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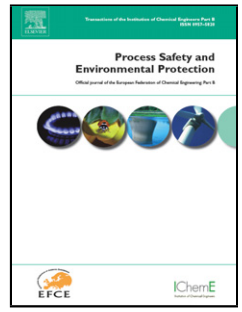

Title: Managing process chemicals, technology and equipment information for pilot plant based on Process Safety Management standard

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Managing Process Chemicals, Technology and Equipment Information for Pilot Plant based on Process Safety Management Standard

Research Highlights:

- A structured system to manage process chemicals, technology and equipment information based on OSHA PSM.
- Organized strategies to manage documentations, communicate information, and written program for maintaining, revising and updating process information.
- P&ID is used as a foundation for data management.
- Successfully tested to manage PSI in pilot plant.

Managing process chemicals, technology and equipment information for pilot plant based on Process Safety Management standard

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Abstract

Injuries, accidents or even fatalities while working in pilot plant are reported worldwide. The OSHA Laboratory Standard and Hazard Communication Standard have been used as a guideline to manage safety of laboratories and pilot plant. In spite of the implementation of these standards, incidents which result in injuries and property loss are continuously occurring. The implementation of OSHA Process Safety Management (PSM) Standard in pilot plant is expected to further reduce the risks of accidents. This paper presents a new system for managing process chemicals, technology and equipment information in pilot plant and the concept is developed based on Process Safety Information (PSI) element of PSM 29 CFR 1910.119(d). It provides organized strategies to manage documentations, communicate information, and written program for maintaining, revising and updating related information. Process and Instrumentation Diagram (P&ID) is used as a foundation for data management. Implementation of this system at the CO2 Hydrocarbon Absorption System pilot plant as a case study is examined and discussed.

Keywords: Process safety information; Pilot plant; Process Safety Management; Hazardous chemicals; Process technology; Equipment information

1. Introduction

Pilot plant occupies a grey area somewhere in the middle of the spectrum from basic research to real process plant production. Some of the items are physically part of research unit operations, whereas others are part of the manufacturing operation. Pilot plant also handles hazardous chemicals such as acids, bases, corrosive, flammable, combustible liquids, oxidizers, water-reactive, explosive, compressed gasses, asphyxiants, toxics, and unstable chemicals. The inventories of hazardous chemicals in pilot plant are typically smaller than commercial plant and considered to be safe without the requirement of extra precautions. However, due to the novel operations and processes which are being used, high operation density of equipment, unproven or changing technology, lack of safety related information at developmental stages, waste generated by operation, and use of sophisticated instruments could give a significant hazardous impact that can cause injuries, fatalities and damage of properties (Langerman, 2008, 2009a; Reinart, 2003). As an example, in real process plant, the plant layout and equipment safe siting distance normally follows standards to avoid the damaging effect in the case of the accident. However, pilot plant does not have such a standard to follow and normally the users intend to design a compact pilot plant system. The users normally assume it is safe to operate in a compact design due to small quantity of hazardous chemicals to be handled. Due to high density of operating equipment, the risk of the accident may be significant. The various heating devices installed like furnaces, heaters and electrical equipment in the designated area could increase the risk. In the event of the accident such as fire or explosion, it may involve numbers of equipment that varies from reactors to compressors. These equipment have different hazard potential that installed close with each other will make the accident worst.

Most of the pilot plants are housed inside the buildings. In the case of chemical leaks, the accumulation of vapour could cause major problems. In addition, vapour cloud formation, pressure builds up, asphyxiation and short-term exposure to toxic gases could also endanger people present in the pilot plant. As hazards are considered minimal in the lab, the lab safety is not given priority due to the perception that small quantity of materials would not give a significant hazardous impact to people and environment (Langerman, 2009a). It is therefore, not surprising to know that rate possibilities of the lab accidents in schools and colleges are 100 to 1000 times greater than at Dow or DuPont as estimated by James Kaufman (Benderly, 2009).

Hazard recognition in laboratories and pilot plant is generally managed under, either Occupational Safety and Health Administration (OSHA) Laboratory standard 29 CFR 1910.1450 or Hazard Communication standard 29 CFR 1910.1200. According to Mason (2000), pilot plant is dedicated to the development of a potential new production process which is specifically exempted from the OSHA Laboratory standard because it fails to meet the definition of 'laboratory'. In addition, West (1999) in his studies classified that pilot plant and full-scale production has similarity in terms of typical stages in assessment of chemicals.

Investigation of the pilot plant incidents also reveals that the underlying causes are similar to those found in major full-scale plant accidents. Thus, the approach towards improving safety of pilot plant cannot be different from that of the full-scale plant. Therefore, a mandatory regulation imposed for full-scale plant that effectively controls the high risk operation could also be extended to the pilot plant. One of the established standards is Process Safety Management (PSM) Standard 29 CFR 1910.119. However, PSM applies to industrial processes handling more than 10,000 pounds of hazardous material. Due to rigour requirements and management programs of OSHA PSM, it is therefore suitable to be implemented at any other plants including pilot plant. The application of the methods outlined in the OSHA PSM to pilot plant operations may provide significant reduction to the risks associated with the operations in this location (Aziz et al., 2012; Langerman, 2009b).

OSHA PSM is designed to provide specific guidance, which is needed to manage operational safety, particularly related to process hazards without excessive operational interference. In response to many major accidents in process plants, OSHA PSM was introduced in 1992 (OSHA, 1992). Many reports have been written on the implementation of PSM on the Chemical Process Industry (CPI) but none for pilot plant scale (Kwon, 2006; Langerman, 2009a).

