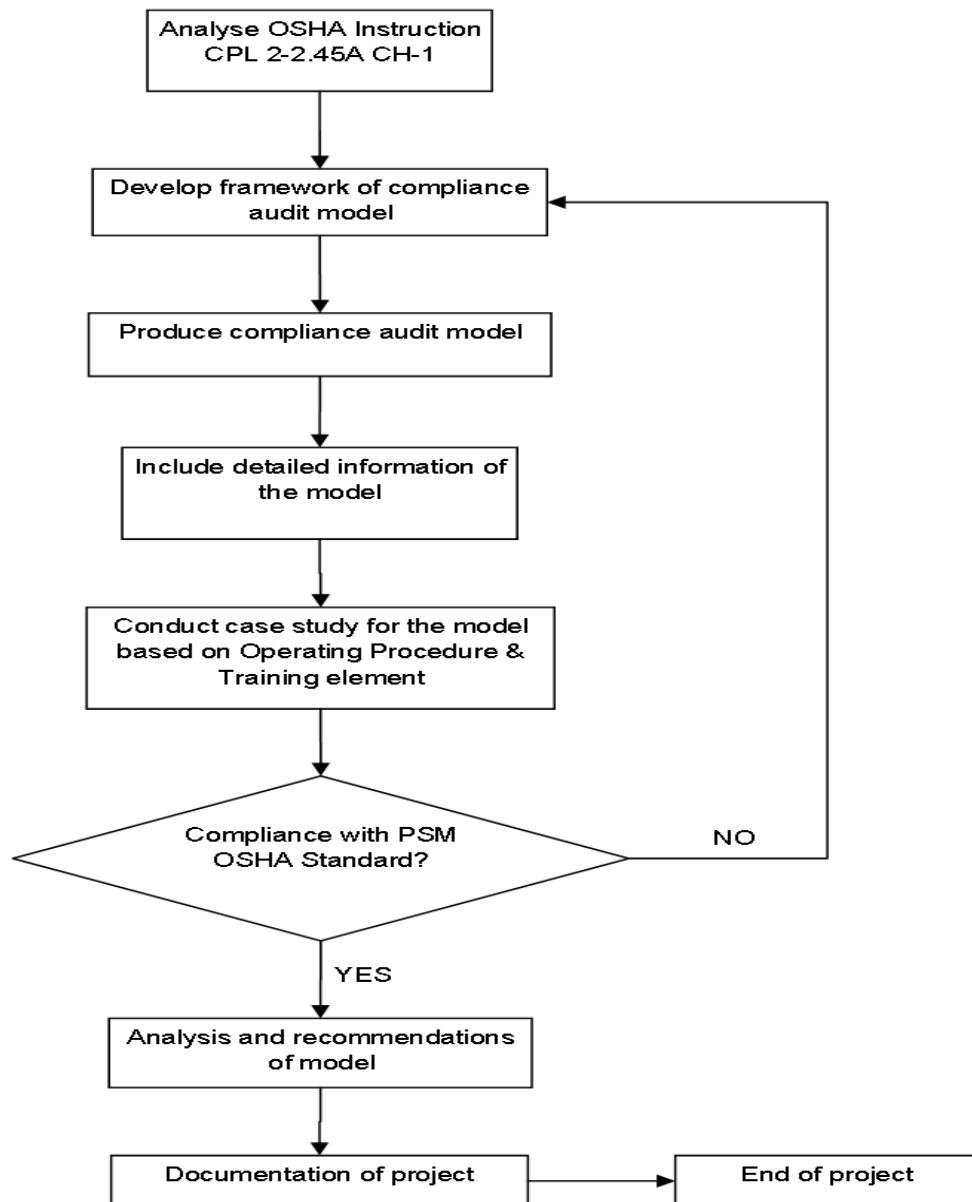


Figure 3: Flow Chart of Research Methodology

The research methodology of compliance audit element consist of:

- i) Analysis of OSHA Instruction CPL 2-2.45A CH-1, OSHA PSM CFR 1910.119 and other relevant materials.
- ii) Develop a general framework for compliance audit model.
- iii) Using the information of PSM elements and the framework, a working model can be produced using appropriate tools such as Microsoft Excel and Microsoft Access.
- iv) Conduct of case study for the model.
- v) The result of the effectiveness of the case study is analysed to determine the model achieve the intended requirements of PSM audit. Recommendations for further improvement are also included.
- vi) Documentation of research.

3.2 Key Milestones

The key milestones for this research are as follows.

- i) Literature review of related materials.
- ii) Analysis of OSHA Instruction CPL 2-2.45A CH-1 and OSHA PSM CFR 1910.119.
- iii) Framework of system.
- iv) Produce compliance audit model.
- v) Case study of the model based on Operating Procedure and Training element.
- vi) Analyse results from the case study.
- vii) Documentation.

Appendix B shows the Gantt Chart of the research.

