Development of Process Safety Management Expert System (PSMES) for UTP Mini Plant of High Gravitational Natural Gas Dehydration Unit

by

Nor Hidayah binti Usop

Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Chemical Engineering)

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Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

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Approved by,

_____

(Assoc. Prof. Dr. Azmi Mohd Shariff)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

July 2009

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.

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NOR HIDAYAH BINTI USOP

ABSTRACT

This report is prepared as the final documentation for the proposed final year project entitled 'Development of Process Safety Management Expert System (PSMES) for UTP Mini Plant of High Gravitational Natural Gas Dehydration Unit'. Process Safety Management (PSM) is a standard promulgated by the United States Occupational Safety and Health Administration (OSHA) in 2000 intended to prevent major accidents hazards from occurring. This standard comprises of fourteen (14) main elements to manage the hazards associated with highly hazardous chemical (HHC).

The main objective of this research is to develop an expert system named PSMES to be used in process plants and other companies which will ensure that they comply with OSHA regulations and requirements. For this project, PSM elements are divided into two (2) major categories; Process Flow Diagram (PFD) Elements and Block Diagram (BD) Elements. The author chose UTP mini plant of High Gravitational Natural Gas Dehydration Unit as the project case study. Furthermore, for this project, the author is developing only 7 (seven) out of 14 (fourteen) PSM elements. These elements are Process Safety Information, Training, Operating Procedures, Management of Change, Hot Work Permit, Incident Investigation, and also Compliance Audit.

The development PSMES utilizes tools such as Microsoft Visual Basic for programming purposes. The concept of the system is initially represented by the frameworks constructed in flow chart forms, designated for each element.

The results show how the expert system is executed using the approved frameworks constructed earlier. The development of this PSMES is expected to assist the company in managing its operation in an effective and convenient manner.

ACKNOWLEDGEMENT

In the name of Allah, The Most Gracious, The Most Merciful. Praise to Allah S.W.T by whose grace and blessing I receive guidance in completing this dissertation report. Thanks for His greatest love and blessings.

First and foremost, I would like to extend my sincere appreciation to my supervisor AP Dr. Azmi Mohd Shariff for being such a wonderful mentor in guiding and assisting me, also for his knowledge shared with me through skills, advises and experiences, which is simply priceless. Thank you to Dr Azmi for his willingness to spend his valuable time assisting me and my colleagues to finish this project.

Then, to the management of UTP Mini Plant of High Gravitational Natural Gas Dehydration Unit and its personnel especially Ms Nurhayati for giving me a chance to be part of the family, with lots of new knowledge and information gained through meetings and discussions. With her trust, I have been exposed to the operation of the plant which helps to escalate the process of PSMES development.

A special thanks to my colleagues Mohammad Faizal Che Daud and Mohd Rafizie Roslan from Universiti Teknologi Petronas (UTP), who have given full commitment, share brilliant ideas as well as give unconditionally assistance to ensure this project is successful.

Lastly, thanks to my family members in helping me going through this one year duration. With the help and assistance all of these people mentioned above, I would say it's been a very valuable and unforgettable experience for me. Again, thank you very much.

A Special Dedication of This Grateful Feeling to My…

Beloved Mum and Dad;

Inspiring Supervisor;

AP Dr. Azmi Mohd Shariff

Enthusiastic and committed colleagues;

Mohammad Faizal Che Daud

and

Mohd Rafizie Roslan

My life aspiration;

Jeff

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LIST OF ABBREVIATION/NOMENCLATURE

1. PSMES - Process Safety Management Expert System
2. PSM - Process Safety Management
3. OSHA - Occupational Safety and Health Administration
4. HHC - Highly Hazardous Chemical
5. II - Incident Investigation
6. HWP - Hot Work Permit
7. CA - Compliance Audit
8. TS - Trade Secrets
9. PFD - Process Flow Diagram
10. BD – Block Diagram
11. P&ID - Piping and Instrument Diagram

CHAPTER 1

INTRODUCTION

1.1 Background

In the past 20 years, there are numerous major disasters happened including the Bhopal incident in India which killed more than 2,000 human lives, followed by the Phillips Petroleum Company, Pasadena, Texas in October 1989 incident which caused in 23 deaths and 132 injuries. Although these major disasters involving highly hazardous chemicals (HHC) drew worldwide attention to the potential for major catastrophes, the public record is replete with information concerning many other less notable releases of highly hazardous chemicals (HHC). Hazardous chemical releases continue to pose a significant threat to employees and provide awareness drive, internationally and nationally, for authorities to develop or consider developing legislation and regulations to eliminate or minimize the potential for such events.

To prevent such unfortunate events from re-occurring, the U.S. Occupational Safety and Health Administration (OSHA) has taken an initiative to issue the Process Safety Management (PSM), a regulation which contains requirements for the management of hazards associated with processes using highly hazardous chemicals (HHC) to help assure safe and healthy workplaces.

PSM clarifies the responsibilities of employers and contractors involved in work that affects or takes place near covered processes to ensure that the safety of both plant and employees is considered. The standard also mandates written operating procedures; employee training; prestart up safety reviews; evaluation of mechanical integrity of critical equipment; and written procedures for managing changes. PSM specifies a permit system for hot work; investigation of incidents involving releases or

near misses of covered chemicals; emergency, action plans; compliance audits at least every three years; and trade secret protection.

PETRONAS, the national oil and gas company is the pioneer in assuring the PSM implementation is being executed in Malaysia. PETRONAS recommends its HCU/OPUs to apply PSM in every oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities, or any other such facility, and thereby to achieve maximum technical and economic benefit from the standardization.

1.2 Problem Statement

Nowadays, there are several companies that already implement PSM at their work places. However, some issues arise pertaining on how to fully implement all the fourteen (14) elements of PSM in a process plant and how to relate them to each other. The current implementation of PSM is not feasible and user-friendly. This is because for instance, a company tends to keep their important documents such as PFD, P&ID, HAZOP report and training schedule in multiple locations and in multiple folders. Therefore, it is tedious for an employee to search for the documents everywhere in the plant if he or she were to use the P&ID and HAZOP report at the same time. In other words, the documents are not being grouped based on the PSM elements they belong to. By far, the current practice of PSM implementation does not fully involve all of its fourteen (14) elements and there are still no tools that can integrate all the PSM elements into one (1) practical and effective system where all the information of the company is available at one time. This is the main reason of introducing the PSM Expert System (PSMES) which will benefit not only the employees, but also the employers, contractors, vendors and clients.

1.3 Objectives and Scope of Study

The main objective of this project is to develop an expert system named PSMES to be applied in process plants and other companies which will ensure that they comply with OSHA regulations and requirements. However, the scope of the project is narrowed in terms of the application whereby in order to demonstrate the effeciencies of the system, the author selects UTP mini plant of High Gravitational Natural Gas Dehydration Unit as the project case study. Furthermore, for this project, the author is developing only 7 (seven) out of 14 (fourteen) PSM elements. These elements are Process Safety Information, Training, Operating Procedures, Management of Change, Hot Work Permit, Incident Investigation, and also Compliance Audit.

The work scopes of this project include constructing the concept of the expert system by developing the selected framework for each PSM elements extracted from OSHA regulation. Next is to develop the expert system by using the frameworks that have been approved by the supervisor. The expert system that has been developed is expected to demonstrate at least one working example for each category of PSM elements.

CHAPTER 2

LITERATURE REVIEW AND/OR THEORY

As stated in the Process Safety Management (PSM) publication by U.S Occupational Safety and Health Administration (OSHA) in 2000, PSM comprises of fourteen (14) main elements namely as follow [1]:

1. Process Safety Information
2. Process Hazard Analysis
3. Operating Procedures
4. Employee Participation
5. Training
6. Contractors
7. Pre-Start-up Safety Review
8. Mechanical Integrity
9. Hot Work Permit
10. Management of Change
11. Incident Investigation
12. Emergency Planning and Response
13. Compliance Audit
14. Trade Secrets

The standard mainly applies to manufacturing industries—particularly, those pertaining to chemicals, transportation equipment, and fabricated metal products. Other affected sectors include natural gas liquids; farm product warehousing; electric, gas, and sanitary services; and wholesale trade. It also applies to pyrotechnics and explosives manufacturers covered under other OSHA rules and has special provisions for contractors working in covered facilities. [2]

The following paragraphs are the citations obtained from various resources regarding the weakness of current PSM implementation.

[3]Currently, the PSM standard is applied only to installations containing more than a threshold amount or either flammable or toxic chemicals; the threshold is typically 10,000 pounds of flammables, usually somewhat fewer pounds of toxic chemicals. Most of the time, installations used in process development activities fall below the thresholds outlined in the PSM standard, so legally, strict adherence is not required. Although the quantities of materials may be smaller than the OSHA thresholds, most process development activities have the potential for serious injury or fatality, even if the extreme numbers envisioned when the PSM standard was crafted are not possible.

[4]There are insufficient data due to incomplete record keeping. Some companies began incorporating PSM as part of their culture many years ago. For some of these companies, much of the labor and other cost data were not being tracked until recently.

[5]OSHA is experiencing similar "start-up" difficulties regarding enforcement of the standard. Some of the more difficult challenges facing OSHA are listed as follows:

- consistent interpretation of the standard
- a shortage of trained and qualified inspectors
- a shortage of sufficient resources to conduct inspections
- complexity due to other state and proposed federal process safety regulations

[6]A number of recent devastating process safety failures have been ascribed to poor process safety management (PSM) systems, inadequate process safety culture, and weak

corporate oversight. This has been validated by both the BP North American Refineries Independent Safety Panel and the Hertfordshire Oil Storage Terminal Report.

[7]Several problems commonly occur with companies attempting to meet the audit requirements of the standard:

- auditing the PSM system is often a new experience for managers
- little guidance is available on specifically how to evaluate compliance
- even less guidance is available on how to evaluate effectiveness
- no commonly accepted ranking system is available to rate performance
- since the standard is performance-based, it is difficult to conduct an audit unless specific goals have been set to measure performance against

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.1 The Development Process

In order to develop PSMES, the first task is to study and comprehend each PSM element and note the OSHA regulations they should comply with. It is observed that some of the PSM elements have connection with the other element. It is important to ensure that there will be no redundancy occurs once the expert system is developed. Next, the author proceeds with developing the concept of the expert system by constructing the framework for selected PSM elements. This is the most vital task as frameworks will be the back bone of the expert system. The frameworks are similar to flow charts constructed from OSHA regulations of each PSM elements. The purpose of constructing the frameworks is to demonstrate the engineering point of view on how the expert system should operates without violating any OSHA regulations. Then, the frameworks are to be reviewed and checked by the supervisor, AP Dr Azmi M Shariff in order to clarify that they are valid to be executed into an expert system. After making some adjustments and modifications, the frameworks are then approved by the supervisor. Once the frameworks are approved, the author starts to develop the expert system using computer programming aid. The following flow chart (Figure 1) simplifies the process of PSMES development.

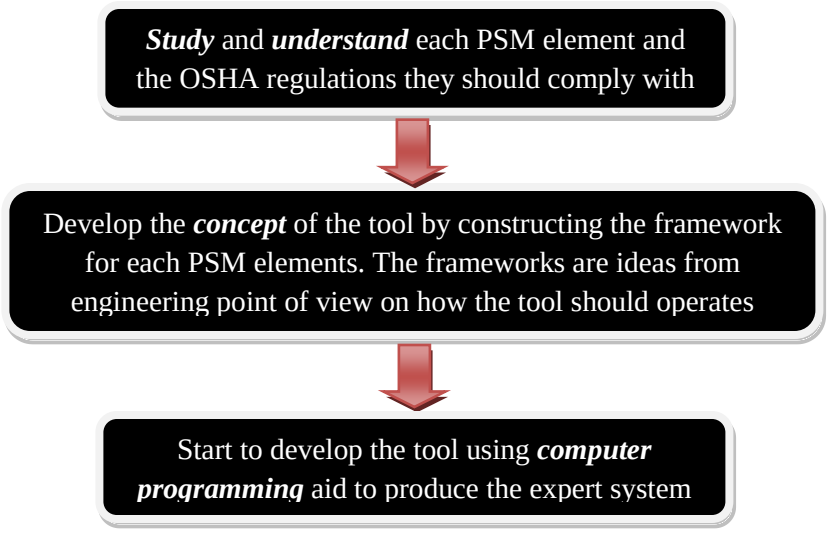


Figure 1: The Process of PSMES Development

3.2 Separation of Elements

All PSM elements are divided into two (2) categories based on the characteristics of each element. The purposes of dividing the PSM elements into two (2) groups are to differentiate each element as well as to give convenience while developing the expert system. Process Flow Diagram (PFD) elements are referring to any PSM element that can be accessed via the PFD of the plant. On the other hand, the Block Diagram (BD) elements are referring to any elements that cannot be accessed via the PFD of the plant and they are separately placed on the Homepage of the expert system unlike the PFD elements.

Table 1: Categories of PSM Elements

TYPES OF ELEMENTS	LIST OF ELEMENTS
Process Flow Diagram (PFD) Element	• **Process Safety Information** • Process Hazard Analysis • **Operating Procedures** • Pre-Start-up Safety Review • Mechanical Integrity • **Management of Change**
Block Diagram (BD) Element	• Employee Participation • **Training**

	• Contractors • **Hot Work Permit** • **Incident Investigation** • Emergency Planning and Response • **Compliance Audit** • Trade Secrets

**The elements in bold are developed by the author.*

The author develops only 7 (seven) out of 14 (fourteen) PSM elements. The elements constitute 3 (three) Process Flow Diagram (PFD) element and another 4 (four) Block Diagram (BD) elements.