PSM covers 14 integrated elements, including Process Safety Information (PSI) 29 CFR 1910.119(d) (Mason, 2001a, b). PSI focuses on process chemicals 29 CFR 1910.119(d)(1), technology 29 CFR 1910.119(d)(2) and equipment 29 CFR 1910.119(d)(3) management. The compiling of this information will provide a necessary resource to a variety of users, including the team that will perform the Process Hazards Analysis (PHA), the Operating Procedure (OP), and local emergency preparedness planners. However, the usefulness of PSI depends on the accuracy and reliability of the information. It is also essential that all employees know that the information exists, where it is located and how it can be accessed (Aziz et al., 2013).

Updating of process information is quite common in pilot plant, especially when changes involving hazardous raw materials, unproven or changing technology, facility issues, etc. Any changes of these components need to be adequately managed, so that process hazards and risk could be effectively controlled. Even though its implementation would drive a major improvement in pilot plant safety, lacking of a systematic technique for easy adoption of this standard had delayed its application in pilot plant. This paper presents a structured PSI management system, focusing on hazardous chemicals, technology and equipment information in pilot plant that complies with PSM standard.

2.0 Methodology

2.1 Compliance with PSI 29 CFR 1910.119(d) Requirements

The objective of this section is to provide complete information concerning the management of process chemicals, technology and equipment in the pilot plant operation as required by OSHA PSI 29 CFR 1910.119(d). The framework based on this standard is given in Fig. 1.

The first step in PSI implementation is to check the availability of PSI program. If the information is not available, the end user is required to take necessary actions for the development of the PSI program as required under 29 CFR 1910.119(d)(1). Once the PSI program is established, the written information of the process is compiled and tracked following 29 CFR 1910.119(d)(1)(i-vii), 29 CFR 1910.119(d)(2)(i)(A)-(E) and 29 CFR 1910.119(d)(3)(i-iii) respectively. The availability of the information is monitored using checklist system and stored together with revision date, approval information and evidence location. For any incomplete information, the data should be obtained within suitable time frame prior to the development of hazards analysis and risk assessment.

2.2 Using Piping and Instrumentation Diagram (P&ID) as a Foundation for Data Management

In this work, a node system technique based on P&ID is used to manage and track documents of the process information. Fig. 2 shows the framework of how P&ID is utilized in managing the process information within a pilot plant. The P&ID is divided into several nodes. The number of nodes depends on the design intent and the number of equipment within the pilot plant considered manageable by the end users. The PSI implementation for each node is carried out according to 29 CFR 1910.119(d)(1) – (d)(3) standards as shown in Fig. 1. Once information has been compiled and updated for the selected equipment or stream, the end users can choose next equipment or streams within the selected node. After all the information within the node has been updated, the end users can select the next node to review or update the data. The updating information process will continue until all nodes in the P&ID are completed.

2.3 Computer Database Prototype System

The implementation of this concept was assisted by a computer database system for managing and communicating the process information. Even though the compilation of written process chemicals, technology and equipment requirements can be completed manually, the best results can be obtained through the help of a computer database system. Process Safety Information Management System (PSI4MS) was developed to demonstrate the proposed concept as illustrated in Fig. 1 and 2 using Microsoft Office Access 2010.

PSI4MS could fulfil all the PSI requirements based on OSHA PSM standard and could ensure that information is kept current throughout process changes, equipment maintenance and other normal activities. The system has been designed to allow for capturing documented data at specific evidence location either in the paper form within files, in computer data bases or using a computer-aided design system.

3.0 Case Study

To demonstrate the developed concept, a case study was conducted using CO_2-Hydrocarbon Absorption System (CHAS) pilot plant under the Research Centre of CO_2 Capture (RCCO_2C) at Universiti Teknologi Petronas. The pilot plant is used to study the absorption performance of amine solvent in removing carbon dioxide (CO_2) from the natural-gas stream for pressure of up to 80 bars. Since the pilot plant is handling a flammable gas at a high pressure condition, it is a compulsory requirement by the university that the test rig is subjected to process hazard assessment and management. The research team used PSI4MS to manage the process information for CHAS.

Referring to the concept illustrated in section 2.2, the P&ID was divided into several nodes according to its intended design. Fig. 3 shows the selected node for this case study, which consists of absorption column (AC01) with inlet and outlet streams.

3.1 Development of PSI

Fig. 4 shows the main interface of PSI4MS. This interface is used to assess and monitor the compliance status of all sub-standards under 29 CFR 1910.119(d). All the requirements are managed and monitored through digital forms that can be stored in a centralized database. The forms present the required written information for process chemicals, technology and equipment based on OSHA PSM standard as shown in Fig. 5, 6 and 7 respectively. Most importantly, the end users would always be alerted of insufficient process information of the pilot plant that needs to be compiled to ensure the accomplishment of hazards control and risk reduction program.

Fig. 5 shows the interface of PSI4MS for chemical information. All hazardous chemicals involved in the selected node and data completeness status based on the 29 CFR 1910.119(d)(1) requirements are shown in this tab. The listed sub-standard 29 CFR 1910.119(d)(1)(i-vii) in the interface acts as guidelines that provide crucial information that needs to be documented and compiled by end users. The 'Description' and ‘Evidence Location’ columns prompt the authorized personnel to briefly describe and locate the PSI information. Authorized personnel can be a safety team member, lab manager, plant coordinator, etc., who are familiar with the information related to pilot plant. They are responsible to upload and update the information and make necessary follow up if any actions required by PSI4MS.