CHAPTER 4.0

RESULTS AND DISCUSSION

4.0 RESULTS AND DISCUSSION

4.1 Compliance Audit Framework

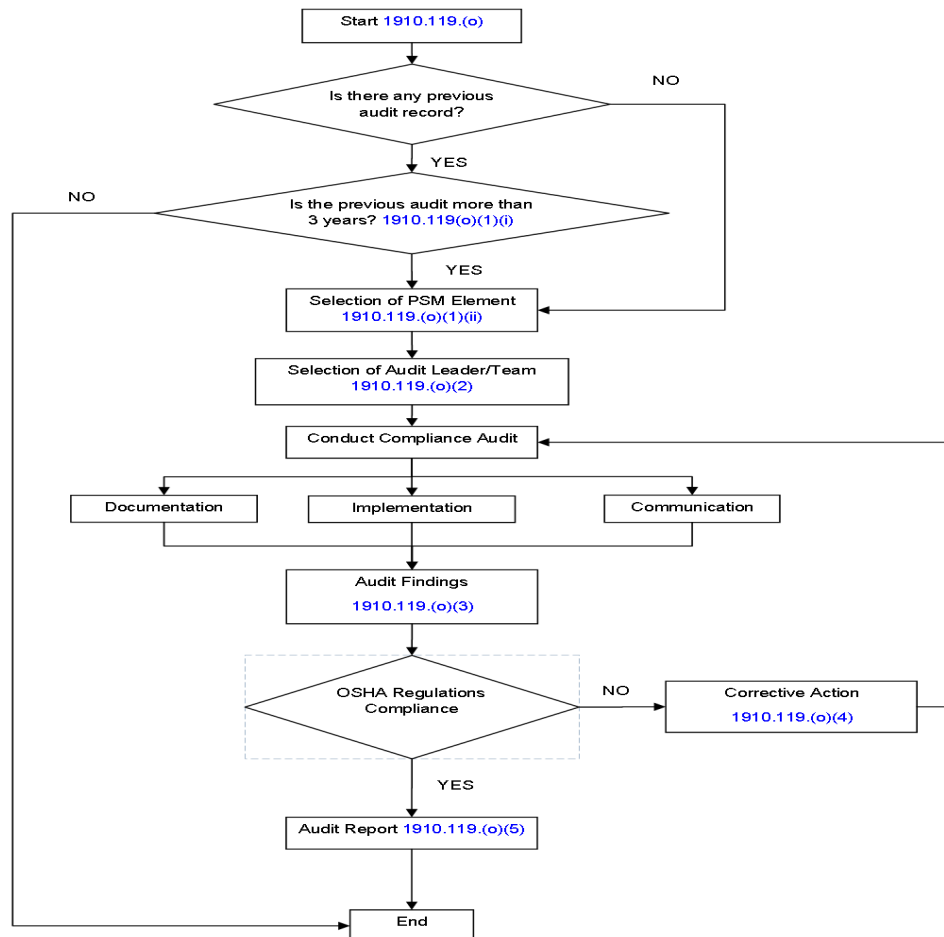


Figure 4: Framework of Compliance Audit Model

4.1.1 Framework Description

Figure 4 (Appendix D) shows the framework of the compliance audit which starts from the initiation of the audit, selection of the element, selection of the audit leader or audit team, commencement of the audit, data gathering, and verification of compliance with OSHA PSM Standard, corrective action, documentation of audit and finally end of the audit. After corrective action is performed, the audit process will repeat again to satisfy the OSHA PSM Standard before documentation of the audit.

The compliance audit of PSM in the process industries begins with the initiation of the audit by the company top management level. The compliance audit will have to audit all the other 13 elements of PSM, which are the employee participation, process safety information, process hazard analysis, operating procedures, training, contractors, pre-startup safety review, mechanical integrity, hot work permit, management of change, incident investigation, emergency planning and response, and trade secrets. The audit can take place simultaneously for all the elements or the management could select a few elements to be conducted first and the rest is done in stages over a period of time. The audit must be done every 3 years according to OSHA PSM Standard, thus the audit of all the elements involved could be staggered in the period of 3 years.

After an element was chosen to be audited, a leader or a team of audits are selected to perform the audit. The leader or team members should be familiar with the process of the plant, has experience in process safety management and has also experience in audit techniques. This characteristic is required in the leader or the team members. The number of team members can be in the range of two to 6 people. The size depends on the size of the facility, scope of the audit and the amount of work required to be performed. The audit team comprises of personnel from different background to offer a fresh look into the process, thus avoiding bias opinions. Some companies do tend to hire external auditors to perform the audit as an independent audit team but usually external parties are only used when the audit

is performed in a very big scale for example the audit of the whole company. For the audit of PSM element, it is better to use internal personnel to perform the audit as the personnel could capitalize on the missing gaps of the elements and could enhance the personnel's knowledge in the field.

Next, will be the commencement of the audit where it will be divided into three parts which are the Documentation, Implementation and Communication criteria. This will be form the basis of the implementation of the audit. In documentation, the necessary documents related to the elements are prepared for the team to evaluate. The review of the documents is performed to identify whether the documents required for the elements are available, the content and whether the documents are easily accessible by personnel related to the element. For example, in Operating Procedure element, the document related to the element is operating procedure for the unit audited. The operating procedure must include startup, shut down, emergency and normal operations procedure. The review of the operating procedure will include whether the operating procedure is the latest available one, the information in the procedure is valid for the process, and whether the operating procedure is available for all personnel involve in the operations of the unit.

In implementation criteria, the audit team will perform an on-site inspection of the audited unit or the section. The on-site inspection will provide the audit team hands on insight whether the process is conducted as stated in the documents that has been audited. The inspection will also clarify on any information which is included in the documents and to determine whether the information gathered during audit is sufficient and could satisfy the required standards set by the company or OSHA PSM. The site inspection could provide an alternative angle for the audit, and the auditors could audit on the working condition of the personnel as well.

The next step is the communication, where a personal communication is held with the working level staff of the section or unit that is in the scope of the audit. The communication can be in the form of interview, questionnaire and checklist. The method use varies from auditors to auditors. For example, interview

can be performed on the working level during the site inspection, to gauge whether the personnel is aware about the changes that have been made beforehand. The communication between working level staff and auditors can be in an informal state where the interview can be held on site. The purpose of the communication is to establish whether any confusion in information gathered before this can be explained by the working level staff. Consistency of the answers provided will also be identified as the working level staff are working in the same location and thus should have a solid and accurate explanation on the same subject matter. Checklist and questionnaire can also be used to determine whether the working level staffs are aware on certain information that is available for their usage.

The next step is the compilation of data gathered from the audit performed. During this period, the audit team will sit down and discussion on the audit will be conducted. Then, the data and information is review for compliance with the OSHA PSM Standard and also the company standards or regulations if the management insists. The main compliance of the audit should be towards the OSHA PSM Standard, to verify whether the implementation of the process safety management is up to the bar set by the standards. If the audit team identify on the missing links or gaps in the element, a corrective action should be proposed to rectify on the missing gaps. Once the corrective action has been performed, audit is performed again to check whether all the corrective action has been properly implemented and has satisfy the requirement of the standards used. If the element audited satisfy the OSHA PSM standards, then documentation of the audit could be performed before finishing the audit process. The documentation of the audit details the whole process of the audit and provides recommendation to the management if there is any for further improvement. Finally the audit can be considered close, and could move on to the next element to be audited.

4.2 Use of Piping and Instrumentation Diagram in Compliance Audit

Piping and Instrumentation Diagram (P&ID) contains schematics for all piping, valves, various components such as pneumatic air lines and control

mechanisms such as control valves. It provides an additional level of detail for the design of a process plant. The P&ID is used as a basis to conduct and manage information regarding compliance audit. Since, the P&ID contains details of the equipment and its fixtures and necessary control system, P&ID is used to develop a model for compliance audit. P&ID is commonly used in process plants, whereby engineer refers to it whenever a problem occurs or for training purposes. Thus, P&ID is useful as it contains information that is essential to conduct an audit and could also be easily implemented in a process plant.

In a P&ID, it contains several nodes depending on the number of equipments and its auxiliary components. Commonly, there are hundreds of P&ID available in a process plant. Thus, it is most appropriate to start by selecting an element to be audited. After the necessary documents have been collected and reviewed, then only the audit can be conducted. The cycle continues for each node for the corresponding P&ID documents that is audited. Once all the nodes have been audited, a report of the audit findings should be developed and any deficiencies found during the auditing should be reported. A corrective action should be proposed for each finding and must be implemented to rectify the deficiency. After the corrective action has been implemented, audit is performed again to check whether standards have been met accordingly to the OSHA PSM Standards. The audit is repeated until all 14 elements have been audited. Figure 5 summarizes the implementation of the usage of P&ID as the basis for Compliance Audit.