3.3 Tools Required

In order to develop the PSMES, several tools are used to assist the author. Listed below are the tools required for developing the entire PSMES.

1. Microsoft Office Word – To develop frameworks
2. Microsoft Visual Basic – To develop system software

3.4 Project Activity and Schedule

Last semester, the project activities basically focus on finding the related journal/thesis regarding the flaws of current PSM implementation. These activities include books review and online journal research. The proofs of study are important to ensure the project of developing PSMES will be unique, cost-effective and beneficial in the future. Furthermore, literature reviews help in developing the understanding of PSM as well as give ideas to the author so that the system can be developed efficiently. Next, the author has started to construct the framework for PFD elements which are Process Safety Information, Operating Procedures and Management of Change. The frameworks will assist the system development in the future.

For this semester, the project activity continues within the first 3 (three) months by constructing the frameworks for rest of the Block Diagram (BD) elements which include Training, Work Permit, Incident Investigation and Compliance Audit.

The author has already met one of the researchers of High Gravitational Natural Gas Dehydration Unit, Ms Nurhayati to get a clear explanation on the mini plant flow sheet. The flow sheet of the plant will be the main component mostly utilized in the development of the expert system. Furthermore, the author has also visited the mini plant and has better understanding on the equipment arrangement and the processes that take place. Then, the author has discussed with the mini plant contractor, ABA Gas Technologies Sdn. Bhd. and Ms Nurhayati to obtain more information for developing the expert system.

Once all the required information has been collected, the author starts to develop the expert system using Microsoft Visual Basic. The system is expected to show at least one element of each PSM category is successfully developed.

Table 2: Suggested Milestone for the Second Semester of Final Year Project

No.	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project Work Continue															
2	Submission of Progress Report 1															
3	Project Work Continue															
4	Submission of Progress Report 2															
5	Seminar (compulsory)															
5	Project work continue															
6	Poster Exhibition															
7	Submission of Dissertation (soft bound)															
8	Oral Presentation															
9	Submission of Project Dissertation (Hard Bound)															

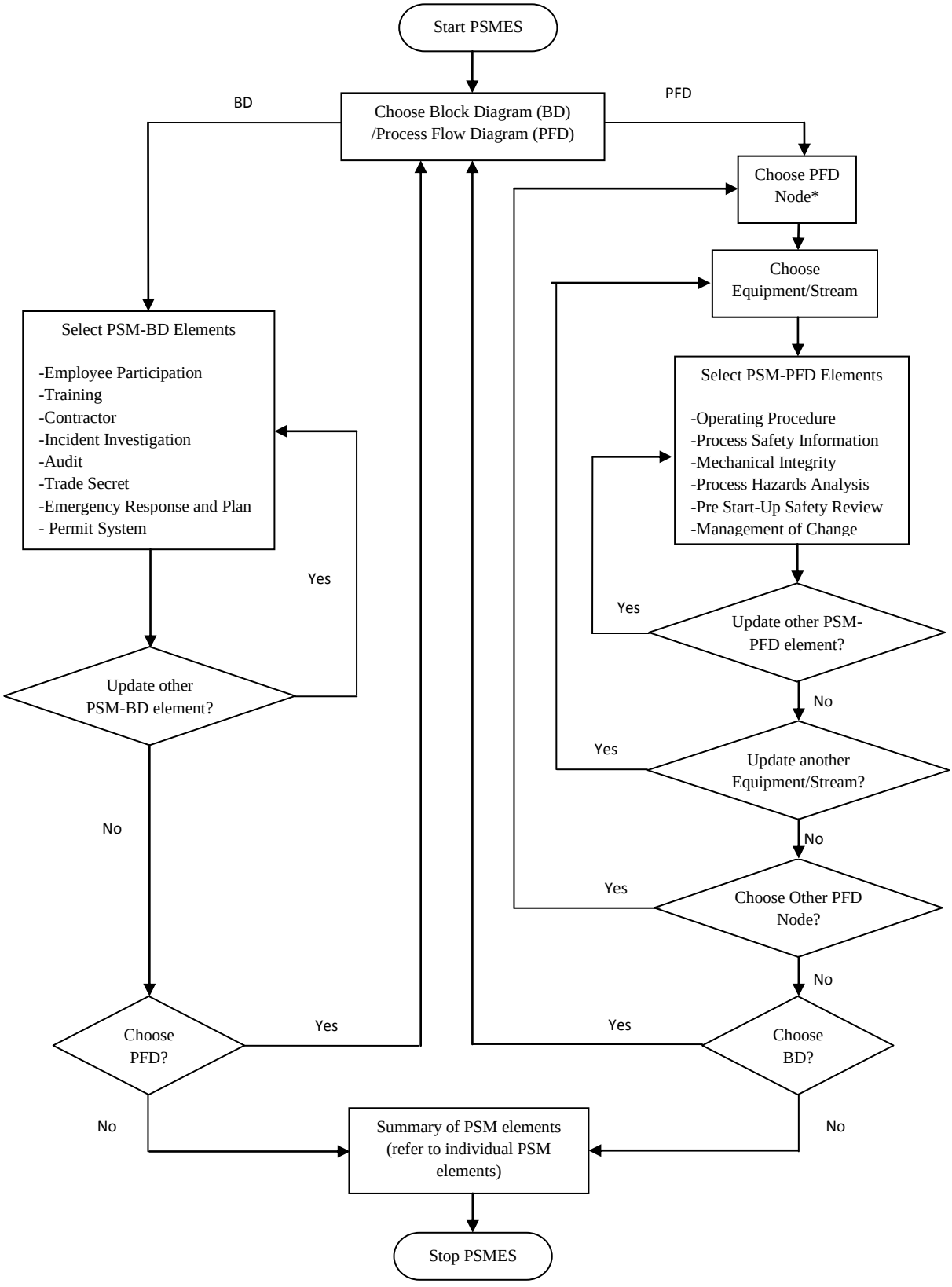
CHAPTER 4

RESULTS AND DISCUSSION

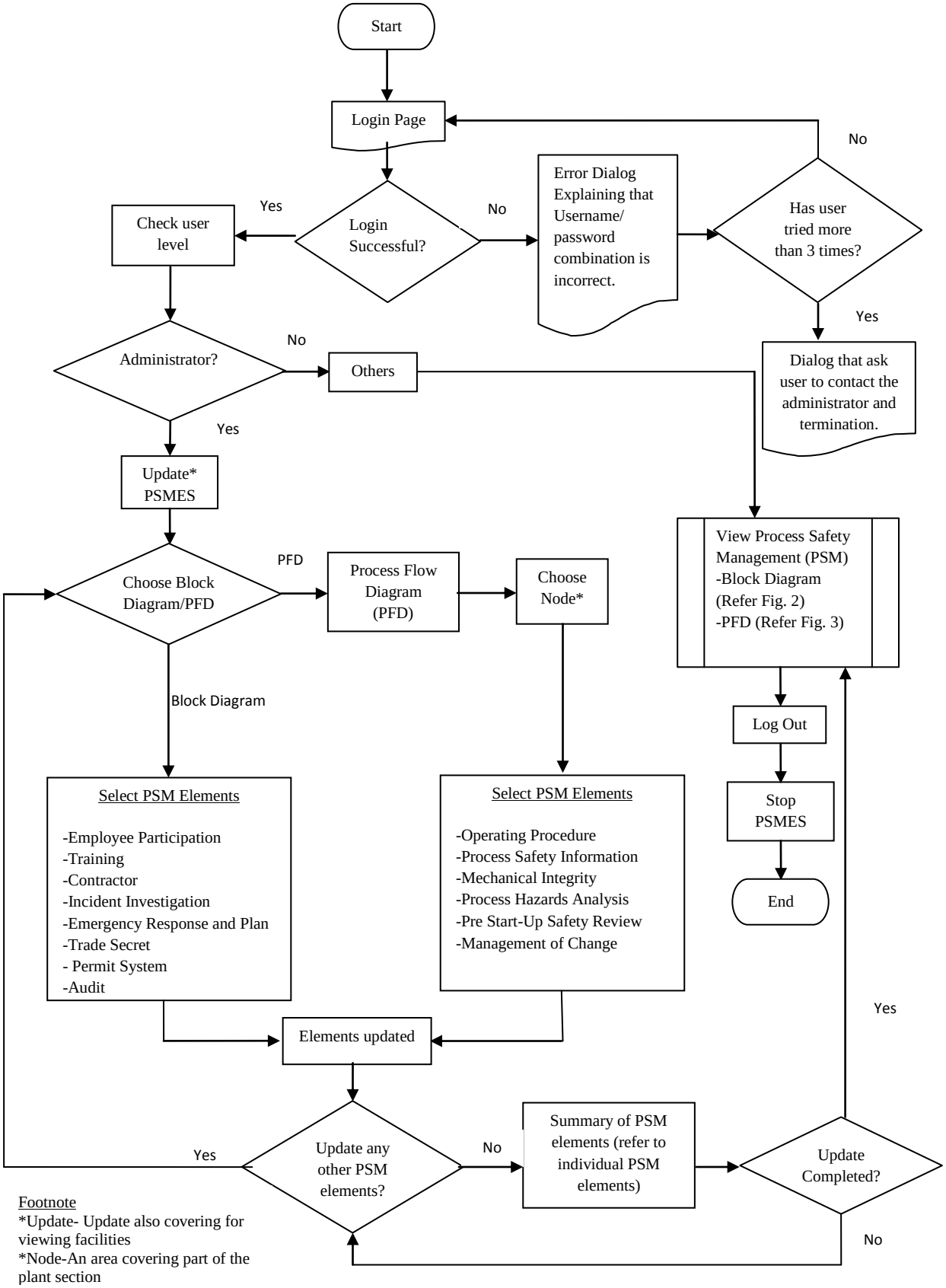
This section is divided into two (2) parts. The first part will discuss the results in terms of the frameworks that have been developed for the selected elements including the framework for Homepage while in the second part the results discuss the expert system execution. In the Homepage framework, there is no separation of elements being shown to avoid confusion among the readers. The frameworks are developed based on the requirements by OSHA [7].