Different access level is required for authorized personnel to ensure the security of the data. Other personnel only can read the information and give feedback if necessary. The document issued can be tracked by referring to the date as given in the 'Revision date' column. This system allows for tracking the PSI data changes. The frequency of updating the data is depending on the changes required in pilot plant and also the new data updated in other PSM elements such as from PHA, Management of Change (MOC), Pre Start up Safety Review (PSSR), etc. The information on the revised date is important to ensure the compiled PSI data is updated, maintained and consistent with the on-going operations.

The completeness of the written process chemical information is tracked by a checklist in the interface. Once completed, the authorized personnel must tick the 'Complete' box to confirm the completeness of the information. Further actions are required for the incomplete information. The superior can assign the qualified personnel to provide the specific information in the 'Action By' column, and provide a reasonable due date at 'Reply date' column. Therefore, the appropriate action can be taken, monitored and resolved in a timely manner.

3.2 Information of Process Chemicals

According to Einolf and Menghini (1999), the information about the process chemicals to be compiled should be comprehensive enough for an accurate assessment of the fire and explosion characteristics, the reactivity hazards, the safety and health hazards to workers, the corrosive or erosive effects on the equipment and instrumentation, and the existence of incompatibilities between materials commonly found around the processes. Normally, this information can be extracted from Material Safety Data Sheets (MSDS). Some standards such as Hazard Communication CFR 1910.1200(g) specifically request the end user to provide MSDS information. However, PSI element in PSM does not mention MSDS as a mandatory requirement. Regardless of the availability of MSDS, the chemical data according to 29 CFR 1910.119(d)(1) must be compiled. Therefore, PSI4MS provides flexibility to accept any data as long as it can fulfil the above requirement, including MSDS.

In this case, the completed written information on process chemicals of the selected node is given in Fig. 5. For example, the Methane (CH_4) documentation is available at C:\CHAS\PSI\Chemicals\MSDS300000000087-CH4.pdf. The data consistency is checked against the date of revision (i.e. 26-07-2010) and the approval authority (i.e. research scientist).

3.3 Information of Process Technology

Rigorous information of process technology is important to ensure identification and assessment of process hazards could be undertaken appropriately. Without this information, the consequences of many process deviations cannot be adequately defined. Referring to Fig. 6, PSI4MS captures information pertaining to process flow diagram, maximum intended inventory and safe upper and lower operating limit of AC01. However, a few gaps were identified related to the availability of process chemistry data, and consequence of deviation as required by OSHA PSM. PSI4MS allows an appropriate action to be taken in order to minimize the identified gap. In this case, 'WMK' and 'ASZ' had been identified as the designated personnel to provide the information with the due date given at 'Due date' column.

3.4 Information of Process Equipment

The information of process equipment to be compiled is all the critical and auxiliary equipment that involves with hazardous chemicals. The process comprises of using, storing, processing, handling, transferring of materials, or combination of these activities. The process may involve with a spectrum of equipment, including reactors, storage tanks, process vessels, separators, heat exchangers, piping systems, etc. (OSHA, 1992).

Detail information pertaining to process equipment such as P&ID, material of construction and safety valves should be provided to ensure the personnel could operate and maintain the system appropriately. For this case study, as shown in Fig. 7, PSI4MS captures all the important information except for material and energy balance data. Materials of construction, electrical classification, design code and standard employed information have been recorded in Technical Specification (003AC01) of CHAS. The document is stored at C:\CHAS\PSI\Equipment\003AC01Technical specification CHAS.pdf. Whereby, information of relief system design and design basis for this column is captured in pressure relieve valve (PRV06/07) specification at C:\CHAS\PSI\Equipment\9100-threaded-boucher.MERCER.pdf. It shows that, all the information is supplied by manufacturer and verified by 'AMS' (i.e. principal investigator) of the pilot plant.

For the incomplete material and energy balance information, the task was assigned to research officer 'WMK' who should provide the information within the time frame. All the required information of process equipment for this node is considered complete once this information is available and updated in PSI4MS. All the above information is accessible by relevant personnel such as researchers, students, affected contractor and emergency response team for reference and task delegation.

5.0 Conclusion

This study proposes an OSHA PSM compliance system for pilot plant in order to manage process chemicals, technology and equipment information. The strategies for implementation and process data management are clearly presented in PSI and P&ID frameworks. PSI4MS is developed based on these frameworks that could comply with OSHA PSM-PSI element. It assists end users to manage the process information and to identify gaps in a systematic manner.

The conducted case study successfully showed that the PSI4MS is capable of maintaining the updated process information for pilot plant in a structured manner. The PSI4MS shown that the introduced concept could help any institutions or company to manage their pilot plant process information systematically. The availability of the process information is vital to control process hazards and prevent accidents of the pilot plant.