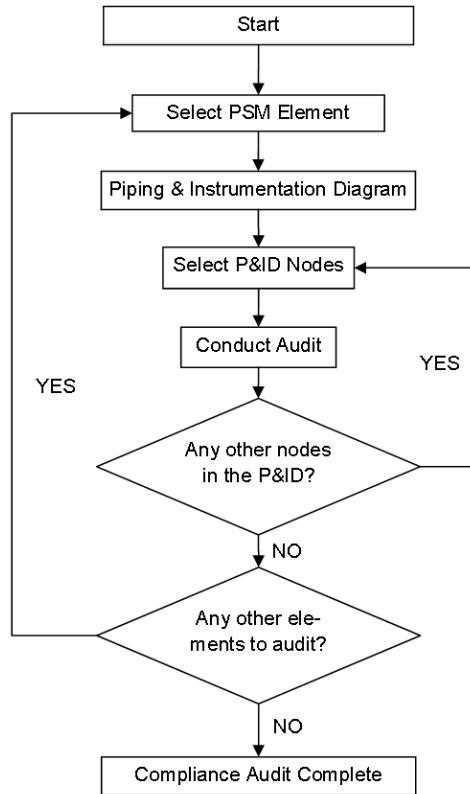


Figure 5: P&ID as Basis of Compliance Audit

4.3 Compliance Audit Model

The implementation of the usage of P&ID as the basis for compliance audit can be further strengthened by the use of a model to manage and keep track of audit activities. The use of computer database software can be utilized for the said purpose. The proposed database is developed using Microsoft Office Access to demonstrate on the effectiveness of the compliance audit program.

The function of the compliance audit model is as following:-

- i) To evaluate the effectiveness of PSM programs.
- ii) As a tool to manage and track the progress of compliance audit.
- iii) To provide user with consistent format of auditing and ease of reporting.
- iv) Can provide a simple report for the compliance audit.

- v) Provide access of information to employers and employees

The model takes into account on the requirements for employers to comply with the OSHA PSM Compliance Audit Standard. The model is designed to ensure that the audit is performed systematically and consistently throughout the audit process. The model is divided into two parts, whereby the first part is the main interface of the model where it deals with the management side of the auditing which includes planning, staffing and the standards of PSM elements. The second part of the model is the collection of data from the audit process. The details of the mode will be discussed further in Section 4.3.1 and Section 4.3.2 respectively.

4.3.1 Main Interface

The main interface is based on the requirements set upon by the OSHA PSM Standard 1910.119(o) where stated that there are five requirements that are to be considered. The main interface provides an overview of the audit based on the input of data from the users. The requirements are audits to be performed at least every three years, maintenance of audit reports for at least two audits, audits conducted by at least one knowledgeable individual in the audit process, documentation of appropriate response for each findings and documentation of deficiencies found have been corrected. Based on that, five sub sections of the interface are proposed. The main interface comprises of the following subsections according to the requirements:-

- i) Planning of audit.
- ii) Staffing of audit.
- iii) Audit findings.
- iv) Corrective action.
- v) Report.

Standard	Description	Complete	Incomplete
1910.119(o)(1)	Planning	<input checked="" type="checkbox"/>	<input type="checkbox"/>
1910.119(o)(2)	Staffing	<input checked="" type="checkbox"/>	<input type="checkbox"/>
1910.119(o)(3)	Audit Findings	<input checked="" type="checkbox"/>	<input type="checkbox"/>
1910.119(o)(4)	Corrective Action	<input checked="" type="checkbox"/>	<input type="checkbox"/>
1910.119(o)(5)	Report	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Figure 6: Main Page - Audit

Figure 6 shows the main interface page which consists of the standard requirement of compliance audit, the description of the standard, a complete and incomplete check box of the audit and a remarks column. The five standards requirement will be discussed further in the subsequent section. The complete and incomplete check box is to determine whether the task of audit program according to the requirements have been completed or otherwise. From Figure 6, based on the case study conducted, all five requirements have been completed and satisfied complying with the OSHA PSM Standard for compliance audit element.

PSM ELEMENT	Date of Previous	Date of Next	Completion Date	Compliance	Non Compliance	Previous Report	Previous Report Location
Compliance Audit				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Contractors				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Emergency Planning and Res				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Employee Participation				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Hot Work Permit				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Incident Investigation				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Management of Change				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Mechanical Integrity				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Operating Procedure	7/19/2010	7/22/2016	7/22/2013	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	..\DATABASE\Report - OLD\Pre
Pre-Startup Safety Review				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Process Hazard Analysis				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Process Safety Information				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Trade Secrets				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
Training	7/19/2010	7/22/2016	7/22/2013	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	..\DATABASE\Report - OLD\Pre

Figure 7: Planning - Audit

Figure 7 shows the planning section of the audit model. This section refers to information of the previous audit and to assist user to plan on which element that will need to be audited. The model consist of the list of PSM element, date of

previous audit, date of next audit, completion date of the audit, compliance or non-compliance of the PSM element, an availability of report. According to OSHA PSM Standard 1910.119(o)(1), it is stated that the compliance audit should be performed at least every three years. Thus, this section will show the timeline of which element that will be audited. The compliance and non-compliance is also important as to gauge on whether the element comply with the OSHA PSM Standard. If an element does not satisfy the requirements set upon, auditing of the element should be conducted to determine on the deficiencies or gaps in the implementation of the element in the PSM program. In OSHA PSM Standard 1910.119(o)(5), it is also stated that employers should keep the two most recent compliance audit reports.

PSM Element	Audit Leader	Member(s)
Mechanical Integrity		
Operating Procedure	Amirrul	Nyoman, Jeremy & Chin
Pre-Startup Safety Review		
Process Hazard Analysis		
Process Safety Information		
Trade Secrets		
Training	Edison	Cindy, Mandy, Taufik & Thiruselvan

Figure 8: Staffing - Audit

The next section of the audit model is the staffing requirement of the audit program as shown in Figure 8. In OSHA PSM Standard 1910.119(o)(2), it is stated that the compliance audit should be conducted by at least one person who is knowledgeable in the process. In a process plant usually each element will be assigned to a custodian who is proficient in the element. The custodian usually will be the audit leader who leads the audit team. The number of members in the audit

team is commonly between three to five members to ensure a variety of insight is available while conducting the audit. The members of the audit team should also be knowledgeable in the unit operation or equipment which is being evaluated. This will ensure that the audit carried out is effective and satisfy the requirement set upon by the standard. In the model as seen in Figure 8, the team leader and members for the audit team can be identified and is stored for record purposes.

PSM Element	No of Findings	Report	Location
Compliance Audit		<input type="checkbox"/>	
Contractors		<input type="checkbox"/>	
Emergency Planning and Response		<input type="checkbox"/>	
Employee Participation		<input type="checkbox"/>	
Employee Participation		<input type="checkbox"/>	
Hot Work Permit		<input type="checkbox"/>	
Incident Investigation		<input type="checkbox"/>	
Management of Change		<input type="checkbox"/>	
Mechanical Integrity		<input type="checkbox"/>	
Operating Procedure	9	<input checked="" type="checkbox"/>	..\DATABASE\Report\Audit Report - Operating Proc
Pre-Startup Safety Review		<input type="checkbox"/>	
Process Hazard Analysis		<input type="checkbox"/>	
Process Safety Information		<input type="checkbox"/>	
Trade Secrets		<input type="checkbox"/>	
Training	9	<input checked="" type="checkbox"/>	..\DATABASE\Report\Audit Report - Training.docx

Figure 9: Audit Findings - Audit

The audit findings section is as shown in Figure 9. It shows the number of findings for each element audit and whether a report for the findings has been developed. The OSHA PSM Standard 1910.119(o)(3) states that a report of audit findings should be developed for each audit. The report can be located via the report location column, whereby the report can be in the form of hardcopy or softcopy which can be stored in the server. Based on the two case studies performed, it is found out that nine findings were recorded for each element. The findings were recorded in the report where it is kept in the computer directory at <C:\DATABASE\Report\Audit Report - Operating Procedure.docx>. and <C:\DATABASE\Report\Audit Report - Training.docx> respectively.