4.1 Part I: Frameworks

4.1.1 PSMES Overall Framework

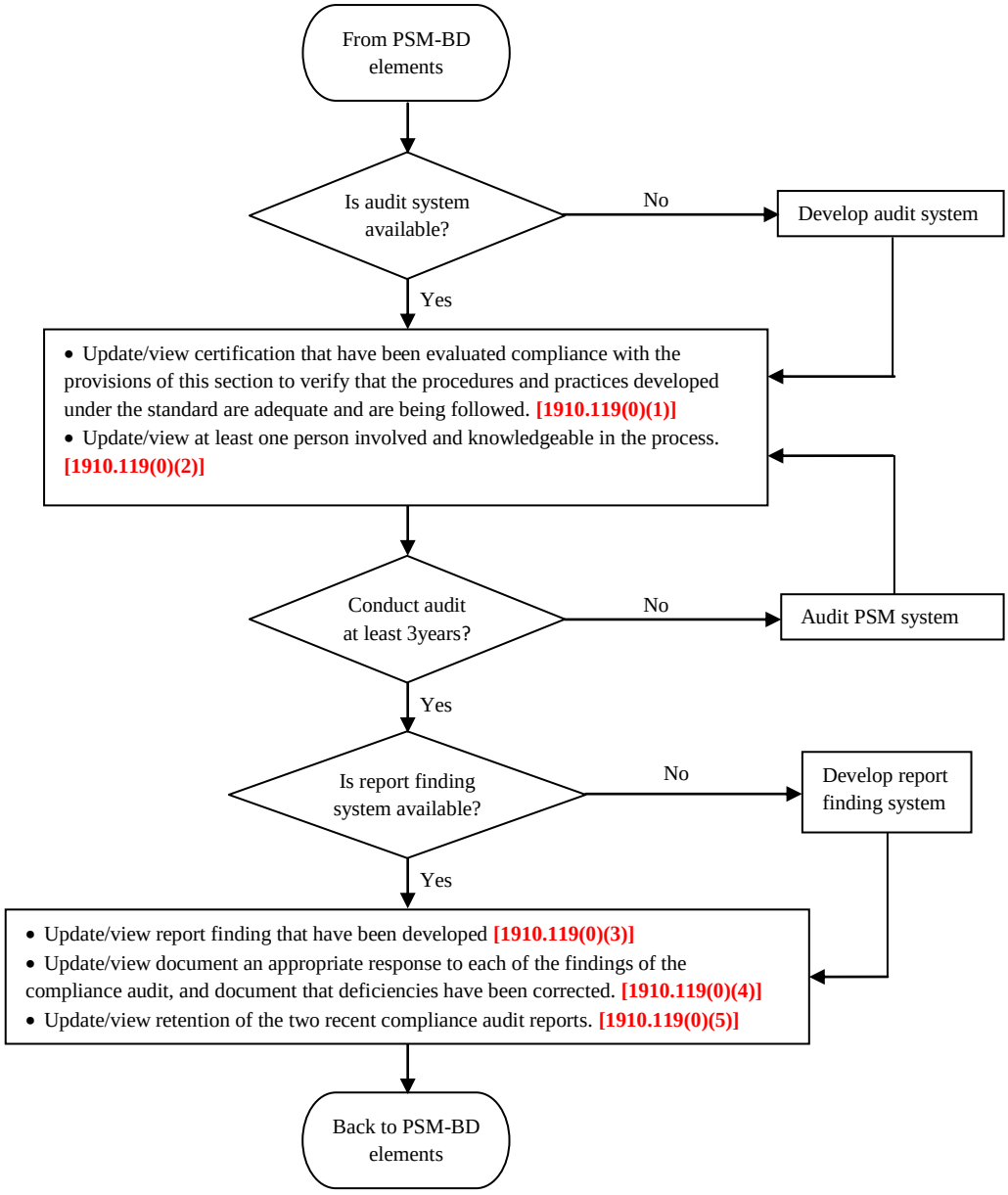


4.1.2 PSMES Homepage Framework

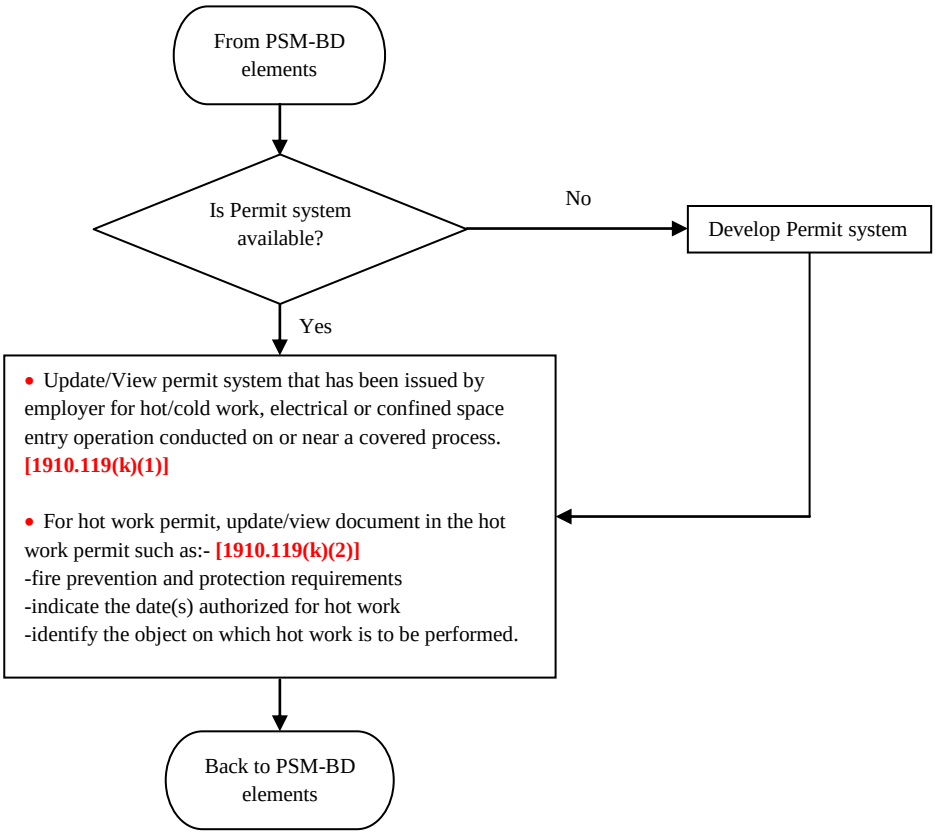


4.1.3 Block Diagram (BD) Frameworks

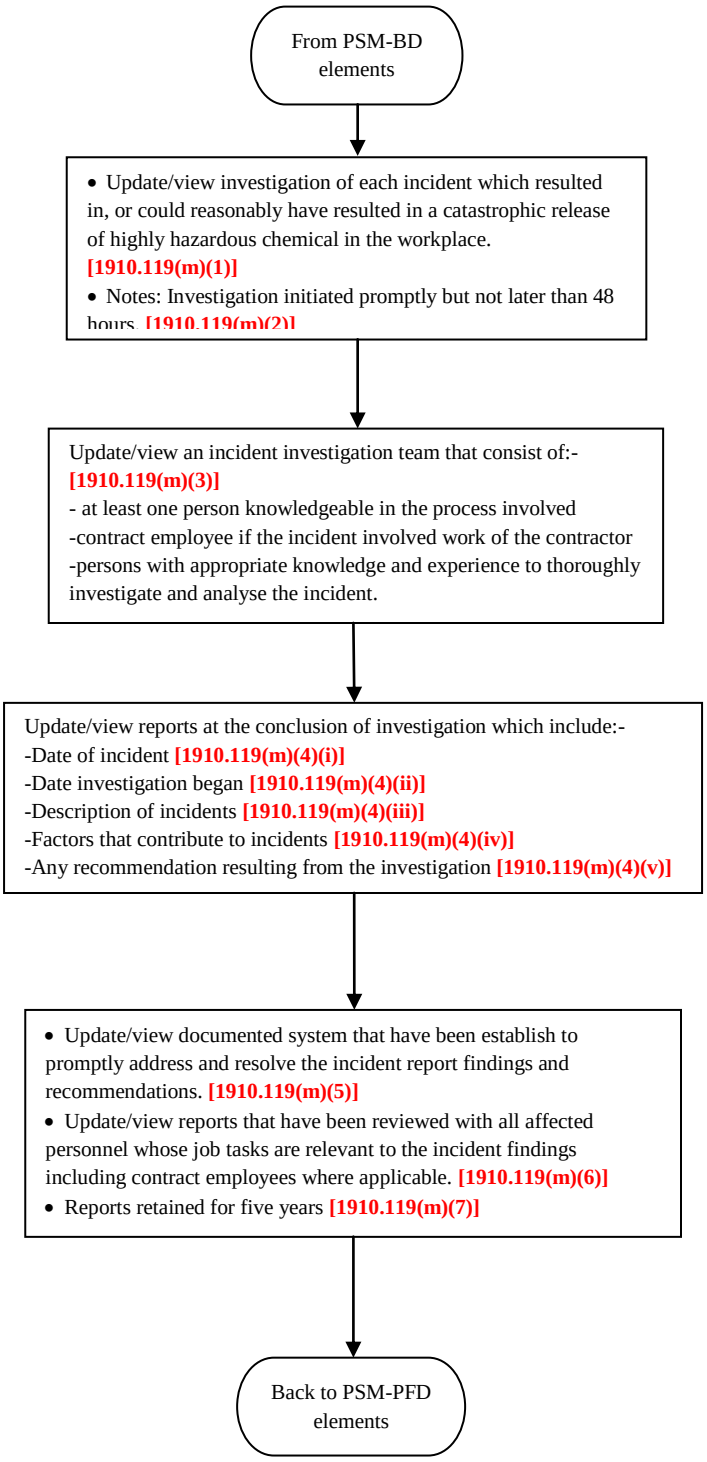
4.1.3.1 Audit Framework



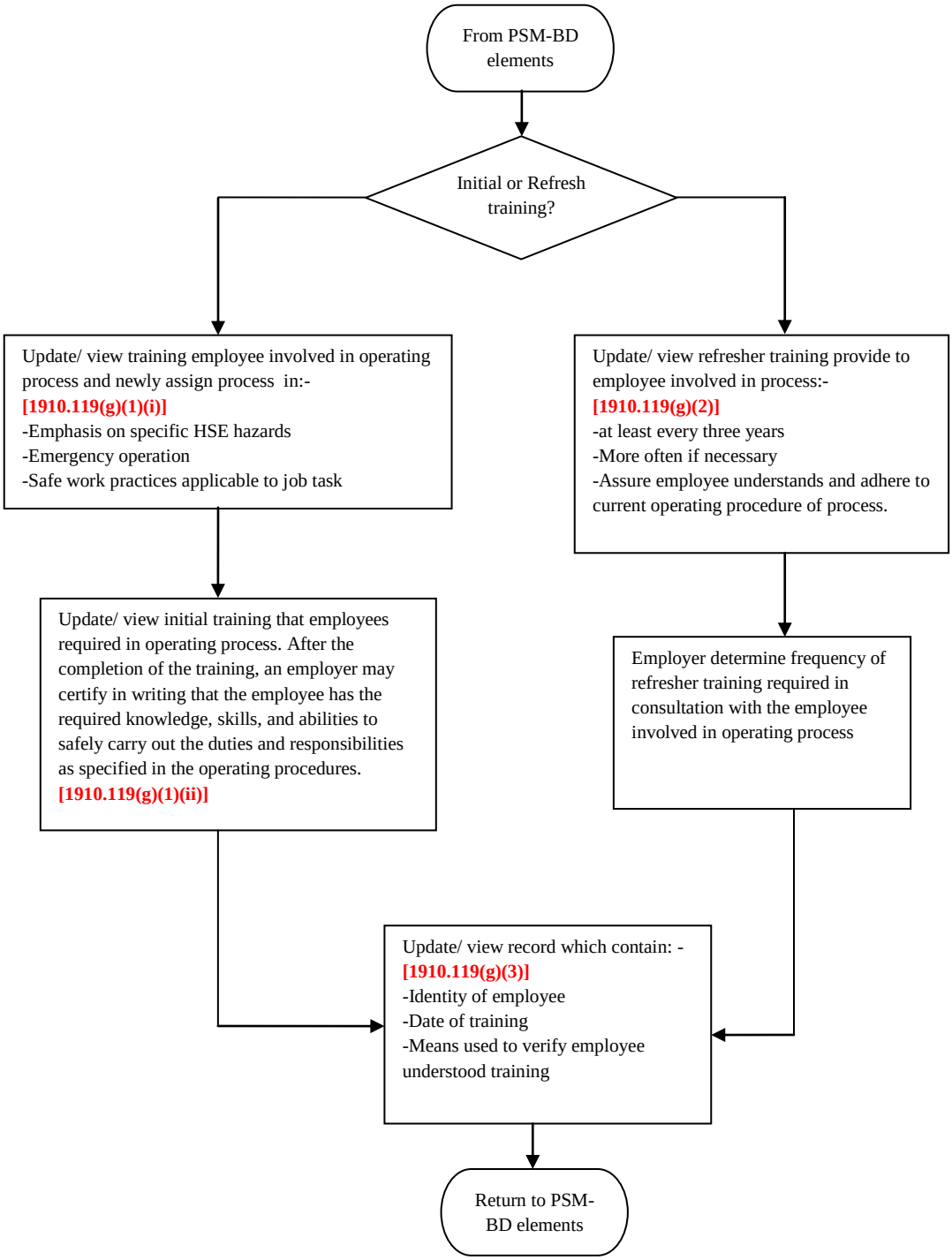
4.1.3.2 Permit Framework



4.1.3.3 Incident Investigation Framework

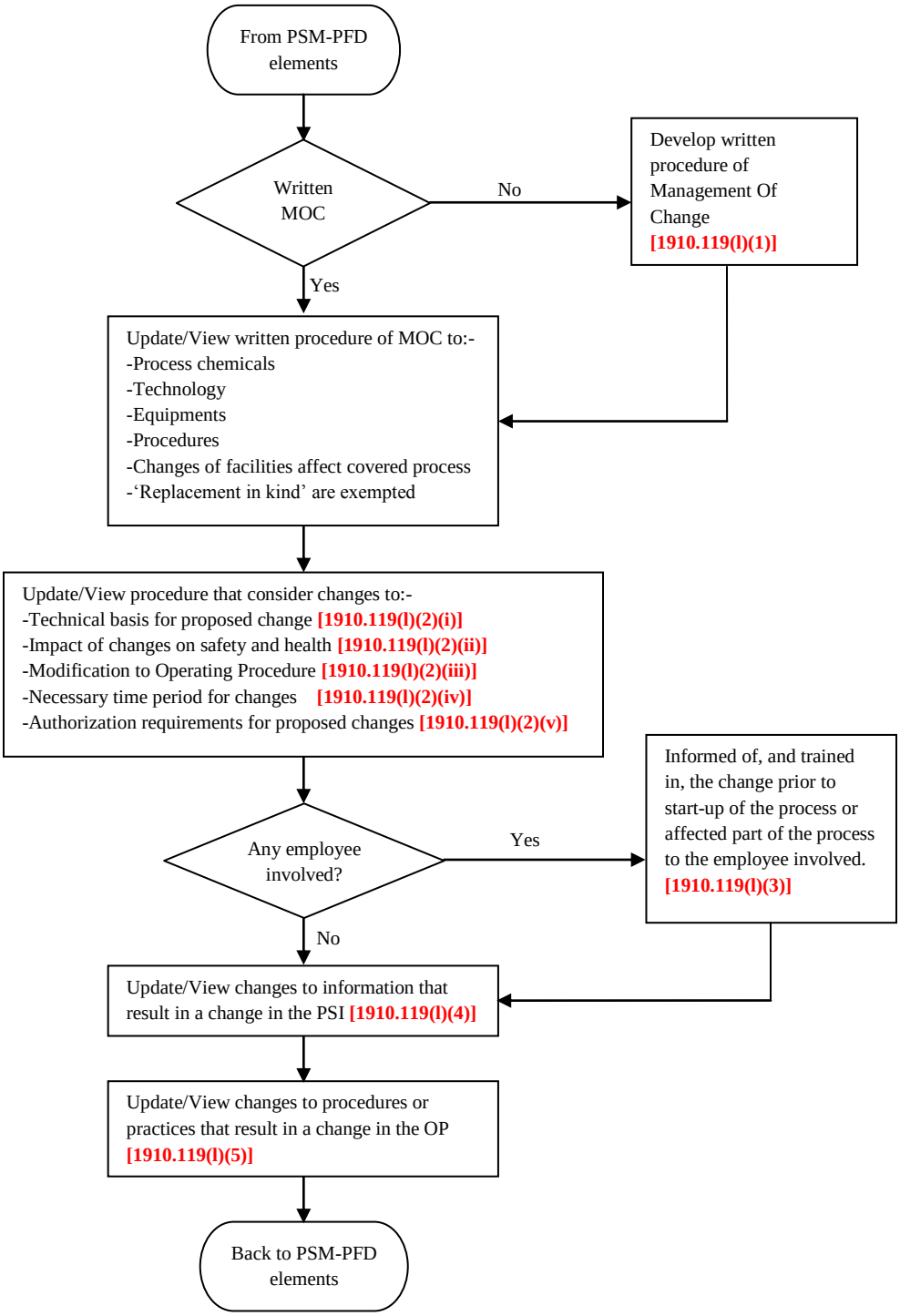


4.1.3.4 Training Framework

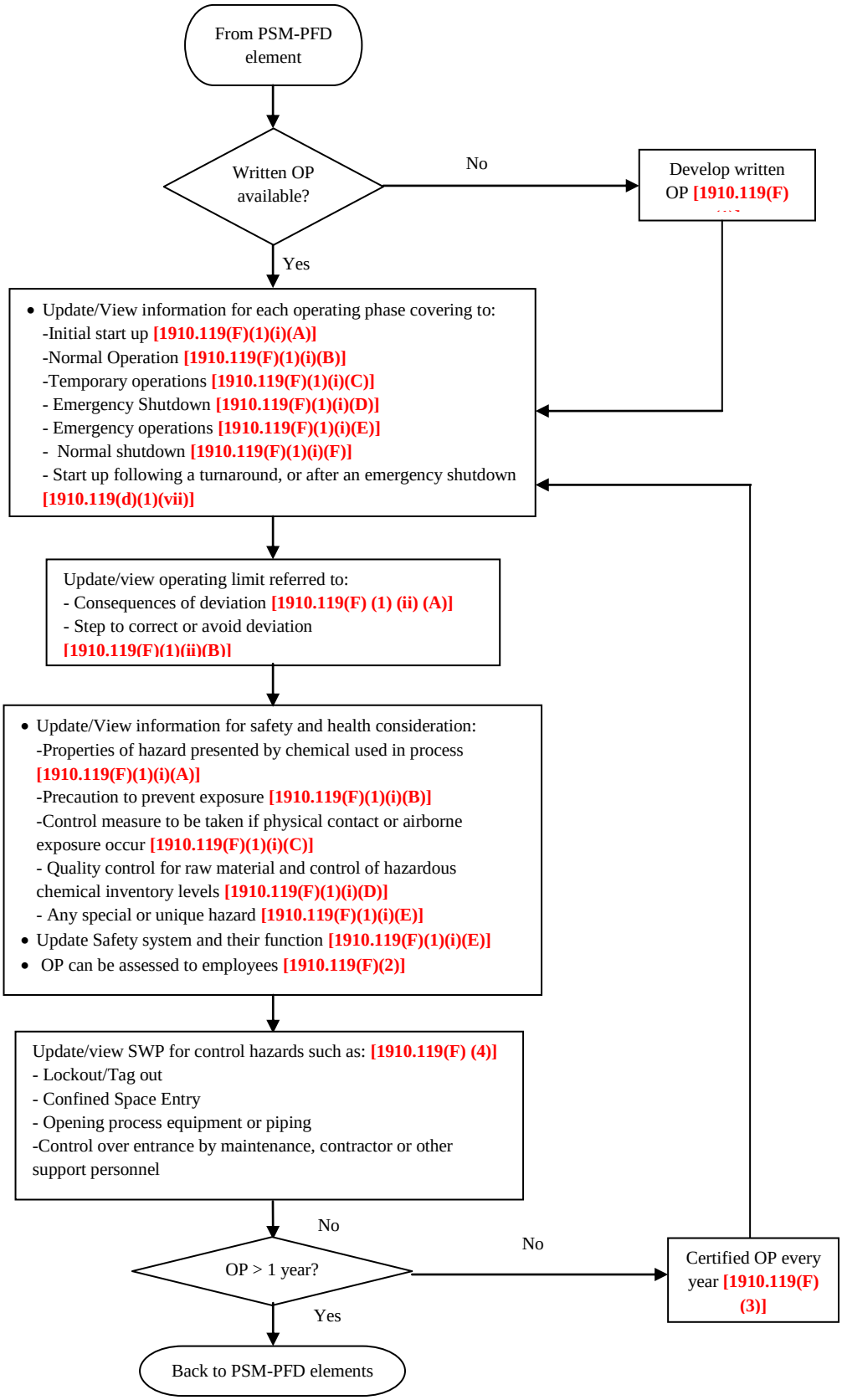


4.1.4 Process Flow Diagram Framework

