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Minimizing Audit Findings by increasing Operational Discipline and Process Safety Culture

Gemma Dunjó, John Cronin, Christian Sarno

ioMosaic Corporation, 93 Stiles Road, Salem, New Hampshire 03079
dunjo.g.nh@iomosaic.com

Many major accidents have taken place in the chemical and petrochemical industry over the past 40 years (e.g. Bhopal (India, 1984), Texas City (USA, 2005)), which have been key driving forces for issuing new regulations (governments), publishing standards (industry groups), developing policies (companies), and ultimately for improving Loss Prevention strategies and Process Safety Management (PSM). On this context, a key standard is the OSHA PSM (29 CFR 1910.119), a process-based program aiming at preventing or minimizing the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals.
The present paper focuses on the results from several PSM audits performed between 2010 and 2016, at several different Chemical Process Industry (CPI) facilities. On the one hand, we have evaluated how well these facilities complied with the requirements of the OSHA PSM Standard. On the other hand, the data from the audit findings has been compiled and statistically processed in order to compare the main common findings with the results of those analyzed by OSHA's Refinery and Chemical National Emphasis Programs (NEP) in 2012.
Key audit findings from the CPI are a valued source of information for understanding current safety weaknesses. The lessons learned from this study help us to identify operational discipline and process safety leadership and culture benefits towards minimizing or avoiding audit findings, and therefore, to contributing to an optimized and sustainable Process Safety management system.

1. Introduction

Many major accidents have taken place in the chemical and petrochemical industry over the past 40 years (Table 1), which have been key driving forces for issuing new regulations (governments), publishing standards (industry groups), developing policies (companies), and ultimately for improving Loss Prevention strategies and Process Safety Management (PSM). On this context, a key standard is the OSHA PSM (29 CFR 1910.119), a process-based program aiming at preventing or minimizing the consequences of catastrophic releases of toxic, reactive, flammable, or explosive chemicals.
The United States (US) Occupational Safety and Health Administration (OSHA) process safety management (PSM) standard 29CFR 1910.119 is a performance-based management system regulation intended to prevent catastrophic releases of highly hazardous chemicals (HHC). This standard contains requirements for the safe management of hazards associated with processes using, storing, manufacturing, handling, or moving highly hazardous chemicals onsite. It emphasizes the management of hazards through an established comprehensive program that integrates technologies, procedures, and management practices. The OSHA PSM 1910.119 standard consists of 14 elements and compliance audits is one of them. It requires compliance audits of all covered facilities every three years; these audits are the ongoing quality assurance process for the process safety management systems.
This study presents a case study that compiles and analyses management system audit findings and related data from a sample of sixteen (16) process facilities. The analysis identifies the most frequently cited elements and compares them with the results obtained by OSHA refinery and chemical National Emphasis Program (NEP) inspections:

- 2007 – Petroleum Refinery Process Safety Management NEP

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- 2009 – PSM Covered Chemical Facilities NEP
- 2011 – PSM Covered Chemical Facilities NEP

NEP are the most significant PSM enforcement actions since the OSHA standard was promulgated in 1992.

Table 1: Examples of major accidents in the chemical and petrochemical industry

Location	Date	Company	Process	Major Incident	Fatalities (F)/Injuries (I)
Flixborough (UK)	6/1/74	Nypro (UK) Ltd	Production of caprolactam	Explosion in oxidation of cyclohexane process	F: 28 workers I: 36 on-site, 53 off-site
Seveso (Italy)	7/10/76	Industrie Chimiche Meda Societa Azionara (ICMSA)	Batch production of 2,4,5-trichlorophenol (TCP)	Toxic release of TCDD (2,3,7,8-tetrachlorodibenzo-p-disoxin)	F: 0 I: 477 people reported skin injuries (burns & chloracne)
Bhopal (India)	12/3/84	Union Carbide India Ltd	Production of Sevin	Toxic release of methyl isocyanate (MIC)	F: 3,787+ workers and near-by residents
Piper Alpha (UK)	7/6/88	Occidental Petroleum (Caledonia) Ltd	Offshore oil and gas processing	Oil platform explosion and fire	F: 167 workers
Pasadena (USA)	10/23/89	Phillips 66	Polyethylene production	Polyethylene plant explosion and fire	F: 23 workers I: 130 to 300
Longford (Australia)	9/25/98	Esso Australia Resources Ltd	Gas and crude oil processing	Gas plant explosion and fire	F: 2 workers I: 8
Texas City (USA)	3/23/05	BP	Oil Refinery	Isomerisation unit explosion	F: 15 workers I: 180

Source: U.S. Chemical Safety and Hazard Investigation Board (CBS), 2018

2. Methodology for performing PSM Audits

The 14 OSHA PSM elements were included in the scope of the audits, as all PSM elements work together to provide multiple layers of protection (Aziz et. al., 2017). Moreover, the scope of the audit also encompassed an assessment of the applicability of the standard based on the chemicals handled on each specific site.