PSM Element	No of Finding	No of Proposed Correct	Complete	Incomplete	Due Date	Re-Audit	Report	Remarks
Mechanical Integrity			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	
Operating Procedures	9	7	<input type="checkbox"/>	<input checked="" type="checkbox"/>	7/29/2013	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Preliminary Report. Need to Re-Audit
Pre-Startup Safety Review			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	
Process Hazard Analysis			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	
Process Safety Information			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	
Trade Secrets			<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	
Training	9	2	<input checked="" type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input checked="" type="checkbox"/>	Report complete

Figure 10: Corrective Action

The corrective action section as shown in Figure 10 is an extension of the audit findings, whereby any findings regarding the audit should have a corrective action to correct the deficiencies in the PSM program. As stated in the standard of 1910.119(o)(4), the response must be promptly determined and documented and any corrective action taken should also be documented. The model will show the number of the proposed correction action from the data collected and show whether the corrective action have been completed or not. A re-audit after the corrective action is also carried out and finally documented. The number of corrective action recommended from the audit performed will be recorded in the model as seen in Figure 10, and whether the corrective action has been implemented or not, the user could track the progress. An estimated date (due date) of completion of the corrective action is also shown. All the corrective action will be recorded in the report which can be retrieved easily from the Report section of the model.

PSM Element	Custodian	Report	Location	Compliance	Non Compliant	Remark(s)
Compliance Audit				<input type="checkbox"/>	<input type="checkbox"/>	
Contractors				<input type="checkbox"/>	<input type="checkbox"/>	
Emergency Planning and Response				<input type="checkbox"/>	<input type="checkbox"/>	
Employee Participation				<input type="checkbox"/>	<input type="checkbox"/>	
Employee Participation				<input type="checkbox"/>	<input type="checkbox"/>	
Hot Work Permit				<input type="checkbox"/>	<input type="checkbox"/>	
Incident Investigation				<input type="checkbox"/>	<input type="checkbox"/>	
Management of Change				<input type="checkbox"/>	<input type="checkbox"/>	
Mechanical Integrity				<input type="checkbox"/>	<input type="checkbox"/>	
Operating Procedure	Amirrul	R101A	..\DATABASE\Repc	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Preliminary Report
Pre-Startup Safety Review				<input type="checkbox"/>	<input type="checkbox"/>	
Process Hazard Analysis				<input type="checkbox"/>	<input type="checkbox"/>	
Process Safety Information				<input type="checkbox"/>	<input type="checkbox"/>	
Trade Secrets				<input type="checkbox"/>	<input type="checkbox"/>	
Training	Edison	R103B	..\DATABASE\Repc	<input type="checkbox"/>	<input checked="" type="checkbox"/>	

Figure 11: Report

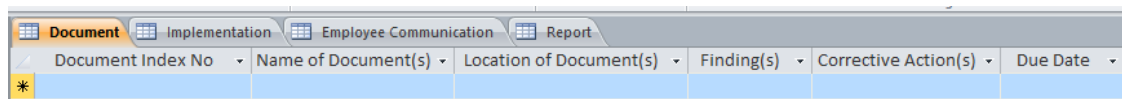
Figure 11 shows the report section for the compliance audit model. The section will determine the report number and the location of the report for each compliance audit conducted. The report will be retained for future audit works as stipulated in the 1910.119(o)(5) standards. The section will also show whether the PSM element audited comply with the OSHA PSM Standard. Each element has its own custodian whereby the custodian is usually the one who leads the audit team whom performed the audit as shown in Figure 11. A report number is given for each report for identification, the location is also stated. The compliance and non-compliance checkbox is also included to identify whether the element audited comply with the standards. Occasionally, a preliminary report is made before corrective action is taken and after proper corrective action, the final report is produced. For example, for the Operating Procedure element compliance audit, the custodian for the element is Mr. Amirrul and after performing the audit, it is determined that the element audited does not comply with the OSHA PSM Standard used. A preliminary report is produced first while waiting for the corrective action to be completed. A report number of R101A is given and the report is stored in the server/computer directory at C:\DATABASE\Report\Audit_Report_-_Operating_Procedure.docx. A re-audit will be performed again so that compliance of Operating Procedure element can be achieved. The model is intended to record the data for safekeeping purpose and as a reference point for the next audit.

4.3.2 Data Collection

The audit data is needed to gauge whether the PSM element comply with the OSHA PSM standard. The data will be available from the audit process conducted and the audit team will use the model to help them to record the data for analysis of compliance. A listing of all standards of each PSM elements is provided to ensure a clear and proper guidance on the OSHA PSM requirements that is needed to be fulfilled by the audit process. The listing of the standards for each element is shown in Appendix C.

The user of the model will have to input the audit findings into the model to enable the data is recorded and stored in the model. This will centralize the collection of the data and could help manage the data. The data will be obtained from the process of auditing of the P&ID drawings. The model for the data capturing section consists of the following:-

- i) Document
- ii) Implementation
- iii) Employee Communication
- iv) Report



Document	Implementation	Employee Communication	Report		
Document Index No	Name of Document(s)	Location of Document(s)	Finding(s)	Corrective Action(s)	Due Date
*					

Figure 12: Document Section

In the Document section, whereby any documents related to the nodes of the P&ID drawings or the elements will be audited. Documents such as MSDS sheet, operating procedures, and incident reports are evaluated. Each document will have their own specific identification number, which will be used throughout the data model as a common denominator for easy tracking and management of data. In this

section, the user needs to report on the findings that did not comply with the standards of the elements and propose a suitable corrective action to rectify the issue. The rectification should take place as soon as possible to avoid any potential of danger.

Document Index No	On-Site Evaluation	Finding(s)	Corrective Action(s)	Due Date
*	<input type="checkbox"/>			

Figure 13: Implementation Section

Besides review of documents in a compliance audit, auditing can be done via on site evaluation to have a firsthand look regarding the site condition. This will also provide further explanation based on the documents audited previously. Any findings from the implementation of site visit are recorded down and corrective action is again proposed to rectify any deficiencies found. If the deficiency is found to be critical and in need of immediate rectification the audit leader or audit team can suggest on a scheduled date for rectification to avoid any potential accident to occur.

Document Index No	Interview	Questionnaire	Checklist	Finding(s)	Corrective Action(s)	Due Date
*	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			

Figure 14: Employee Communication Section

Another technique for conducting audit is the communication with employee who is involved in the area which is being audited. The audit will engage with the employee for information related to the process area and PSM awareness. The communication can be in form of interview, questionnaire or a checklist. Any findings from the action will be recorded and corrective action will be proposed to correct deficiency found.