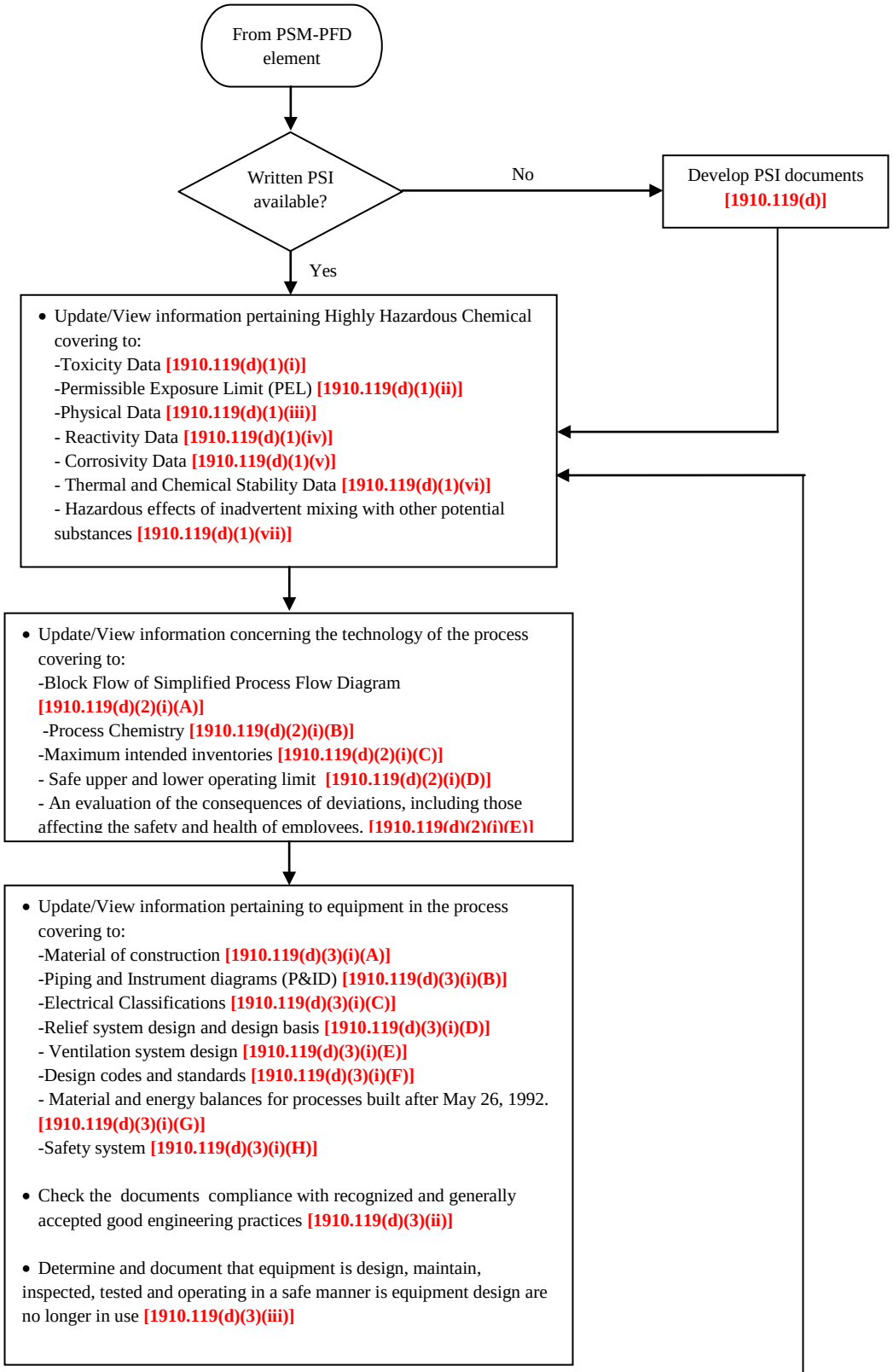
4.1.4.1 Management of Change Framework

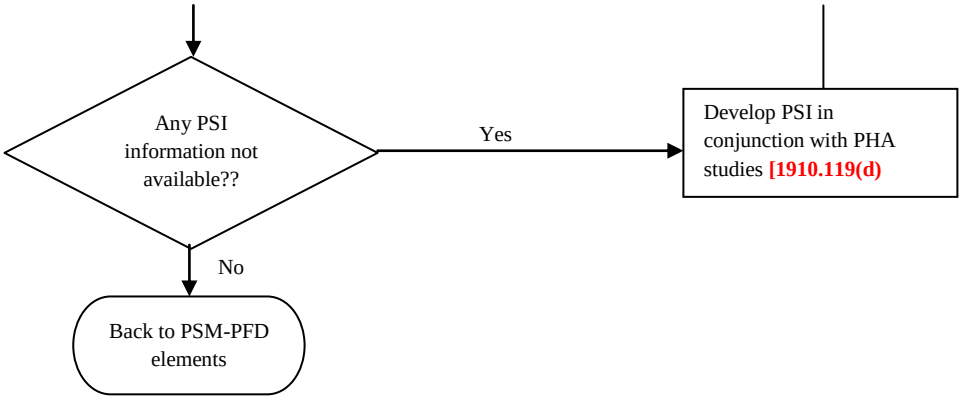


4.1.4.2 Operating Procedure Framework



4.1.4.3 Process Safety Information Framework




Any PSI information not available??
Yes
Develop PSI in conjunction with PHA studies [1910.119(d)
No
Back to PSM-PFD elements

4.2 Part II: PSMES Execution Example

This section shows a series of screen shots captured when the expert system is executed.

4.2.1 The Login Process

Figure 2: The Login Page. Employee to enter ID and password or user can login as guest