Acknowledgement

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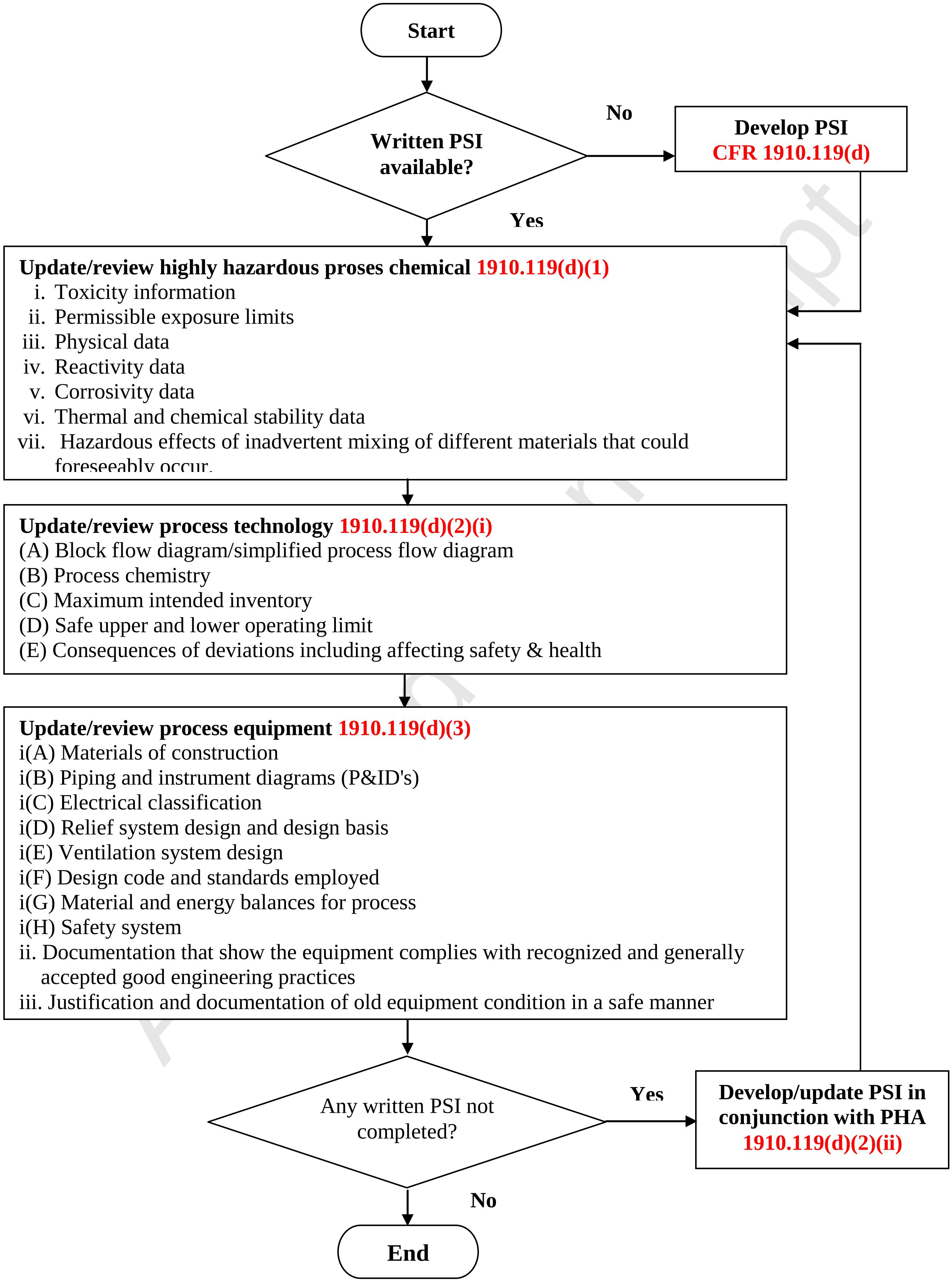

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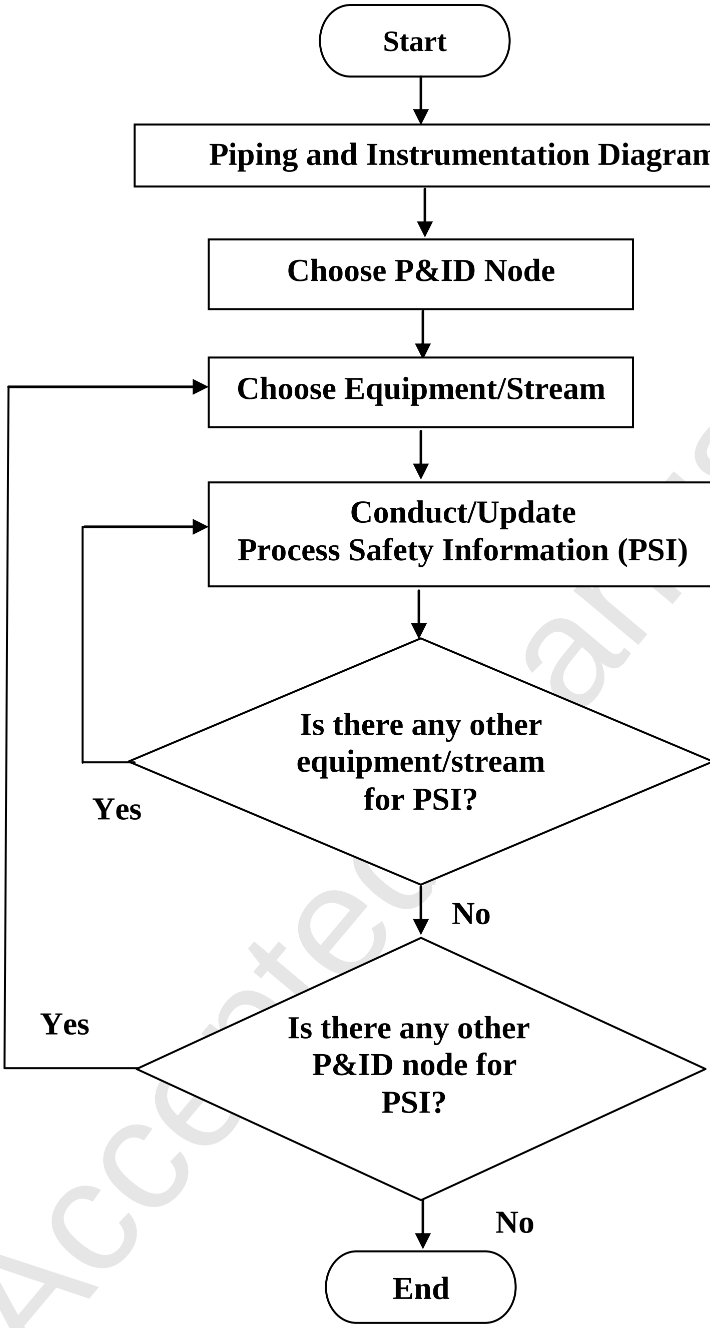