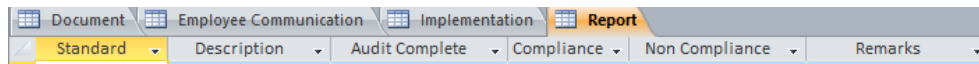


Figure 15: Report Section

The last section of the data capturing model is report. This section is where information regarding audit report is stored. This section identifies whether an audit has been completed according to the standards of the PSM element and to check for compliance with the elements standards. The standard for each element is unique to the PSM element and is based on the OSHA PSM Standard. Refer to Appendix C for the full list of standards for each element. The data stored here is as a preliminary report for each PSM element which will relate back to the analysis of data section. Compliance and non-compliance of element is based on the standards for each element, and all of the standards have to be satisfied to achieve compliance.

The compliance audit model will provide a consistent and systematic flow of conducting the audit in process industries. The model will identify on the needs of corrective action to improve and maintain the quality of the PSM program implemented and comply with the OSHA PSM standard. To demonstrate the effectiveness and capability of the compliance audit model, a case study is conducted on the model. Two PSM elements is chosen, which is Training and Operating Procedure, as the benchmark for the case study. The two elements will be studied for their suitability and implementation of the model.

4.4 Case Study – Proof of Concept

The best way to verify the concept of the model is by implementing in a process plant but several factor such as data confidentiality, time and cost prohibits the implementation of the model. Thus, the proof of the model concept is via prior PSM element studied in pilot plant. To demonstrate the compliance audit model concept, two elements is selected which is Training and Operating Procedure. The Training element audit is carried out in the CO₂-Hydrocarbon Adsorption System

(CHAS) pilot plant under the Research Centre of CO₂ Capture (RCCO₂C) at Universiti Teknologi PETRONAS, while the Operating Procedure at the High Gravitational Natural Gas Unit (HGNGU) at UTP. Figure 16 shows the piping and instrumentation diagram (P&ID) of the absorption system in the pilot plant. Figure 17 shows the P&ID of the amine system of the HGNGU unit. Only one node highlighted in the red box is selected for the purpose of the case study for training element and operating procedure element. The data from the study of the PSM element is used for the compliance audit model and to verify on the compliance of the element.

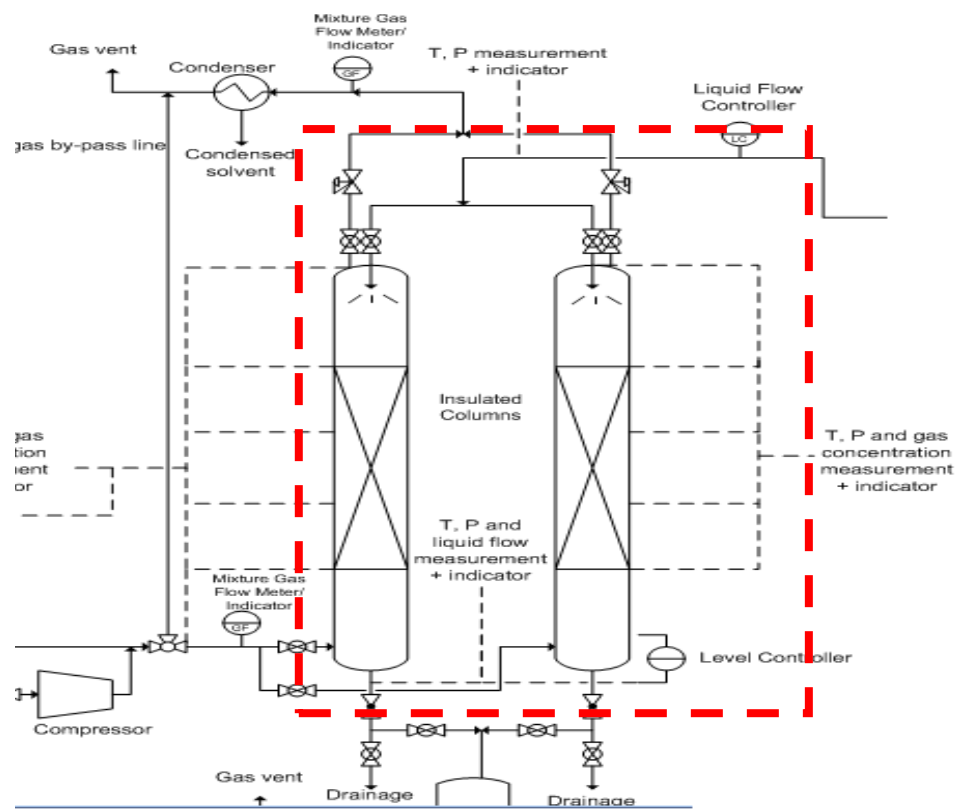


Figure 16: P&ID for Training Element

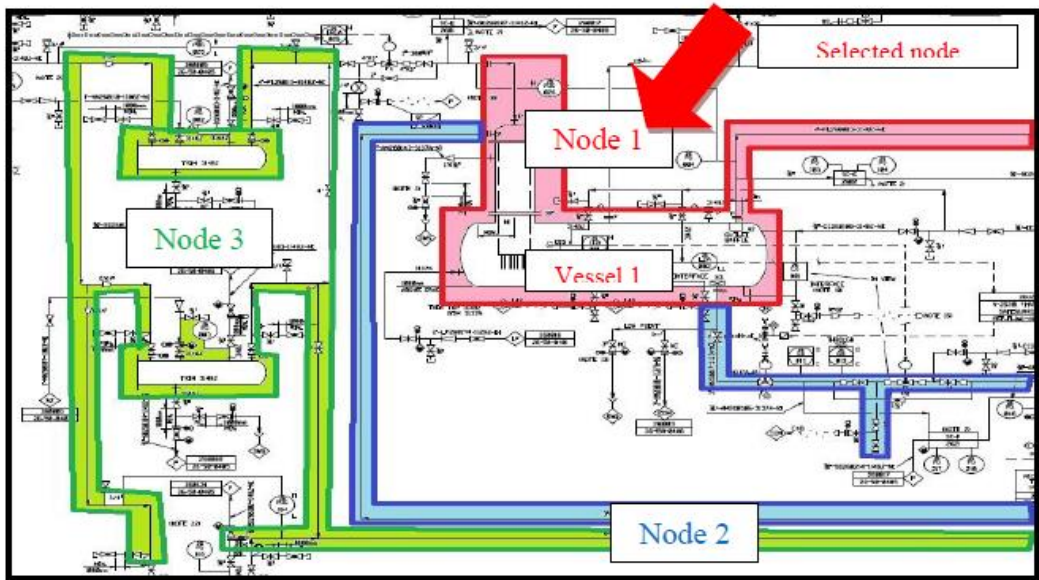


Figure 17: P&ID for Operating Procedure Element

4.4.1 Training Element – Proof of Concept

Document Index No	Name of Document (s)	Location of Document(s)	Finding(s)	Corrective Action(s)	Due Date
M1-AC01	Packing tower section in CHAS overview	..\DATABASE\Training\M1-AC01.docx	Available. Refer to OP.	N/A	
M2-AC01	AC01 standard OP and health and safety section of AC01	..\DATABASE\Training\M2-AC01.docx	Available. Refer to OP	N/A	
M3-AC01	Incident Command System	..\DATABASE\Training\M3-AC01.docx	Available. Refer to OP	N/A	