Figure 3: Successful login notification

4.2.2 The General Interface of PSMES

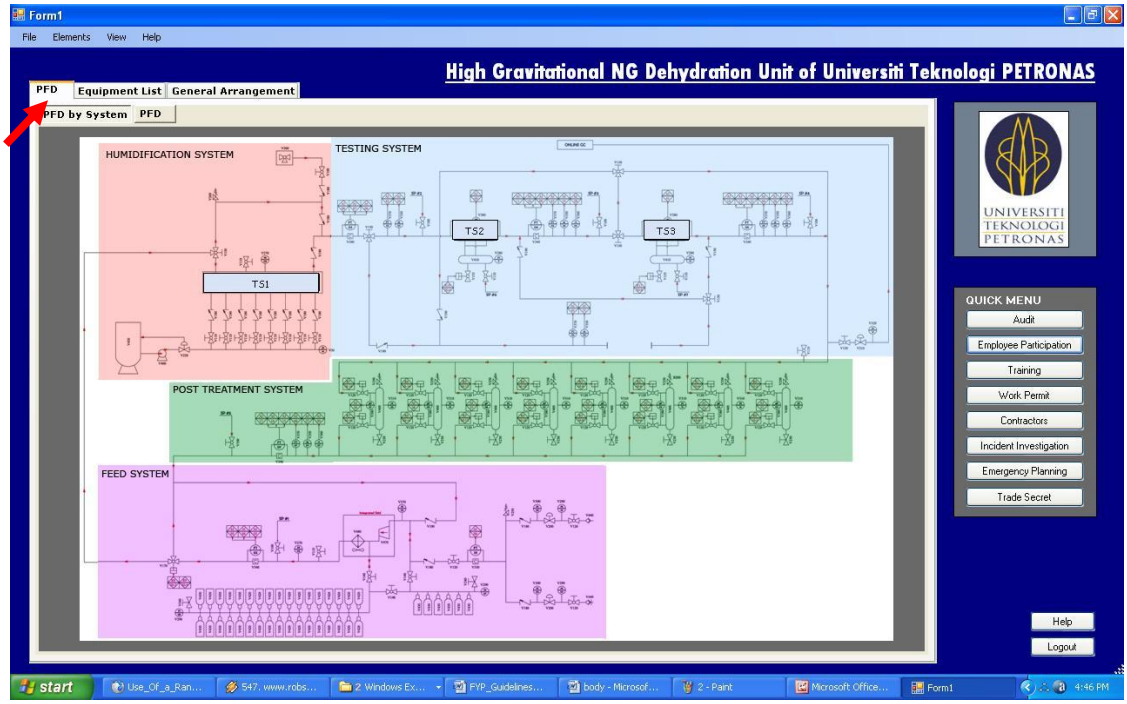
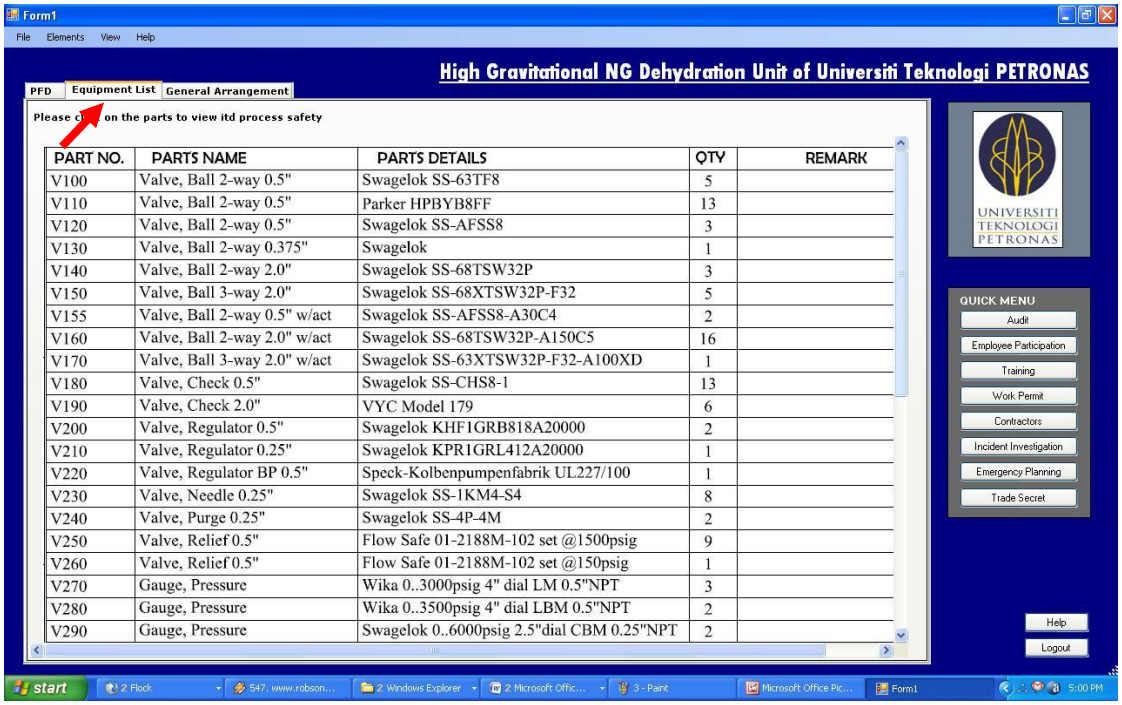


Figure 4: PSMES Homepage shows the PFD of the mini plant which consist of 4 (four) main systems



PART NO.	PARTS NAME	PARTS DETAILS	QTY	REMARK
V100	Valve, Ball 2-way 0.5"	Swagelok SS-63TF8	5	
V110	Valve, Ball 2-way 0.5"	Parker HPBYB8FF	13	
V120	Valve, Ball 2-way 0.5"	Swagelok SS-AFSS8	3	
V130	Valve, Ball 2-way 0.375"	Swagelok	1	
V140	Valve, Ball 2-way 2.0"	Swagelok SS-68TSW32P	3	
V150	Valve, Ball 3-way 2.0"	Swagelok SS-68XTSW32P-F32	5	
V155	Valve, Ball 2-way 0.5" w/act	Swagelok SS-AFSS8-A30C4	2	
V160	Valve, Ball 2-way 2.0" w/act	Swagelok SS-68TSW32P-A150C5	16	
V170	Valve, Ball 3-way 2.0" w/act	Swagelok SS-63XTSW32P-F32-A100XD	1	
V180	Valve, Check 0.5"	Swagelok SS-CHS8-1	13	
V190	Valve, Check 2.0"	VYC Model 179	6	
V200	Valve, Regulator 0.5"	Swagelok KHF1GRB818A20000	2	
V210	Valve, Regulator 0.25"	Swagelok KPR1GRL412A20000	1	
V220	Valve, Regulator BP 0.5"	Speck-Kolbenpumpenfabrik UL227/100	1	
V230	Valve, Needle 0.25"	Swagelok SS-1KM4-S4	8	
V240	Valve, Purge 0.25"	Swagelok SS-4P-4M	2	
V250	Valve, Relief 0.5"	Flow Safe 01-2188M-102 set @1500psig	9	
V260	Valve, Relief 0.5"	Flow Safe 01-2188M-102 set @150psig	1	
V270	Gauge, Pressure	Wika 0..3000psig 4" dial LM 0.5"NPT	3	
V280	Gauge, Pressure	Wika 0..3500psig 4" dial LBM 0.5"NPT	2	
V290	Gauge, Pressure	Swagelok 0..6000psig 2.5"dial CBM 0.25"NPT	2	

Figure 5: The plant equipment list

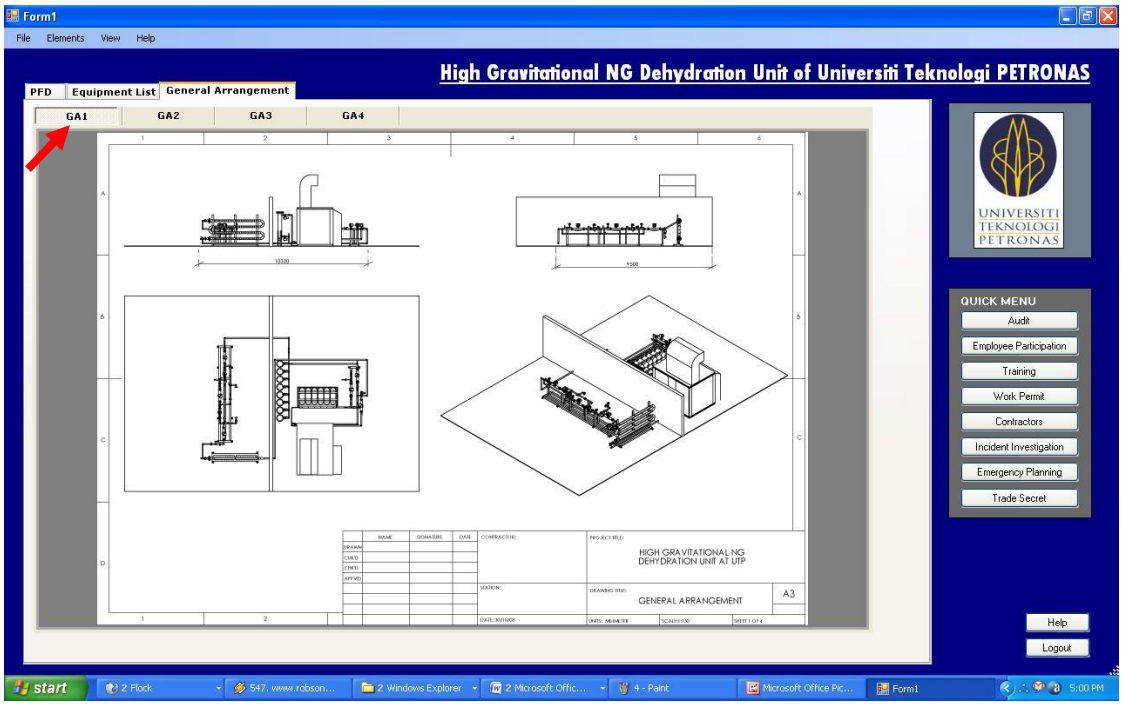


Figure 6: The General Arrangement of the plant; from Angle 1

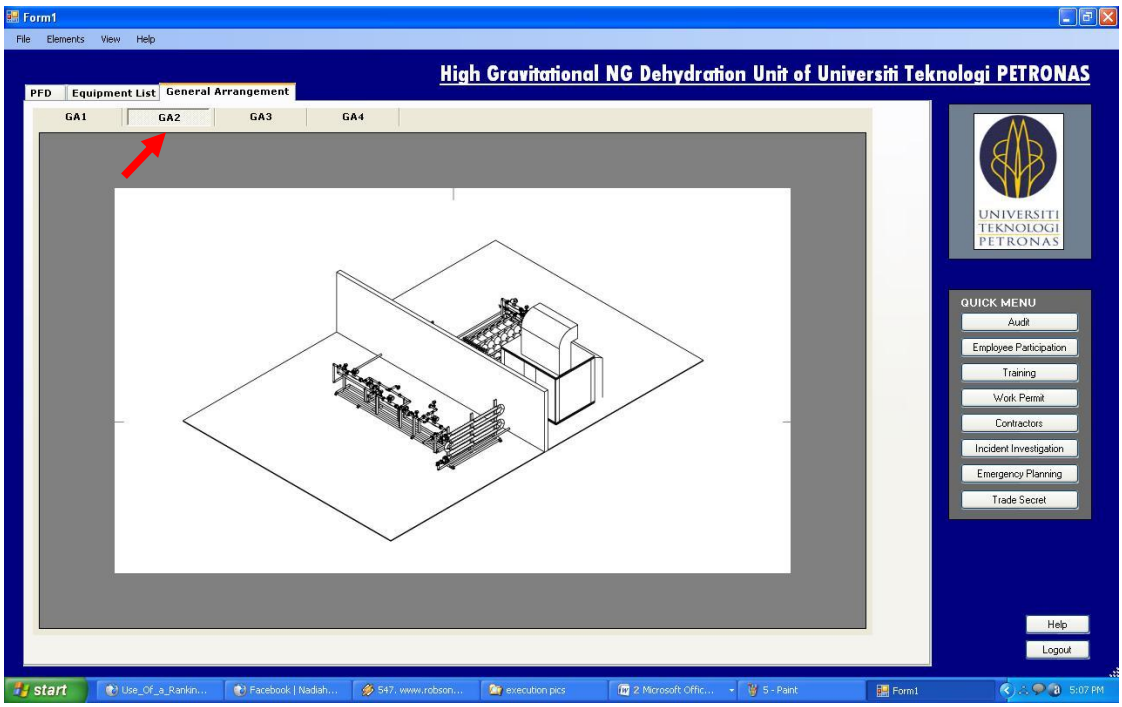


Figure 7: The General Arrangement of the plant; from Angle 2

4.2.3 Application Example 1 - To show one element from PFD category is successfully developed. The element selected is Process Safety Information (PSI).

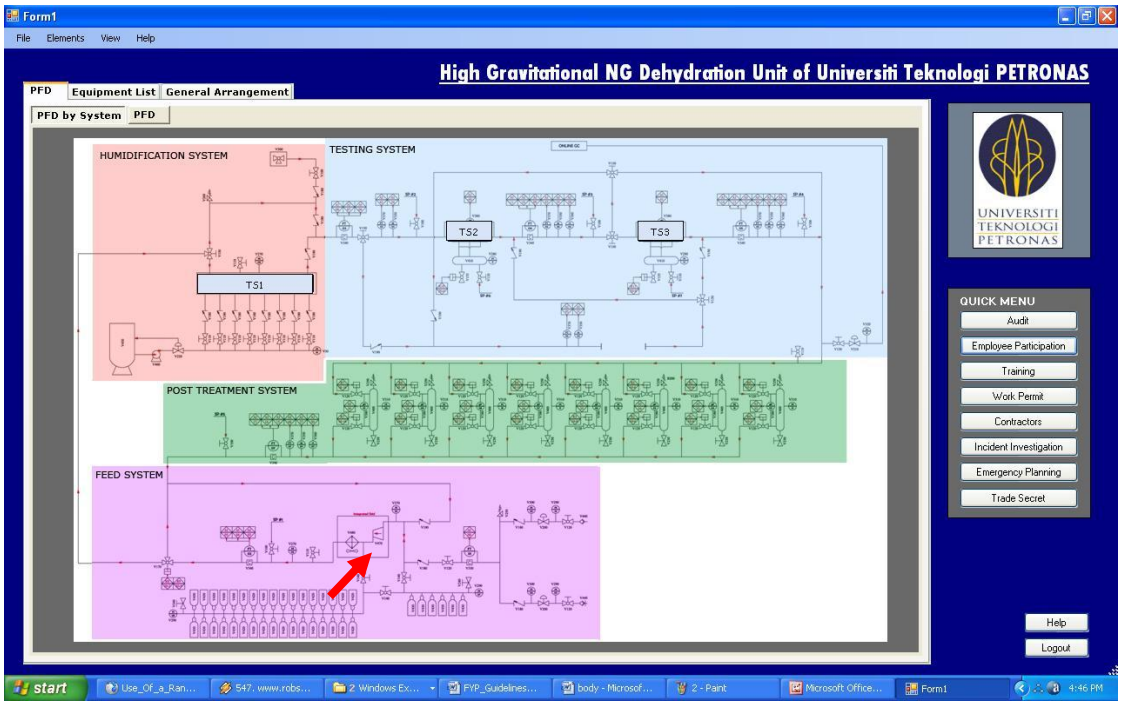


Figure 8: From PFD, user to click on the desired equipment (compressor)