The audits were conducted by a person knowledgeable in audit techniques and who was impartial towards the facility or area being audited. All 14 OSHA PSM Elements were distributed among the several members of the Audit Team. Likewise, the compliance audit was conducted by at least one person knowledgeable in the process.

Prior to arriving on site, a pre-audit questionnaire was requested to be completed and forwarded to the audit team to help them prepare for the audit. This pre-audit questionnaire had information regarding how the PSM regulation is implemented at the specific facility. Once on site, a kick off meeting was conducted to introduce the audit team, to identify the element champions, to review the plan and approach for conducting the audit, and to establish an agenda according to the team's availability. The audit was based on the following:

- Physical inspections of the facility;
- Examination of selected process safety administrative and operating records;
- Interviews and discussions with key facility management, staff, and contractors; and
- Verification activities to assess the facility's application of, and adherence to, the regulations and related facility policies and procedures

An audit finding, citation or violation was defined as the identification of a part of the PSM program that does not meet regulatory requirements or industry/company standards. Likewise, an audit finding is a conclusion reached by the audit team based on data collected and analysed as to whether part of the PSM program does not meet regulatory requirements or industry standards. Findings from an audit can be categorized as follows:

- Regulatory – finding related to the OSHA PSM Standard
- RAGAGEP – finding related to Recognized and Generally Accepted Good Engineering Practice (or best industry practice)
- Local attention item – finding of a relatively minor nature or not within the scope of the audit
- Compliant – no evidence of non-compliance
- Daily debriefing meetings were held to communicate preliminary findings and observations made by the audit team to facility personnel. In addition, a closeout meeting was also held to present all the regulatory, RAGAGEP, and local attention findings on the last day of the PSM audit.

3. Operational Discipline and Process Safety Culture: the pillars of a robust PSM program

The effectiveness of a Process Safety Management System (PSM), is based on the daily ability of an organization to continuously and thoroughly implement all the system requirements (CCPS, 2011). Just one person, one time, not executing his/her task appropriately, could seriously jeopardize the well-functioning of an operation, which could in turn result in a major accident. Therefore, the success of a PSM program, is believed to be largely dependent on the high levels of operational discipline among the workers of all levels and the overall Process Safety Culture within an organization.

The Center for Chemical Process Safety (CCPS, 2007) defines the process safety culture in an organization as "The combination of group values and behaviours that determine the way process safety is managed. A sound process safety culture refers to attitudes and behaviours that support the goal for safer process operations".

The values that underlie the process safety culture help the individual understand, accept, and do what is right when no written rules or procedures are in place to address a particular situation or when procedures may be out of date or inconsistent with the organization's values and objectives. A sound culture also would ensure that these differences are brought to the forefront and resolved.

Management leadership and commitment to safety are key to promote and ensure a strong process safety culture across the whole organization. It has been proven that the effective conduct of operations and operations discipline start at the Upper Management level, demonstrating the behaviours they want the rest of the organization to emulate. Likewise, if a company lacks process safety culture, this cannot change until the company's attitude about safety changes. It is a development process; it takes time and a lot of tenacious hard work (Cheung and Burch, 2014; Clarke and Flitcroft, 2013).

Proactively managing an effective process safety program displays a high level of corporate responsibility and encourages the company to sustain it long-term. The bottom line is that outstanding process safety performance is a pathway to both financial success and the license to operate. A weak safety culture can be caused by lack of communication, lack of training and conflicting priorities, whereas a sound safety culture has three main pillars: commitment to health, safety, and environment (HSE) as a core value, workforce participation and ownership of safety problems and solutions, and trust between operations and management (IOSH, 2015).