Figure 18: Document – Training Element

Document Index No	Interview	Questionnaire	Checklist	Finding(s)	Corrective Action(s)	Due Date
M1-AC01	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Completed initial training.		
M2-AC02	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Completed initial training for employees.		
M3-AC01	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Some employee have not completed the training	Organize training schedule. Refer to available training schedule	

Figure 19: Employee Communication – Training Element

Document Index No	On-Site Evaluation	Finding(s)	Corrective Action(s)	Due Date	Remarks
M1-AC01	<input type="checkbox"/>	Conducted training for employee			Refresh training every 2 years
M2-AC01	<input type="checkbox"/>	Conducted training for employee			Refresh training every 2 years
M3-AC01	<input type="checkbox"/>	Conducted training for employee. Some have not attended.	Refer to training schedule.		Refresh training every 2 years

Figure 20: Implementation – Training Element

Standard	Description	Audit Complete	Compliance	Non Compliance	Remarks
119(g)(1)(i)	Initial Training	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Some employee have not complete initial training program
119(g)(1)(ii)	Documentation	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
119(g)(2)	Refresher Training	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	

Figure 21: Report – Training Element

In training element (CFR 1910.119(g)) includes three standards which are initial training (CFR 1910.119(g)(1)(i)), training documentation or content (CFR 1910.119(g)(1)(ii)), and refresher training (CFR 1910.119(g)(2)). The three

elements are to be audited accordingly. Figure 18 shows the Document section for the audit conducted in the pilot plant. There are three documents related to the node selected, the three documents are M1-AC01, M2-AC01 and M3-AC01. The documents are of the packing tower of the CHAS system, the operating procedure and its incident command system. The location of the documents is stored at <C:\DATABASE\Training\M1-AC01.docx>. The documents stored are linked to the model for easy reference. The audit found out that the necessary documents are available and are commonly referred to the operating procedures. In Figure 19, it is found out that certain employees have not performed certain training such as the M3-AC01 module. The proposed corrective action is to refer to the training schedule and organize a training session if there is none available in the schedule. The implementation section of the audit as shown in Figure 20, looks into the implementation of the training program in the pilot plant. The training program is implemented and executed but certain employees have not completed the training program for some module. A refresher training program is also implemented as the training program is conducted every two years to all employees. From the audit based on the three standards of training element, we can conclude that the training program implemented comply with the training documentation and refresher training standard. The audit found out that the initial training program did not comply with the standards as some employees have not attended some of the training conducted. Therefore, the Training element can be said to be non-compliance to the PSM Standards. The audit can be revalidated again once all the training programs have been completed.

4.4.2 Operating Procedure Element – Proof of Concept

Document Index No	Name of Document (s)	Location of Document	Finding(s)	Corrective Action(s)	Due Date
A100-001	Start Up of System	..\DATABASE\Operating Procedure\A100-001.docx	Available but not consistent with PSI data	Check with PSI data	8/7/2013
A100-002	Emergency Shutdown	..\DATABASE\Operating Procedure\A100-002.docx	Available but not consistent with PSI data	Check with PSI data	8/7/2013
A100-003	Normal Shutdown	..\DATABASE\Operating Procedure\A100-003.docx	Available but not consistent with PSI data	Check with PSI data	8/7/2013

Figure 22: Document – Operating Procedure Element

Document	Employee Communication	Implementation	Report			
Document Index No	Interview	Questionnaire	Checklist	Finding(s)	Corrective Action(s)	Due Date
A100-001	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	OP is available in server, need to be reviewed	Plan for OP review	8/7/2013
A100-002	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Lack of quality control of chemicals involved	Include quality control measures in OP	8/7/2013
A100-003	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	No control measures if physical contact with chemicals	Include control measures in OP	8/7/2013

Figure 23: Employee Communication – Operating Procedure Element

Document	Employee Communication	Implementation	Report		
Document Index No	On-Site Evaluation	Finding(s)	Corrective Action(s)	Due Date	Remarks
A100-001	<input checked="" type="checkbox"/>	In use. Safe work practice such as LOTO			Develop OP training as a refresher course.
A100-002	<input checked="" type="checkbox"/>	In use. Confined space entry module available.			Develop OP training as a refresher course.
A100-003	<input checked="" type="checkbox"/>	In use. No availability of safe work practices for opening process equipment or piping	Develop module/procedure for opening process equipment/piping	8/7/2013	Develop OP training as a refresher course.

Figure 24: Implementation – Operating Procedure Element

Standard	Description	Audit Complete	Compliance	Non Compliance	Remarks
119(f)(1)	Written Procedure Available and consistent with PSI	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Check available OP for PSI consistency
119(f)(1)(i)	Written Procedure for each operating phase	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Locate or develop missing operating phase OP
119(f)(1)(ii)	Written Procedure includes operating limit and process deviation consequences	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
119(f)(1)(iii)	Written Procedure includes safety and health considerations	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
119(f)(1)(iv)	Written Procedure includes safety systems and its functions	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
119(f)(2)	Access to Operating Procedures	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
119(f)(3)	Review of Operating Procedures	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Develop OP review program
119(f)(4)	Implementation of safe work practices	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Include safe work practices in OP

Figure 25: Report – Operating Procedure Element

The operating procedure element based on OSHA PSM Standard (CFR 1910.119(f)) contained eight standards that need to be complying from the compliance audit conducted. The first five standards (CFR 1910.119(f)(1) to CFR 1910.119(f)(1)(iv)) describe that there must be written procedure for each operating phase, its operating limit, safety and health considerations, and safety systems and their functions. The available written procedure must also be consistent with process safety information available. The other three standards (CFR 1910.119(f)(2) to CFR 1910.119(f)(4)) discusses on the accessibility of the procedures to employees, review of the procedures to reflect current operating practice and implementation of safe work practices in the procedures. Three documents related to the Aminex system where audited namely the start-up procedure, emergency shutdown procedure and normal shutdown procedure. All three procedure are available but the content is not consistent with process safety information (PSI) element. Thus, the PSI aspect of the written procedure must be check again. From the employee point

of view based on a checklist, it is found out that the operating procedure is available for employee access but certain content such as quality control and control measures if in contact with chemicals is not available in the procedure. The proposed corrective action can be taken is to review the procedures and include the missing content into the new procedure. From Figure 24, all three documents are in used from time to time and safe work practices are implemented in the procedure. Safe work practices such as lock out tag out (LOTO) and confined space entry hazards is included in the procedure but there is no written control hazards for the opening of process equipment and piping. The missing safe work practices should be included and operating procedure training should be developed as a refresher course. Based on the audit conducted, from Figure 25, it is concluded that the operating procedure element only comply with four standards as stated by OSHA PSM Standard and thus, the element is in a state of non-compliance. Once the corrective action has been taken, a re-audit will be perform again to check for compliance.