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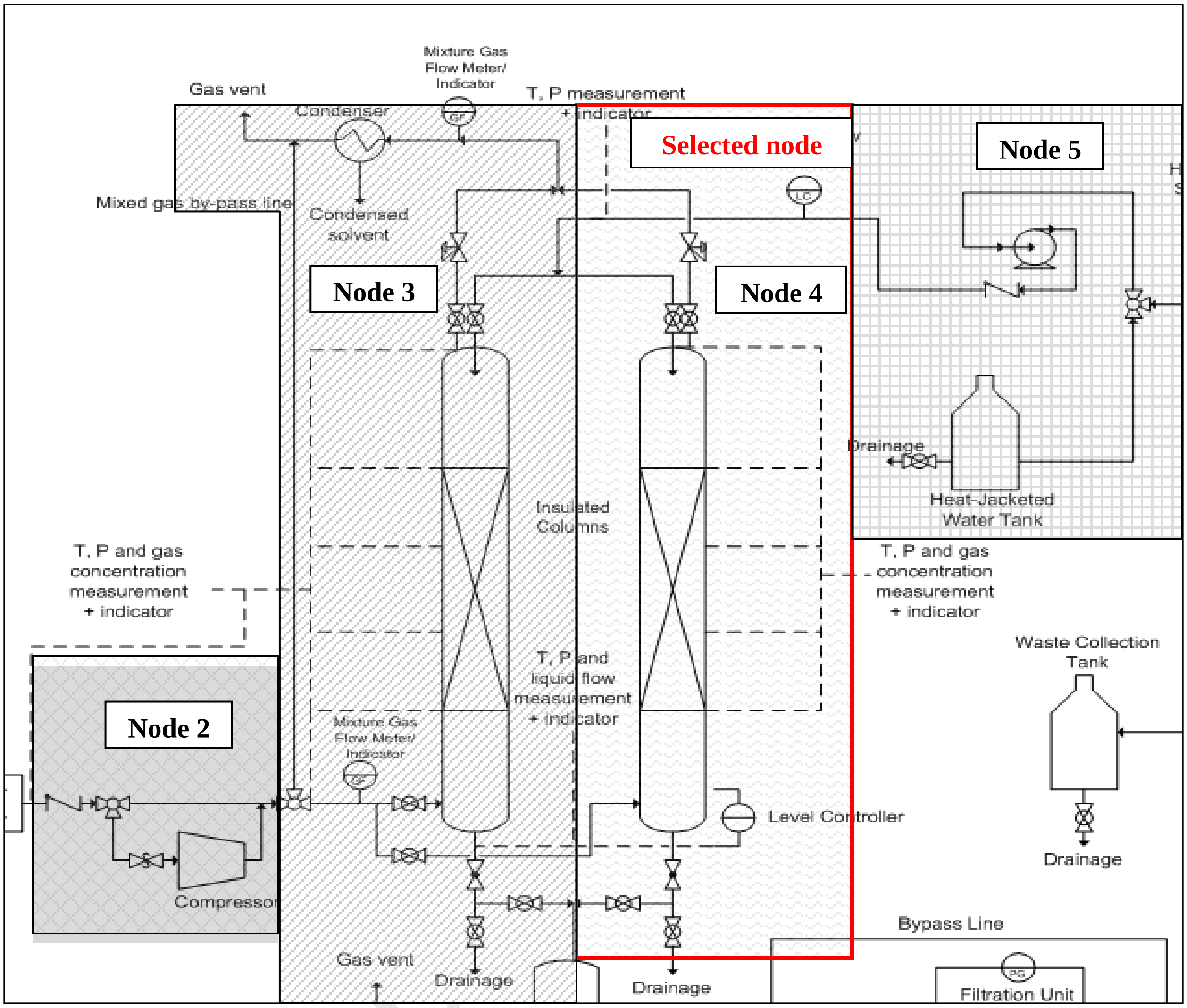