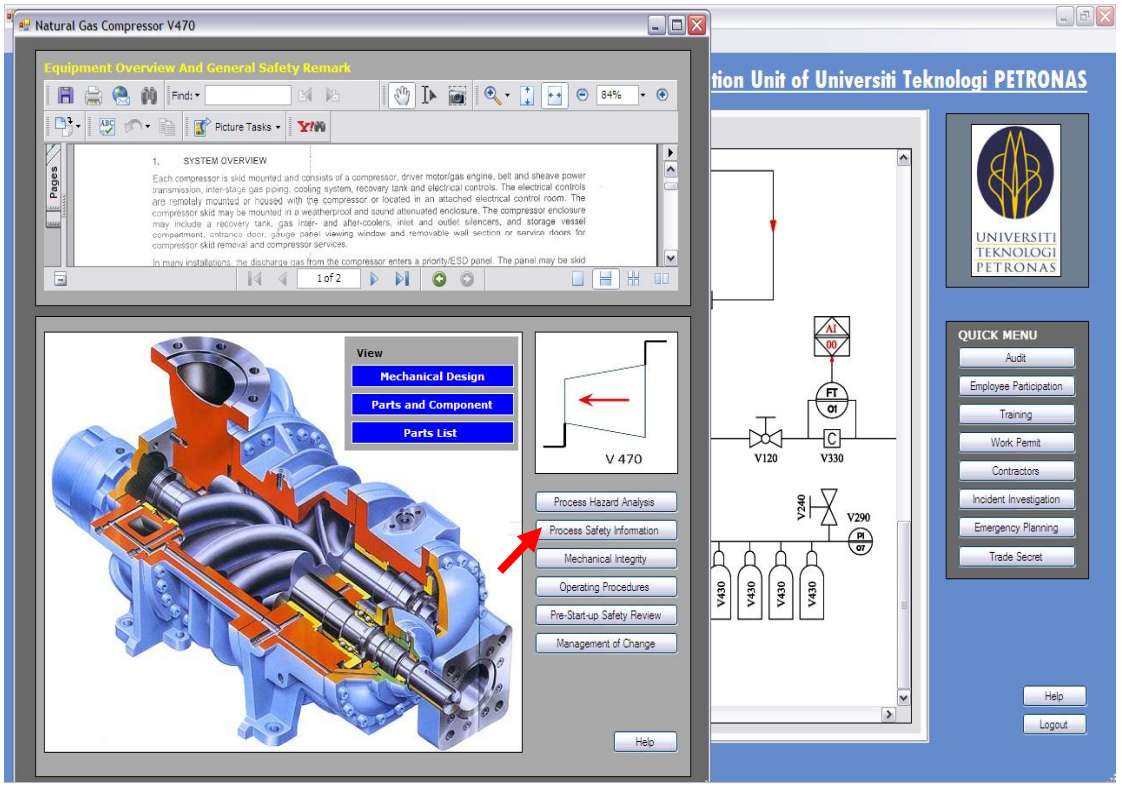


Figure 9: User to click on the PSI button on at the bottom right of the active window