CHAPTER 5.0

CONCLUSION AND RECOMMENDATIONS

This research work proposes a simple and systematic flow of conducting compliance audit. It can be observed that the compliance audit model developed comply with OSHA PSM Standard as stated in CFR 1910.119(o) of the OSHA Instruction CPL 2-2.45A CH-1. The proposed framework details the proper flow of conducting compliance audit and as a guide to determine PSM deficiencies or gaps. The model is designed with the objective of satisfying the six essential components of a compliance audit which is planning, staffing, format, conducting the audit, evaluation and corrective action and lastly documentation. The use of the database model helps auditors to record data and keeps track of data and progress of the audit. In addition, the model also assists to plan for the compliance audit and as a summary on elements compliance with OSHA PSM Standard. The model could identify potential weaknesses or gaps in the PSM programs implemented and recommendations to improve the implementation of the PSM programs can help to reduce potential accidents such as fire, explosion and toxic release to occur. The proposed model of compliance audit developed using Microsoft Access, has the potential to be implemented in the process industries that could be used to assist auditors to conduct compliance audit. The model provide a consistent and standard format to be used for each element that is audited and reduce the number of different tools used before this such as checklist and interview session. The use of Piping & Instrumentation Diagram (P&ID) as a basis to conduct compliance audit promotes uniformity in conducting the audit. The P&ID guides user as each equipment or nodes in the P&ID is audited and thus creating a thorough and complete audit assessment for each element audited.

The proposed model can be improved further by implementing a score system for the audit findings, as a guide for users to prioritize on which corrective action should be implemented first. Besides that, to further enhance the effectiveness of the model, integration between PSM elements can be included in future work. P&ID is used to conduct the audit and usually when a node is selected, there will be an overlap of PSM elements in the node studied. Integration between PSM elements will further improve the audit process of the PSM programs. Furthermore, the model can be developed into a functional system to be used in the process industries. The system can eliminate the need of manual analysis of data whereby the system is independent and could interpret the audit data and can provide necessary feedback based on the data.

REFERENCES

1. (CCPS), Center for Chemical Process Safety. (1993). Guidelines for Auditing Process Safety Management Systems. 136.
2. (CCPS), Center for Chemical Process Safety. (2011). *Guidelines for Auditing Process Safety Management Systems* (Second Edition ed.): Wiley-AIChE.
3. (DEC), Compliance and Assurance Section of Department of Environment and Conservation NSW. (1997). *Compliance Audit Handbook*: Department of Environment and Conservation New South Wales (DEC).
4. (OSHA), US Occupational Safety and Health Administration. (1992). Process Safety Management of Highly Hazardous Chemicals *Occupational Safety and Health Standards* (Vol. 29 CFR 1910.119). Washington, US.
5. (OSHA), US Occupational Safety and Health Administration. (1994). Process Safety Management of Highly Hazardous Chemicals - Compliance Guidelines and Enforcement Procedures (Vol. OSHA Instruction CPL 2-2.45A CH-1).
6. (OSHA), US Occupational Safety and Health Administration. (2000). *Process Safety Management*: US OSHA.
7. Barua, Abhijit, Rama, Dasaratha V., & Sharma, Vineeta. (2010). Audit committee characteristics and investment in internal auditing. *Journal of Accounting and Public Policy*, 29(5), 503-513. doi: <http://dx.doi.org/10.1016/j.jaccpubpol.2010.09.001>
8. Birkmire, John C., Lay, James R., & McMahon, Mona C. (2007). Keys to effective third-party process safety audits. *Journal of Hazardous Materials*, 142(3), 574-581. doi: <http://dx.doi.org/10.1016/j.jhazmat.2006.06.065>
9. Broberg, Pernilla, Umans, Timurs, & Gerlofstig, Carl. (2013). Balance between auditing and marketing: An explorative study. *Journal of International Accounting, Auditing and Taxation*, 22(1), 57-70. doi: <http://dx.doi.org/10.1016/j.intaccaudtax.2013.02.001>
10. Consulting, AcuTech. (2002). AcuSafe Process Safety Management - Compliance Audit. Retrieved 7 February 2013, from <http://www.acutech-consulting.com/acusafe/psm/PSM-ComplianceAudits.html>
11. Downs, David E. (2005). Process Safety Management Assessment Tool. Retrieved from Process Safety Management Assessment Tool website: <http://www.ehsmp.com/software/PSM/PSM.htm>
12. Einolf, David M., & Menghini, Luverna K. (1999). *Process Safety Management/ Risk Management Planning - Auditing Handbook, A Checklist Approach* (First Edition ed.). Maryland, USA: Government Institutes, a Division of ABS Group Inc.
13. Energy, US Department of. (1996). *DOE Handbook - Process Safety Management for Highly Hazardous Chemicals* (First Edition ed. Vol. DOE-HDBK-1101-96). US.
14. Forest, Jerry. (2010). Objective Analysis of PSM Audit Data. Retrieved from Objective Analysis of PSM Audit Data|CCPS website: <http://www.aiche.org/ccps/resources/chemeondemand/conference-presentations/objective-analysis-psm-audit-data>

15. Francis, Jere R. (2004). What do we know about audit quality? *The British Accounting Review*, 36(4), 345-368. doi: <http://dx.doi.org/10.1016/j.bar.2004.09.003>
16. Funnell, Warwick, & Wade, Margaret. (2012). Negotiating the credibility of performance auditing. *Critical Perspectives on Accounting*, 23(6), 434-450. doi: <http://dx.doi.org/10.1016/j.cpa.2012.04.005>
17. Hendershot, Dennis. (2009). Process safety in the American Institute of Chemical Engineers—A brief history and current resources. *Journal of Chemical Health and Safety*, 16(1), 43-44. doi: <http://dx.doi.org/10.1016/j.jchas.2008.11.004>
18. Inc., PSM Compliance. (2004). Elements of PSM. Retrieved 7 February, 2013, from <http://psmcompliance.net/PSM.htm>
19. Joseph, Giby, Kaszniak, Mark, & Long, Lisa. (2005). Lessons after Bhopal: CSB a catalyst for change. *Journal of Loss Prevention in the Process Industries*, 18(4-6), 537-548. doi: <http://dx.doi.org/10.1016/j.jlp.2005.07.009>
20. Mason, Eileen. (2001a). Elements of process safety management: part 1. *Chemical Health and Safety*, 8(4), 22-24. doi: [http://dx.doi.org/10.1016/S1074-9098\(01\)00214-3](http://dx.doi.org/10.1016/S1074-9098(01)00214-3)
21. Mason, Eileen. (2001b). Elements of process safety management: Part 2. *Chemical Health and Safety*, 8(5), 23-26. doi: [http://dx.doi.org/10.1016/S1074-9098\(01\)00239-8](http://dx.doi.org/10.1016/S1074-9098(01)00239-8)
22. Nivolianitou, Zoe S., & Papazoglou, Ioannis A. (1998). An auditing methodology for safety management of the Greek process industry. *Reliability Engineering & System Safety*, 60(3), 185-197. doi: [http://dx.doi.org/10.1016/S0951-8320\(97\)00148-8](http://dx.doi.org/10.1016/S0951-8320(97)00148-8)
23. Safety Resources Co. of Ohio, Inc. (2009). *Process Safety Management Program*.
24. Sarens, Gerrit, De Beelde, Ignace, & Everaert, Patricia. (2009). Internal audit: A comfort provider to the audit committee. *The British Accounting Review*, 41(2), 90-106. doi: <http://dx.doi.org/10.1016/j.bar.2009.02.002>
25. van der Aalst, Wil, van Hee, Kees, van der Werf, Jan Martijn, Kumar, Akhil, & Verdonk, Marc. (2011). Conceptual model for online auditing. *Decision Support Systems*, 50(3), 636-647. doi: <http://dx.doi.org/10.1016/j.dss.2010.08.014>
26. Zhou, Haiyan. (2007). Auditing standards, increased accounting disclosure, and information asymmetry: Evidence from an emerging market. *Journal of Accounting and Public Policy*, 26(5), 584-620. doi: <http://dx.doi.org/10.1016/j.jaccpubpol.2007.08.004>