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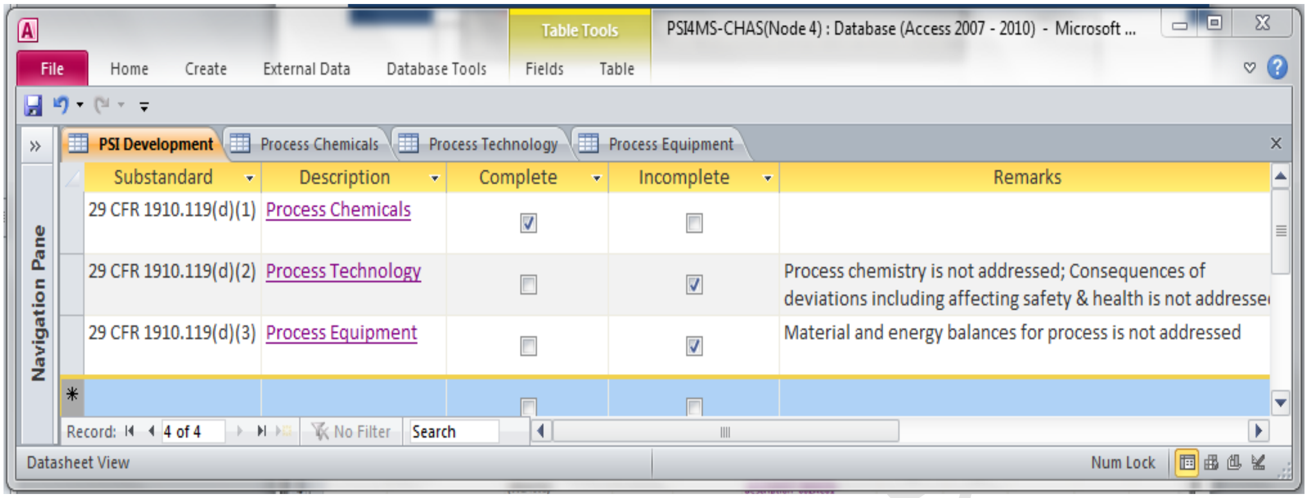