4. Audit Findings: Statistical Analysis

ioMosaic has carried out many audits over the years, and a sample of sixteen (16) audits, from 2010 to 2016, was selected for conducting the analysis described in this paper. This sample of audits covered chemical facilities, refineries, and facilities handling explosives. The objective of the audits was to evaluate how well each facility complied with the requirements of OSHA PSM (OSHA, 2012). All 14 elements were audited:

- Employee Participation (EP)
- Process Safety Information (PSI)
- Process Hazard Analysis (PHA)
- Operating Procedures (OP)
- Training
- Contractor Safety
- Pre-Startup Safety Review (PSSR)
- Mechanical Integrity (MI)
- Hot Work Program
- Management of Change (MOC)
- Incident Investigation (II)
- Emergency Planning and Response (ER)
- Compliance Audits
- Trade Secrets

A total of 1,108 findings were identified when analysing the data of all 16 audits:

Regulatory: 648 (58%)

RAGAGEP: 199 (18%)

Local Attention: 261 (24%).

The compilation of findings for all facilities, identified the Regulatory as the main type of finding, followed by Local Attention and RAGAGEP. The distribution of the audit findings per facility are presented in Figure 1.

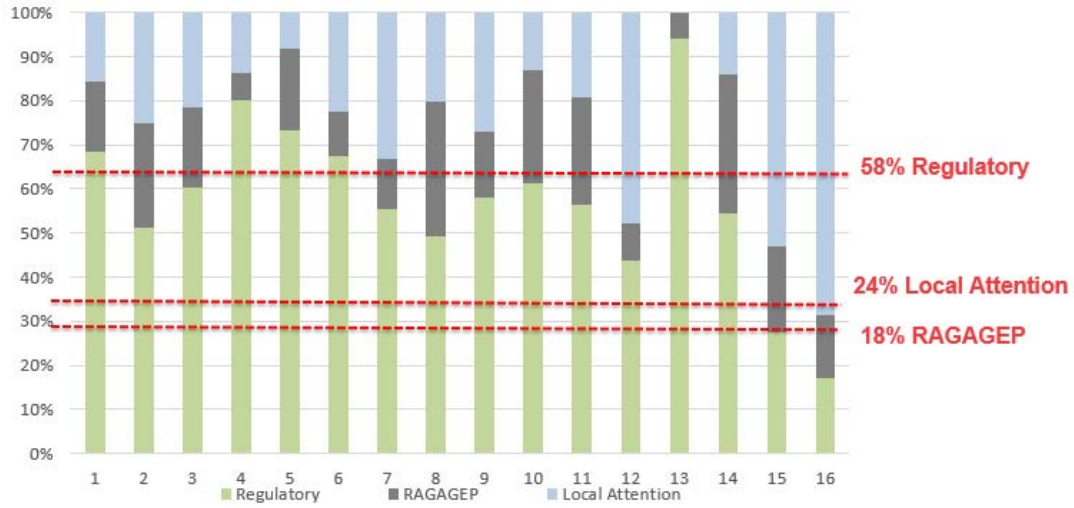

Figure 1: Distribution of the findings per audit conducted

4.1 Regulatory Findings Analysis:

The next step of the analysis was to determine which were the elements most cited for each of the finding's categories. By conducting a detailed analysis of each of the audits, a determination of which elements are more critical in process safety management can be done. The first category to be analysed is "Regulatory", finding related to the OSHA PSM Standard. Out of the 626 Regulatory findings, 104 belong to mechanical integrity, 78 to process safety information, 76 to operating procedures, and 72 to hot work permit. These findings represent a 52.7% of all the Regulatory findings.

4.2 RAGAGEP findings analysis:

The next category to be analysed is the findings related to Recognized and Generally Accepted Good Engineering Practice (RAGAGEP) (or best industry practice). The OSHA PSM standard is a performance-based standard, and it does not specify how the OSHA PSM standard has to be implemented at each facility. Therefore, companies are sometimes not aware of industry best practices or standards that can be followed to ensure a proper PSM implementation and monitoring, and it is the auditor's responsibility to identify and adequately explain the reason for the RAGAGEP finding.
Out of the 199 RAGAGEP findings, 31 belong to Mechanical Integrity (MI), 28 to Incident Investigation (II), 21 to Process Hazard Analysis (PHA), and 20 to Operating Procedures (OP). The sum of these findings represents a 59.4% of all the RAGAGEP findings.