APPENDICES

APPENDIX A: Sample of DOE Compliance Audit Model(Energy, 1996)

PSM Element: PROCESS SAFETY INFORMATION

Major Issues/Questions	PSM Compliance Status			Information Source	Notes/Comments
	None	Partial	Complete		
CHEMICAL INFORMATION Documentation The following chemical information is available. <ul style="list-style-type: none"> • Toxicity data. • Permissible exposure limits. • Physical data. • Reactivity data. • Corrosivity data. • Thermal and chemical stability data. • Chemical incompatibility data. 					
CHEMICAL INFORMATION Communication Employees are aware of where chemical information is located.					
Employees are informed when changes are made to the chemical information.					
CHEMICAL INFORMATION Implementation Written program exists for maintaining, revising, and updating chemical information.					
Responsibility for maintaining, revising, and updating chemical information is clearly established.					

APPENDIX B: Gantt Chart of Research Project

Activities	SEM 1				SEM 2			
	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUGUST
Literature Review	■	■	■	■	■	■	■	■
Proposal Defence		●						
Analysis of PSM Standard		■	■	■	■			
Framework Development			■	■	■			
Submission of Interim Report					●			
Compliance Audit Model Development					■	■	■	
Submission of Progress Report						●		
Case Studies						■	■	
Pre - SEDEX							●	
Data Analysis and Feedback							■	■
Documentation	■	■	■	■	■	■	■	■
Submission of Report - Dissertation (Soft Bound)								●
Submission of Technical Paper								●
Oral Presentation								●
Submission of Report - Dissertation (Hard Bound)								● (END OF SEM 2)

APPENDIX C: List of PSM Element Standards

PSM Elements	Standard	Description of Standard
Employee Participation	119(c)(1)	Written Program
Employee Participation	119(c)(2)	Involvement of Employees
Employee Participation	119(c)(3)	Accessibility
Process Safety Information	119(d)(1)	Chemicals Information Requirement as of 29CFR 1910.1200(g)
Process Safety Information	119(d)(2)	Technology Information
Process Safety Information	119(d)(3)(i)	Equipment Information
Process Safety Information	119(d)(3)(ii)	Documentation of Information (New Standards)
Process Safety Information	119(d)(3)(iii)	Documentation of Information (Old Standards-not in use)
Process Hazard Analysis	119(e)(1)	Priority Order of Equipment Analysis
Process Hazard Analysis	119(e)(2)	Appropriate Techniques
Process Hazard Analysis	119(e)(3)	Address Process Hazards (All Aspects)
Process Hazard Analysis	119(e)(4)	Evaluation by Experts
Process Hazard Analysis	119(e)(5)	Findings and Recommendations
Process Hazard Analysis	119(e)(6)	Update and Revalidation
Process Hazard Analysis	119(e)(7)	Documentation
Operating Procedures	119(f)(1)	Written Procedure Available and consistent with PSI
Operating Procedures	119(f)(1)(i)	Written Procedure for each operating phase
Operating Procedures	119(f)(1)(ii)	Written Procedure includes operating limit and process deviation consequences
Operating Procedures	119(f)(1)(iii)	Written Procedure includes safety and health considerations
Operating Procedures	119(f)(1)(iv)	Written Procedure includes safety systems and its functions
Operating Procedures	119(f)(2)	Access to Operating Procedures
Operating Procedures	119(f)(3)	Review of Operating Procedures

PSM Elements	Standard	Description of Standard
Operating Procedures	119(f)(4)	Implementation of safe work practices
Training	119(g)(1)(i)	Initial Training
Training	119(g)(1)(ii)	Documentation
Training	119(g)(2)	Refresher Training
Contractors	119(h)(1)	Screening of contractor activities
Contractors	119(h)(2)	Selection of contractor
Contractors	119(h)(3)	Contractor safe working practices
Pre-Startup Safety Review	119(i)(1)	A pre-startup safety review for new facilities and modified facilities
Pre-Startup Safety Review	119(i)(2)	Confirmation of information/documents
Mechanical Integrity	119(j)(1)	Identification and Categorization of equipment
Mechanical Integrity	119(j)(2)	Development of written maintenance procedure
Mechanical Integrity	119(j)(3)	Training for process maintenance activities
Mechanical Integrity	119(j)(4)	Inspection and Testing
Mechanical Integrity	119(j)(5)	Correction of deficiencies
Mechanical Integrity	119(j)(6)	Development of quality assurance program
Hot Work Permit	119(k)(1)	Issuance of hot work permit
Hot Work Permit	119(k)(2)	Document compliance with 1910.252(a)
Management of Change	119(l)(1)	Written procedures for managing changes
Management of Change	119(l)(2)	Address technical basis
Management of Change	119(l)(3)	Information and Training
Management of Change	119(l)(4)	Update Process Safety Information
Management of Change	119(l)(5)	Update Operating Procedure
Incident Investigation	119(m)(1)	Process Incident
Incident Investigation	119(m)(2)	Initiation
Incident Investigation	119(m)(3)	Investigation Team
Incident Investigation	119(m)(4)	Report
Incident Investigation	119(m)(5)	Findings and Recommendations
Incident Investigation	119(m)(6)	Review of report
Incident Investigation	119(m)(7)	Report retained for five years
Emergency Planning and Response	119(n)	Establish and implement emergency action with provisions of 29 CFR 1910.38(a) and 29 CFR 1910.120(a), (p) & (q)
Compliance Audit	119(o)(1)	Planning
Compliance Audit	119(o)(2)	Staffing
Compliance Audit	119(o)(3)	Audit Findings
Compliance Audit	119(o)(4)	Corrective Action
Compliance Audit	119(o)(5)	Report

PSM Elements	Standard	Description of Standard
Trade Secrets	119(p)(1)	Information
Trade Secrets	119(p)(2)	Access to information

APPENDIX D: Framework of Compliance Audit