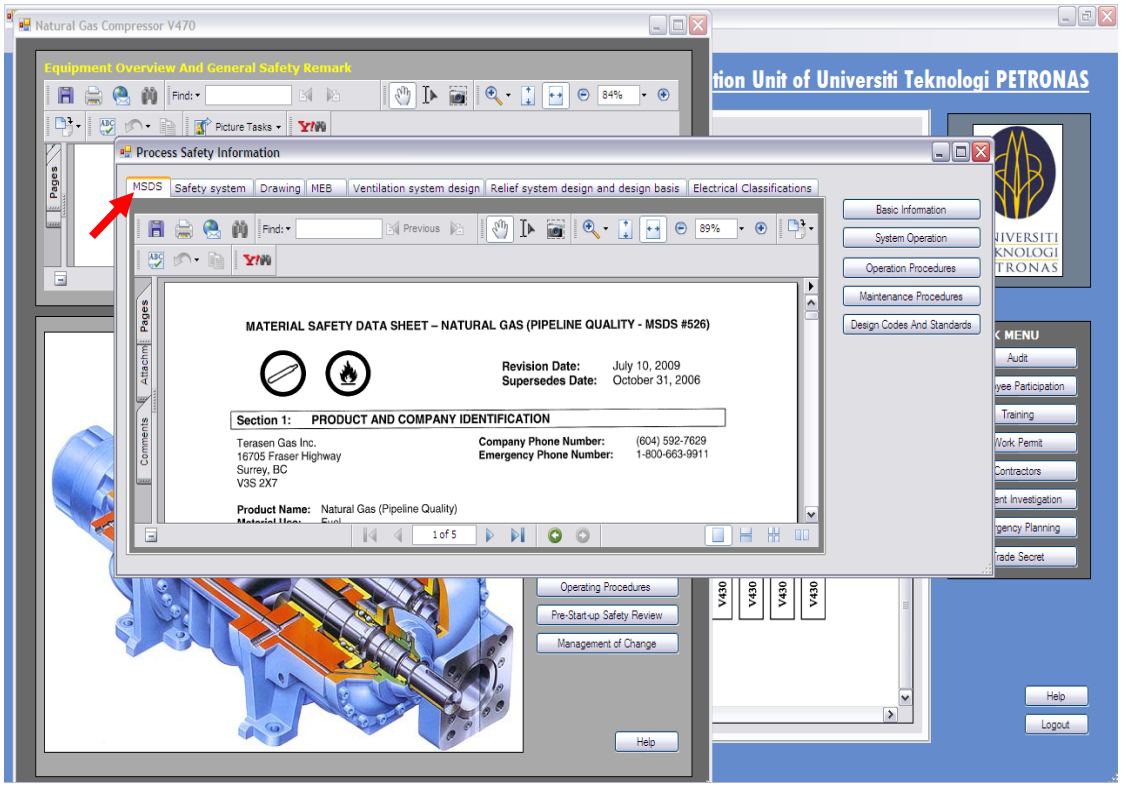


Figure 10: MSDS of Natural Gas

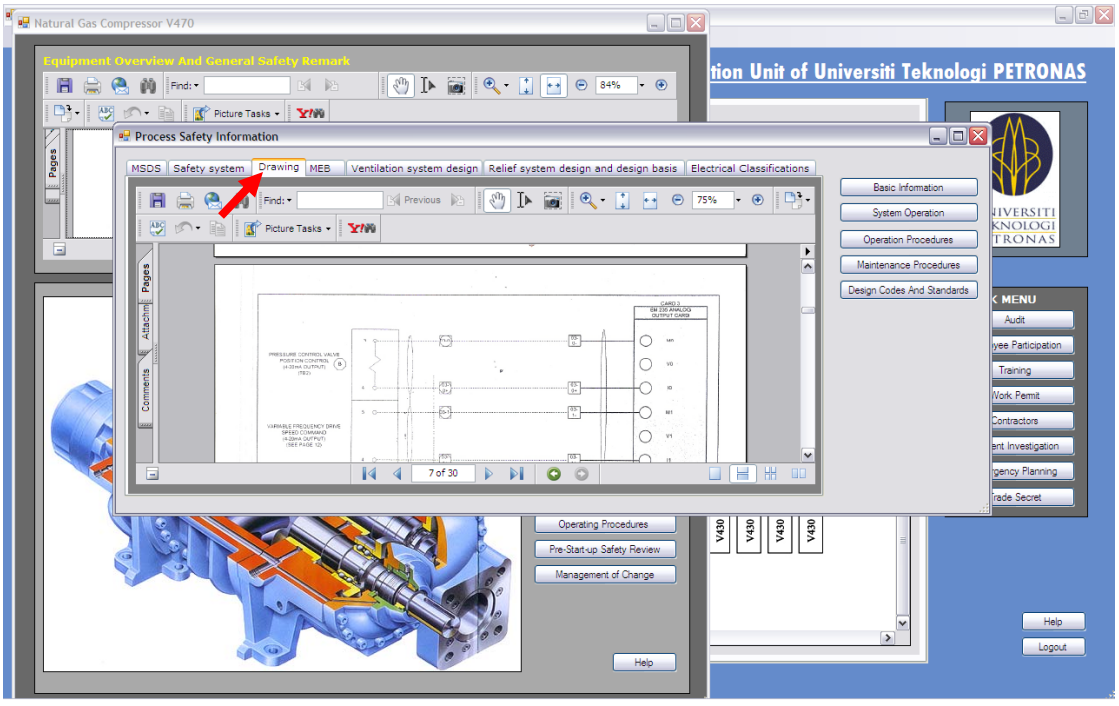


Figure 11: Compressor detailed drawing

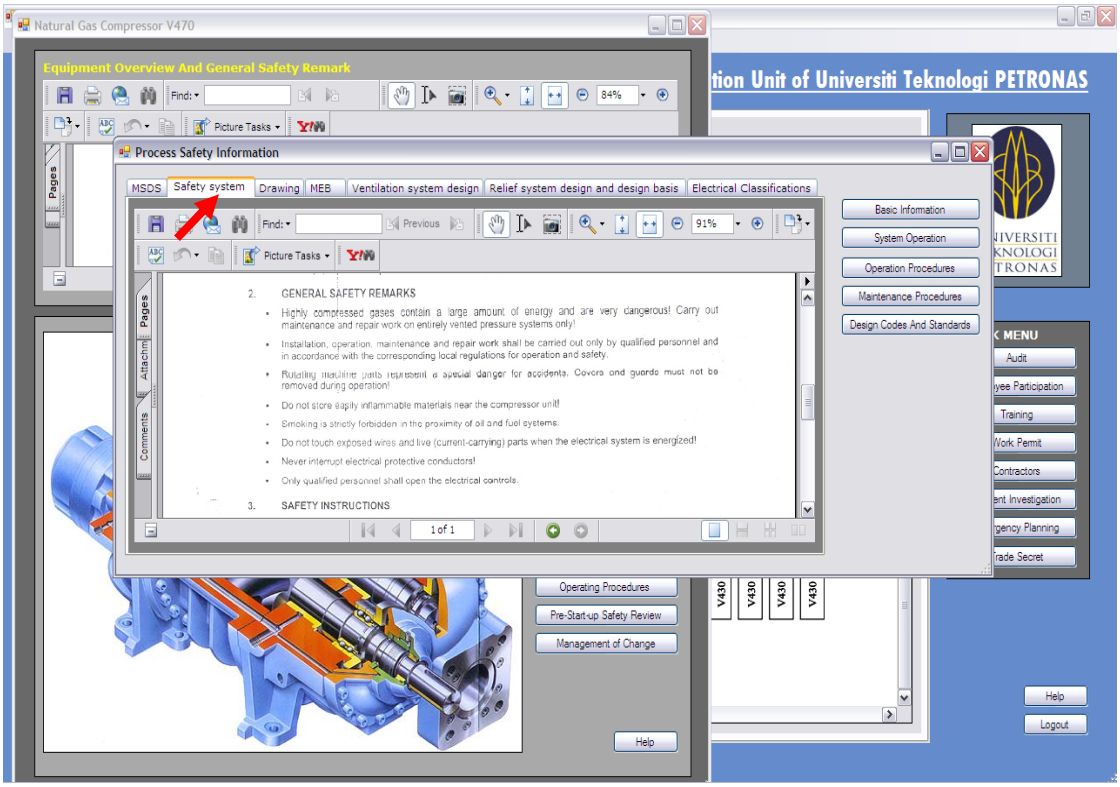


Figure 12: Safety system rules and instructions

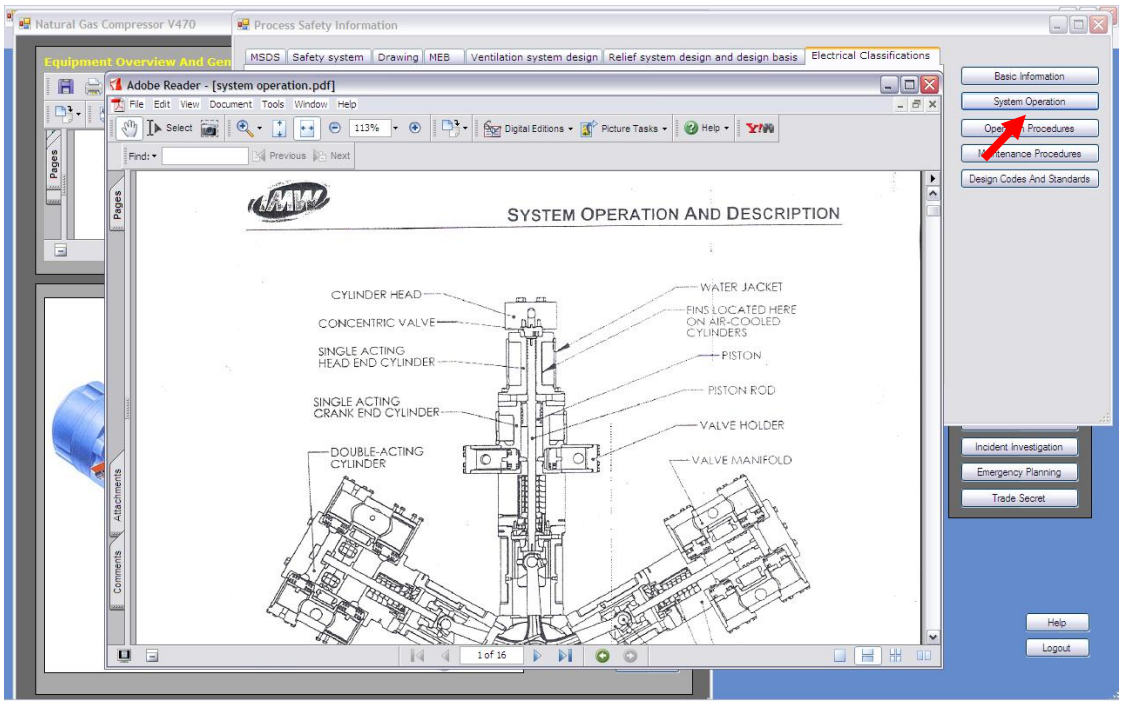


Figure 13: Safety system operation and description

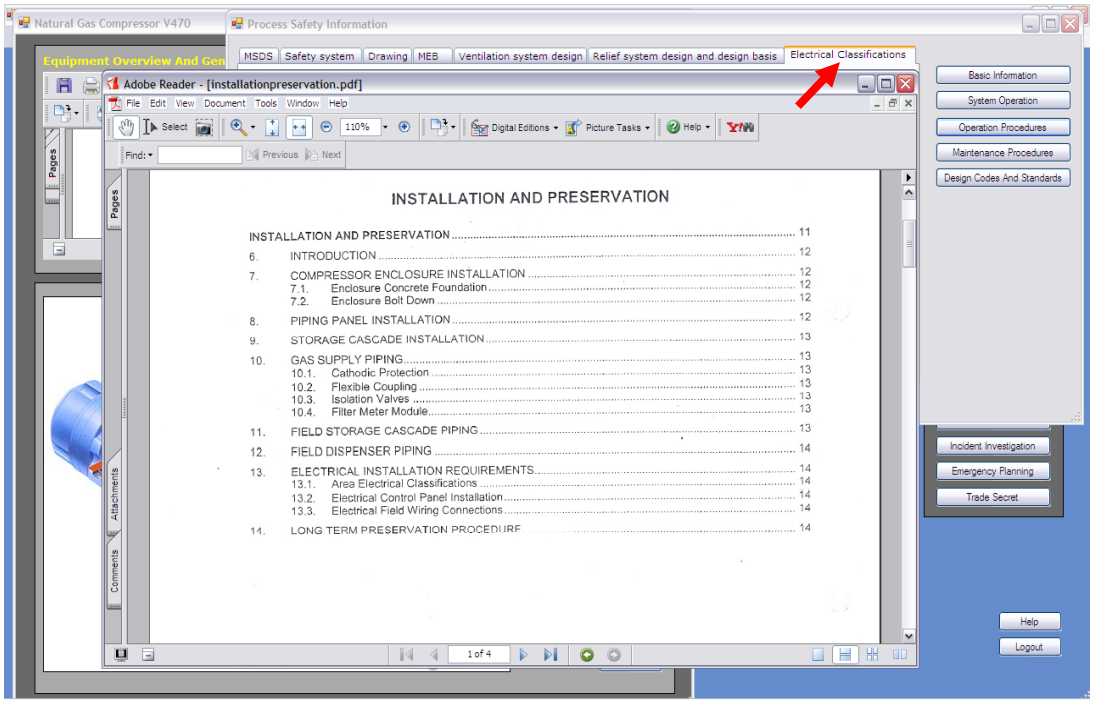


Figure 14: Electrical classification description

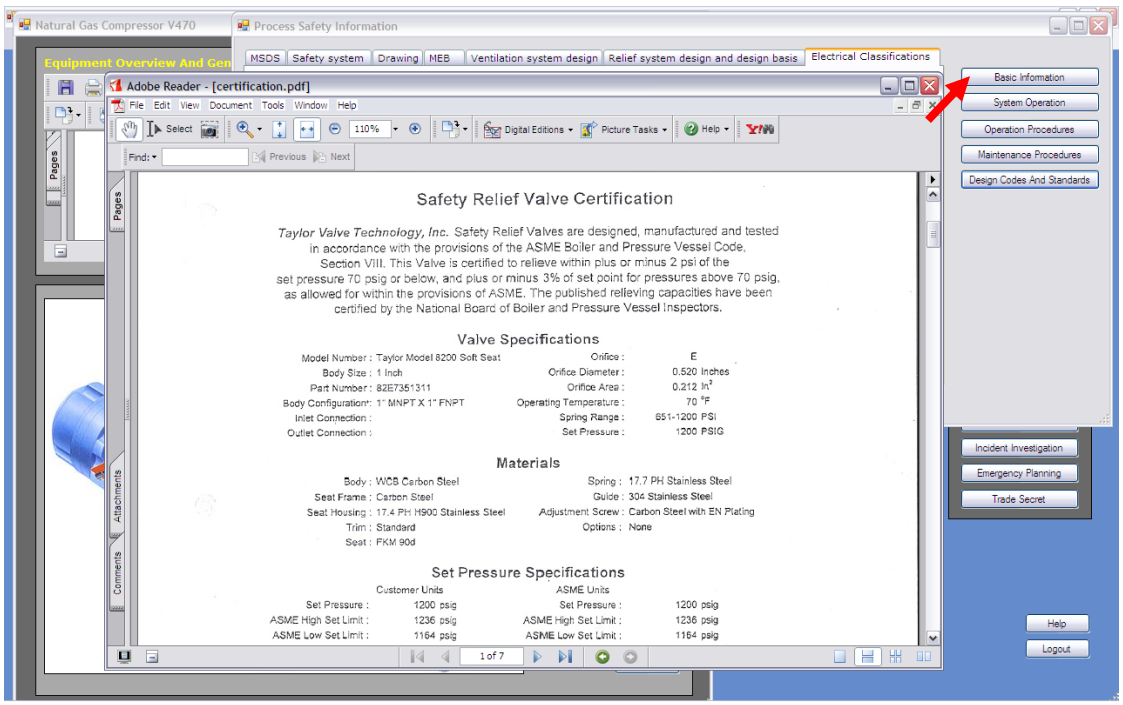


Figure 15: Safety relief valve description

4.2.4 Application Example 2 - To show one element from BD category is successfully developed. The element selected is Compliance Audit.

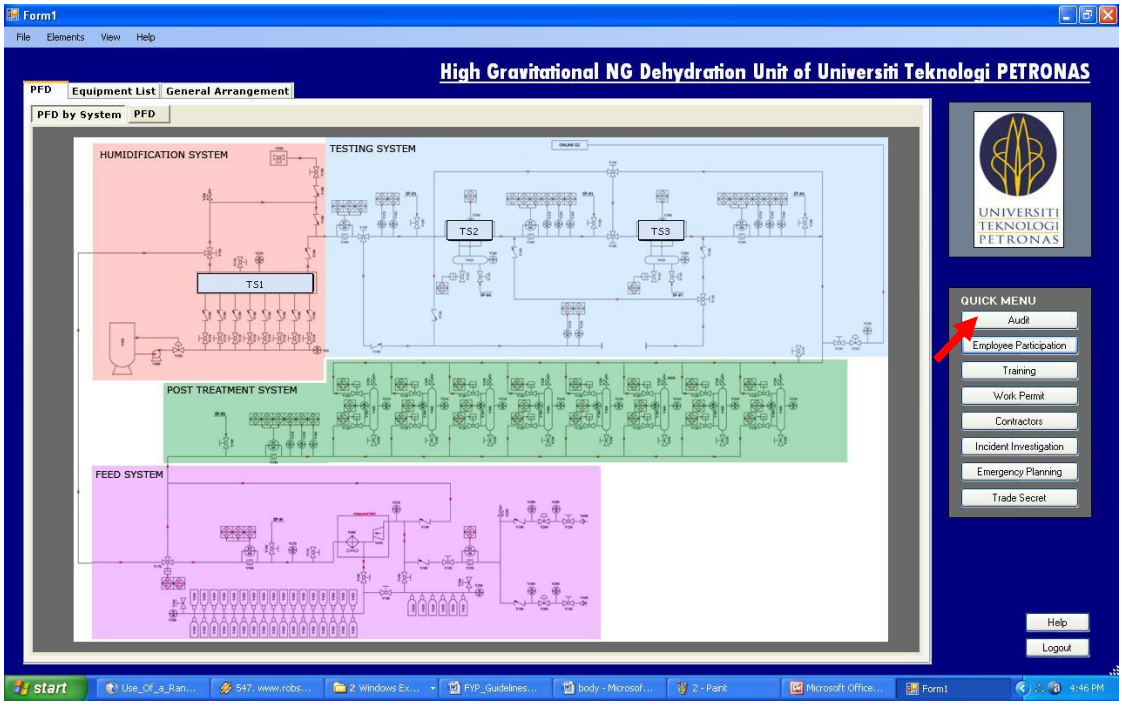


Figure 16: At Homepage, user to click on the Audit button at the right hand side of the window