Fig. 4 PSI Development

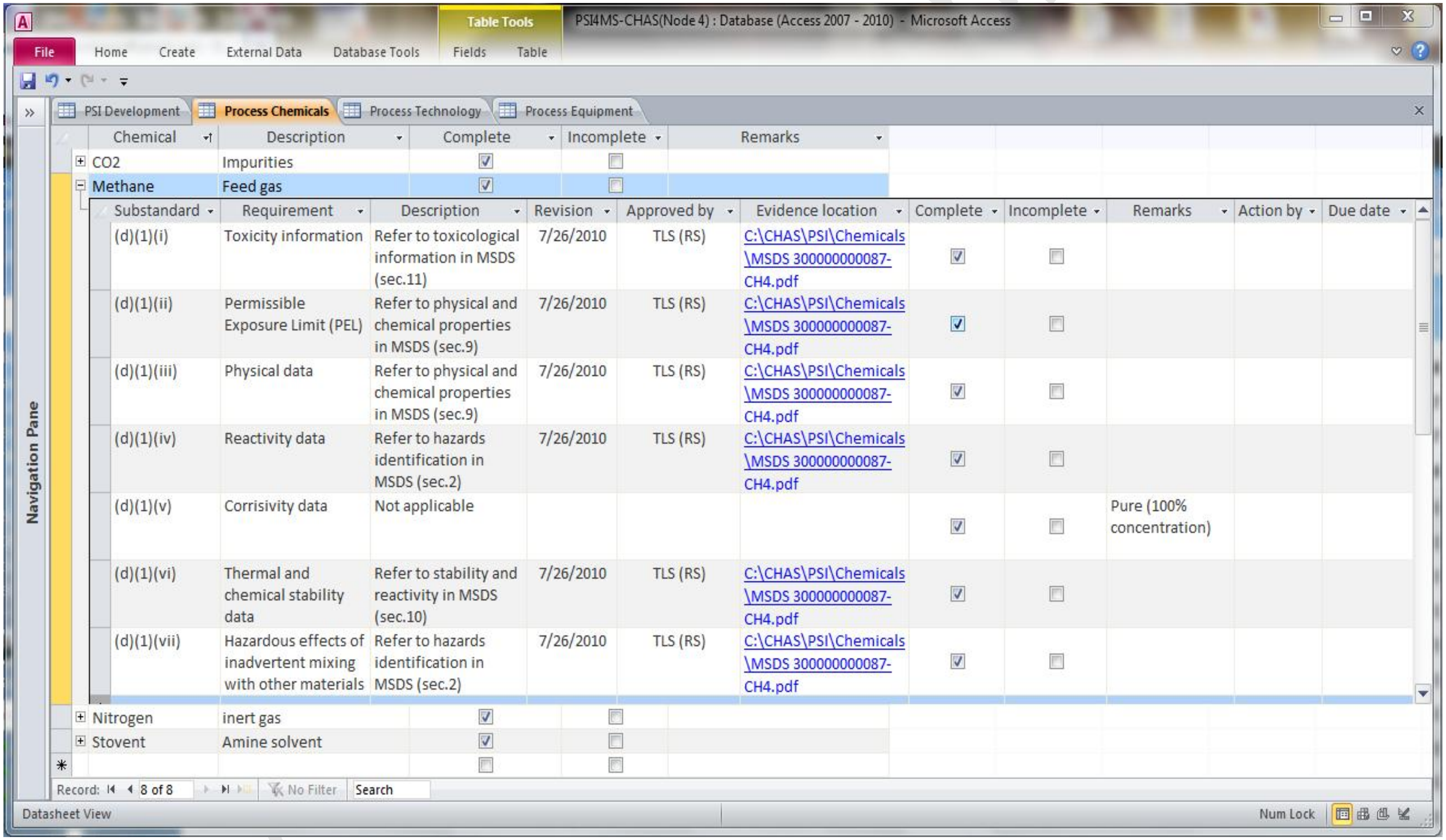
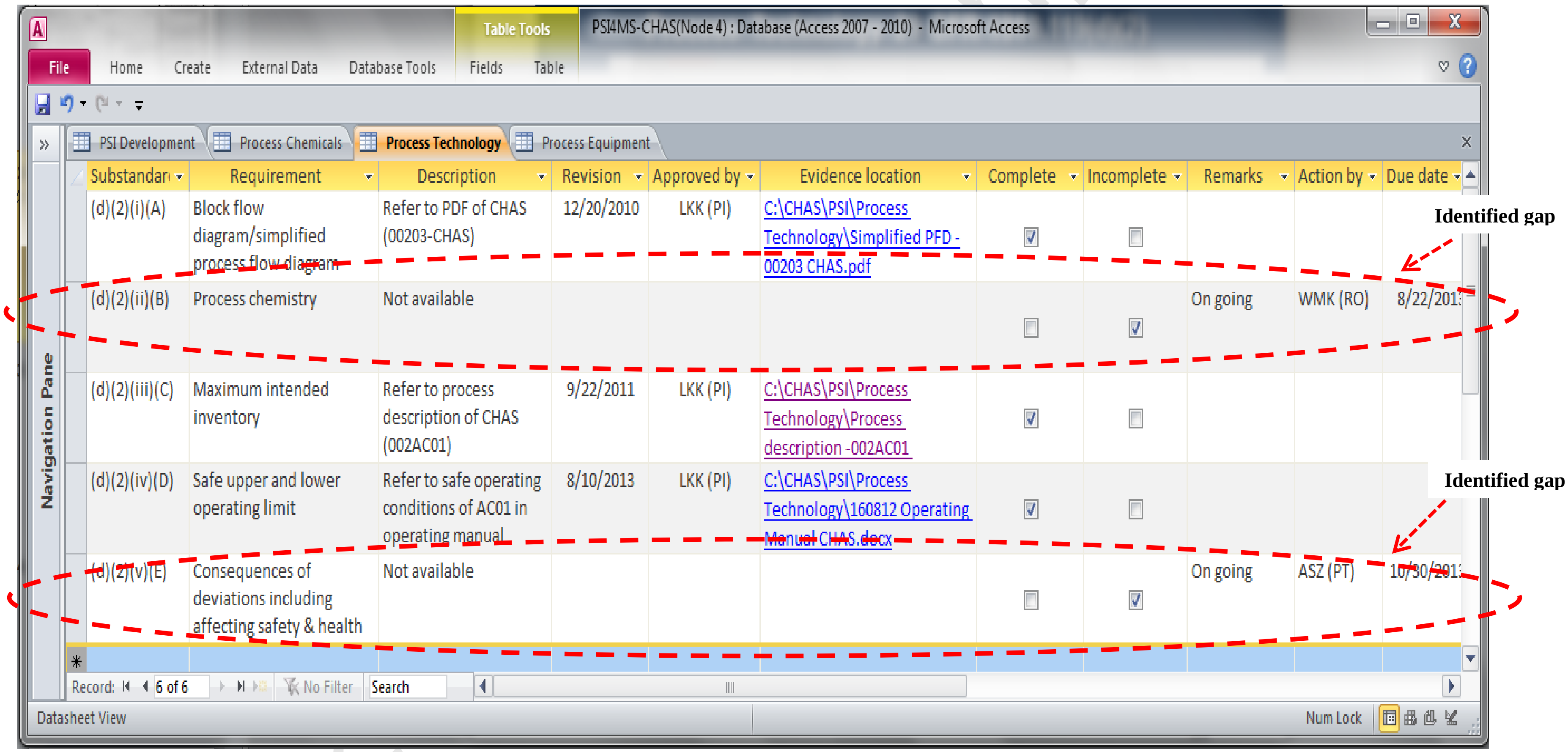
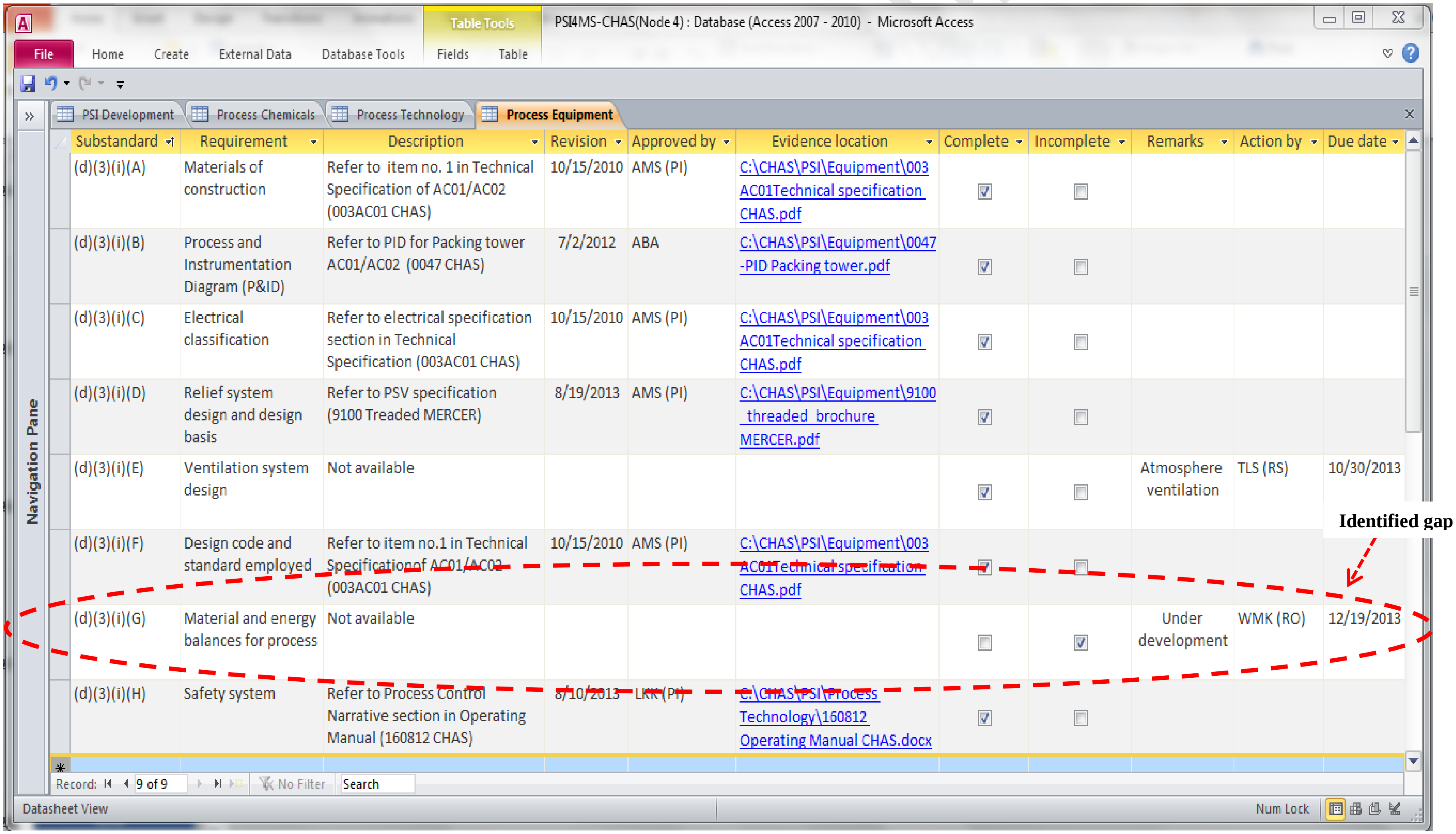