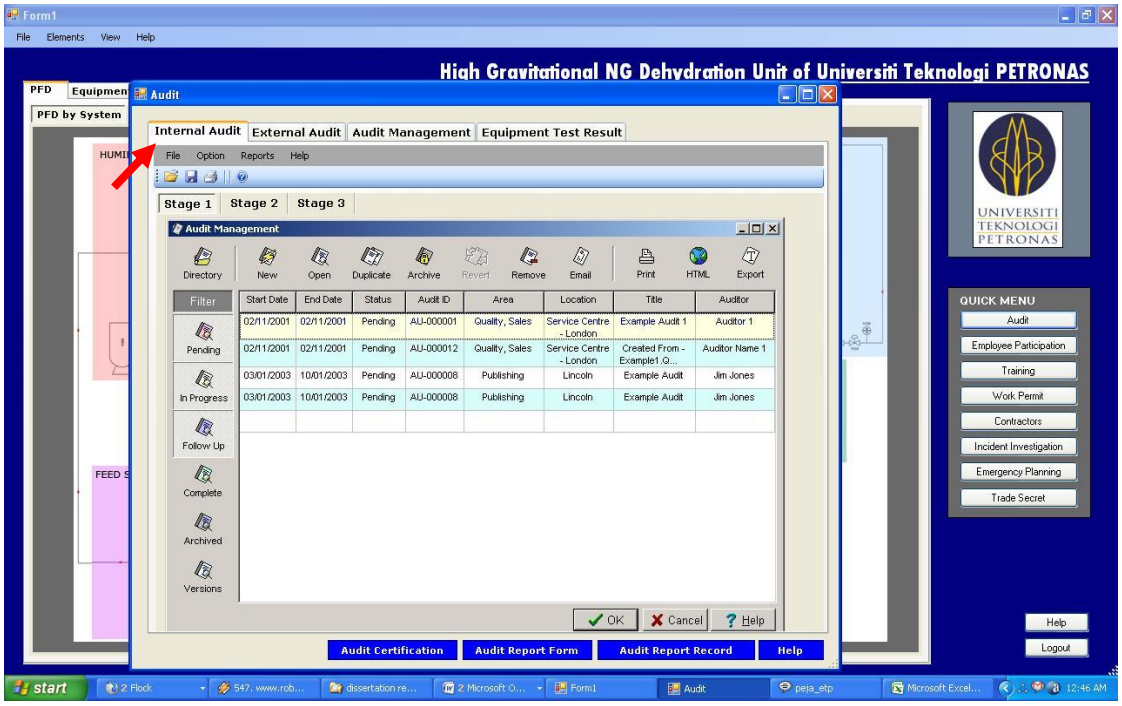


Figure 17: Internal audit record

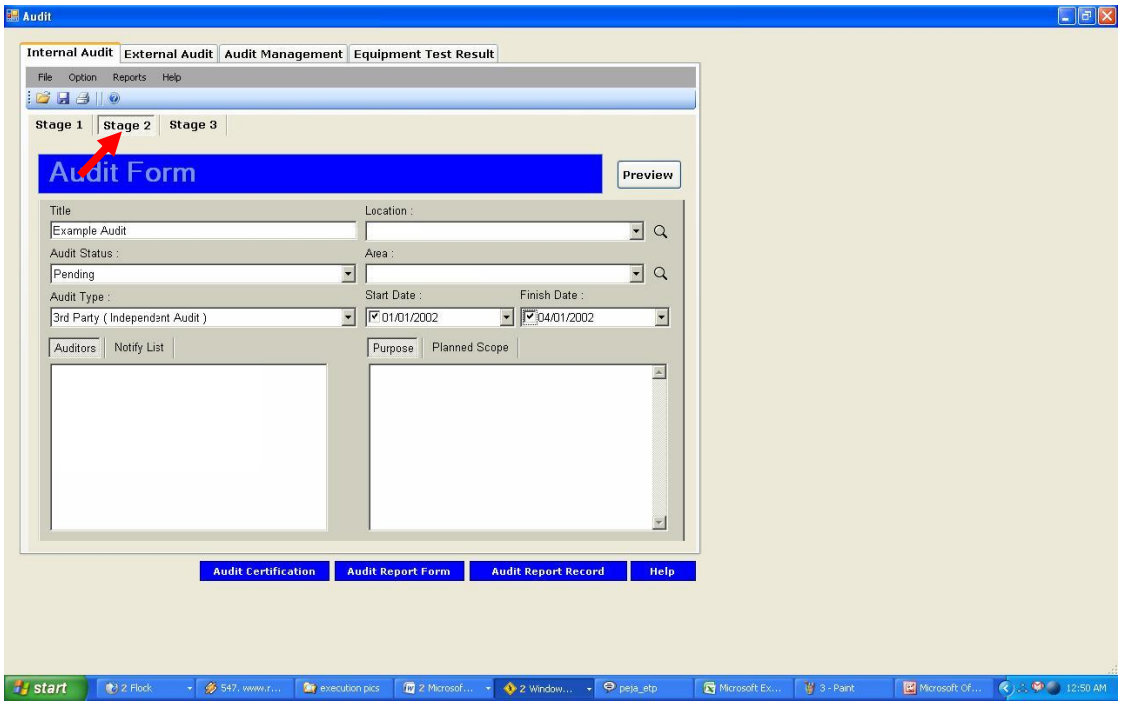


Figure 18: Audit form

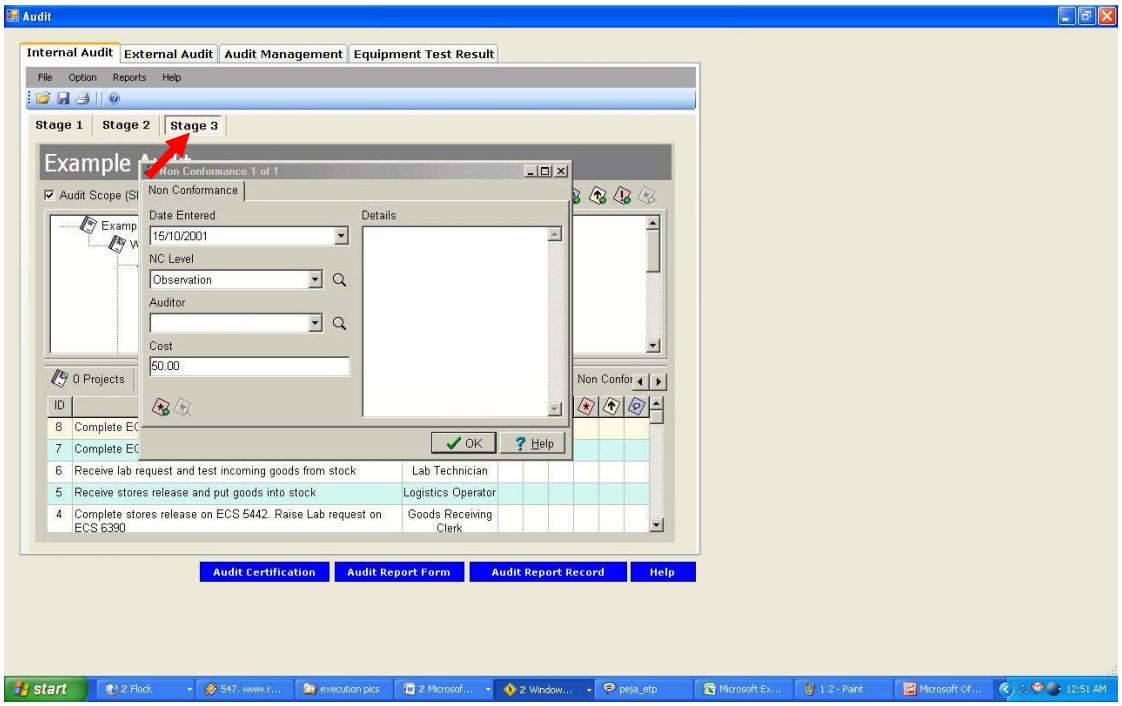


Figure 19: Detailed audit form

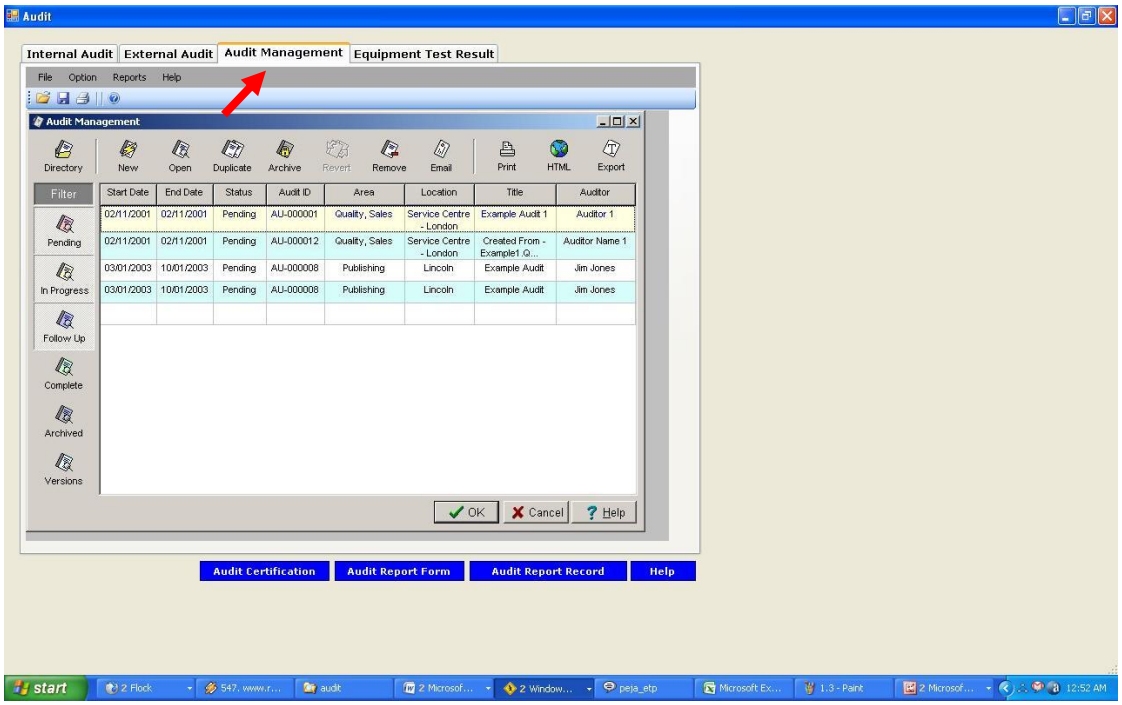


Figure 20: Audit record

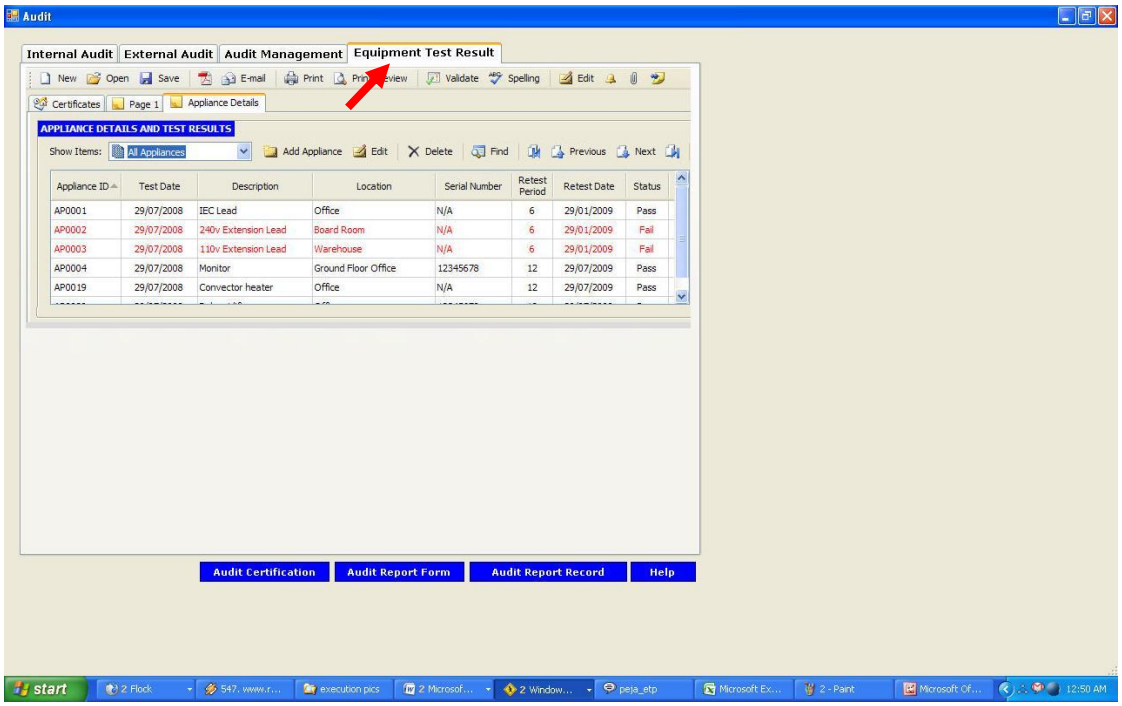


Figure 21: Equipment test result

Figure 22: Audit report form

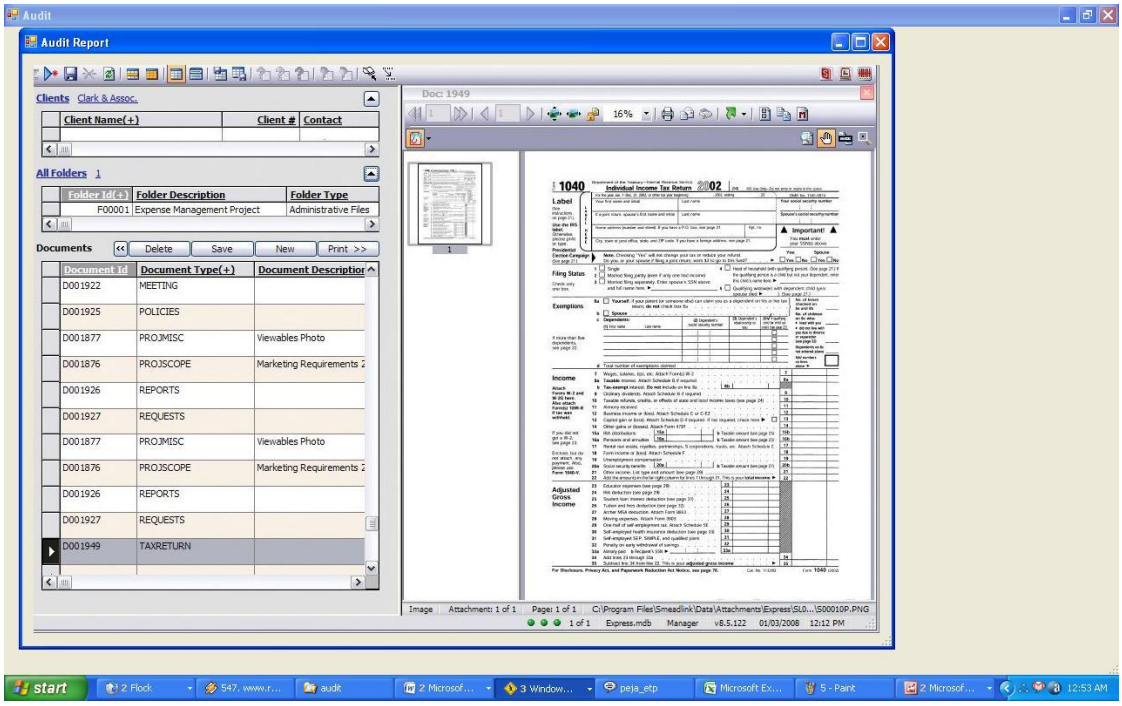


Figure 23: Audit report record

Discussion:

1. The frameworks are developed such that they comply with the regulatory requirements of Process Safety Management (PSM) publication by U.S Occupational Safety and Health Administration (OSHA) in 2000. This is to avoid any incompliance of regulations among the companies.

2. Furthermore, this will assist in the audit process of the system and making it a smooth and easy process if the system follows all the regulatory requirements. If the system fails to comply with even one (1) requirement, then it cannot be established.

3. The fully developed expert system has high potential to be commercialized in the outside market since PSMES will be the ultimate tool that helps companies to comply with OSHA regulations and requirements.

4. The expert system will also helps in minimizing management and maintenance cost of a company as well as saving a lot of time.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

As the conclusion, PSMES is successfully developed by integrating all the selected PSM elements into one practical, efficient and user-friendly system. The author successfully demonstrates one working example from each category of PSM elements. The objective of the project is achieved. The strong frameworks developed for each PSM elements produce a reliable, convenient and user-friendly tool—the expert system. PSMES is an ultimate expert system that will assist the user in fulfilling the regulations of OSHA which is crucial for a company/plant to operate at all times. Developing PSMES is a sustainable achievement because it ensures profit in return as PSMES is the only tool of its kind which available in the market at present.

Recommendations:

1. The expert system must initially be tested by a number of respondents to identify any imperfections or weakness before being commercialized in the outside market.
2. The expert system should maintain a very high security to prevent any break-outs into the system by irresponsible individuals.

CHAPTER 6

REFERENCES

The format of references for the respective sources is as follows:

1. Website refer to http://www.ehso.com/
1. Website refer to http://www.osha.gov/Publications/osha3132.pdf
2. Article refer to W. Theodore and F. Richard (2005)
3. Journal refer to W. Bridges (1994)
4. Journal refer to N. Mulvey (1995)
5. Article refer to Chilworth Process Safety News (2008)
6. Journal refer to M. David
7. Book refer to Chilworth Pvt. Ltd. (2009)

The Elements of Process Safety Management System, http://www.ehso.com/

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W. Theodore and F. Richard, 31st October 1995, *Implementation of Process Safety Standards in an R&D Environment*, Research and Development, Basell USA, 912 Appleton Road, Elkton, MD 21921.

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