Fig. 5 Process Chemicals



Substandard	Requirement	Description	Revision	Approved by	Evidence location	Complete	Incomplete	Remarks	Action by	Due date
(d)(2)(i)(A)	Block flow diagram/simplified process flow diagram	Refer to PDF of CHAS (00203-CHAS)	12/20/2010	LKK (PI)	C:\CHAS\PSI\Process Technology\Simplified PFD - 00203 CHAS.pdf	☑	☐			
(d)(2)(ii)(B)	Process chemistry	Not available				☐	☑	On going	WMK (RO)	8/22/201
(d)(2)(iii)(C)	Maximum intended inventory	Refer to process description of CHAS (002AC01)	9/22/2011	LKK (PI)	C:\CHAS\PSI\Process Technology\Process description -002AC01	☑	☐			
(d)(2)(iv)(D)	Safe upper and lower operating limit	Refer to safe operating conditions of AC01 in operating manual	8/10/2013	LKK (PI)	C:\CHAS\PSI\Process Technology\160812 Operating Manual CHAS.docx	☑	☐			
(d)(2)(v)(E)	Consequences of deviations including affecting safety & health	Not available				☐	☑	On going	ASZ (PT)	10/30/201

Fig. 6 Process Technology



Substandard	Requirement	Description	Revision	Approved by	Evidence location	Complete	Incomplete	Remarks	Action by	Due date
(d)(3)(i)(A)	Materials of construction	Refer to item no. 1 in Technical Specification of AC01/AC02 (003AC01 CHAS)	10/15/2010	AMS (PI)	C:\CHAS\PSI\Equipment\003 AC01Technical specification CHAS.pdf	☑	☐			
(d)(3)(i)(B)	Process and Instrumentation Diagram (P&ID)	Refer to PID for Packing tower AC01/AC02 (0047 CHAS)	7/2/2012	ABA	C:\CHAS\PSI\Equipment\0047 -PID Packing tower.pdf	☑	☐			
(d)(3)(i)(C)	Electrical classification	Refer to electrical specification section in Technical Specification (003AC01 CHAS)	10/15/2010	AMS (PI)	C:\CHAS\PSI\Equipment\003 AC01Technical specification CHAS.pdf	☑	☐			
(d)(3)(i)(D)	Relief system design and design basis	Refer to PSV specification (9100 Treaded MERCER)	8/19/2013	AMS (PI)	C:\CHAS\PSI\Equipment\9100 _threaded_brochure_ MERCER.pdf	☑	☐			
(d)(3)(i)(E)	Ventilation system design	Not available				☑	☐	Atmosphere ventilation	TLS (RS)	10/30/2013
(d)(3)(i)(F)	Design code and standard employed	Refer to item no.1 in Technical Specificationof AC01/AC02 (003AC01 CHAS)	10/15/2010	AMS (PI)	C:\CHAS\PSI\Equipment\003 AC01Technical specification CHAS.pdf	☑	☐			
(d)(3)(i)(G)	Material and energy balances for process	Not available				☐	☑	Under development	WMK (RO)	12/19/2013
(d)(3)(i)(H)	Safety system	Refer to Process Control Narrative section in Operating Manual (160812 CHAS)	8/10/2013	LKK (PI)	C:\CHAS\PSI\Process Technology\160812 Operating Manual CHAS.docx	☑	☐			

Fig. 7 Process Equipment