4.3 Local Attention findings analysis:

The last category to be analysed is the findings related to Local Attention, finding of a relatively minor nature that does not represent a chronic PSM issue or a finding related to requirements not specifically listed in the PSM regulation. Out of the 261 Local Attention findings, 42 belong to Emergency Response (ER), 32 to Operating Procedures (OP), 32 to Incident Investigation (II) and 24 to Mechanical Integrity. The sum of these findings represents a 49.9% of all the Local Attention findings.

4.4 What are the main common PSM elements in the 3 finding categories?

From the analysis above on the different 3 categories of findings, we have identified that main common PSM elements (Table 2). The Mechanical Integrity element is the main audit finding in the 3 audit finding categories, followed by the Operating Procedures and the Incident Investigation elements.

4.5 What is the contribution of each PSM element to the total audit findings?

The last statistical analysis conducted is the overall review of all the findings per element, to identify which elements are the most cited and to be able to compare them with the OSHA inspections. Figure 8 presents the total audit findings %, per each of the 14 OSHA PSM elements.
Based on the ioMosaic audit results, the following elements can be considered the most cited and correspond to the 57% of all findings including all categories and all facilities:

- Mechanical integrity (15%)

- Operating procedures (12%)
- Process Safety information (10%)
- Hot Work (10%)
- Incident Investigation (10%)

Table 2: Main common PSM elements in the 3 finding categories

Regulatory	RAGAGEP	Local Attention
MI (16.6%)	MI (15.6%)	MI (9.2%)
OP (12.1%)	OP (10.1%)	OP (12.3%)
II (7.3%)	II (14.1%)	II (12.3%)
PSI (12.5%)	-	PSI (8.4%)
Hot Work (11.5%)	Hot Work (9%)	-

4.6 Why are these elements the ones that companies fail the most?

Mechanical Integrity:
Companies fail in implementing mechanical integrity because the inspections are overdue or because when deficiencies are identified, they are not addressed.
Operating Procedures:
The OSHA PSM Standard requires companies to develop procedures for each operating phase. This is a requirement that a lot of companies fail to comply with, as well as including the consequences of a deviation and the steps to correct and avoid it.
Process Safety Information:
Companies struggle to complete and keep evergreen all the process safety information required by the OSHA PSM regulation. This process safety information has to be updated when management of change takes place or prior to a process hazard analysis revalidation.
Hot Work:
The hot work procedures and permits sometimes lack continuous Lower Explosive Limit (LEL) monitoring, don't consider a fire watch present during the entire hot work task, or the requirements for venting are not documented on the hot work permit.
Incident Investigation:
Finally, the incident investigation reports do not contain all the required information, and the investigations are not conducted within 48 hours.
Despite best efforts, almost all safety management systems (SMS) have gaps in practicality and effectiveness. A sure way to improve SMS programs is to conduct proper training, promote a high level of operational discipline, improve process safety culture in the organization, conduct third party audits, and implement an enterprise software solution.

5. Comparison of OSHA Refinery and Chem NEP top PSM elements citations with ioMosaic's findings

Are the results of the present statistical analysis consistent when comparing them to the findings obtained from the OSHA Refinery and Chemical NEP inspections? In 2012, OSHA presented the results of their OSHA Refinery and Chemical NEP top PSM elements citations (Barab, 2012). Table 3 summarizes the results of the percentage of regulatory findings for the most cited elements. Mechanical integrity, process safety information, and operating procedures are the elements with more findings. The column on the right corresponds to ioMosaic's audit findings which are similar to the OSHA Refinery and Chemical NEP top PSM elements citations.

Table 3: ioMosaic's audit finding versus OSHA NEP top PSM element citations

Element	% Refinery NEP	% Chemical NEP	% ioMosaic (Regulatory)
MI	19.5	23.2	16.6
PSI	17.4	20.9	12.5
OP	17.1	14	12.1
Total %	54	58.1	41.2

Table 4 shows the total number of facilities inspected or audited, the corresponding number of citations or findings, and its percentage based on citations per inspection

Table 4: Number of audits conducted, and findings identified

Description	Refinery NEP	Chemical NEP	ioMosaic (Regulatory)
Inspections (facilities)	88	173	16
Citations (findings)	962	1487	648
Citations/Inspections (%)	10.9	8.6	40.5

Mechanical Integrity, process safety information, incident investigation, and operating procedures are highly dependent on the personnel's attitudes and behaviours. A strong safety culture competency as well as operational discipline are key in every organization since a safety management program will only be as effective as the underlying safety culture permits.
All audits reveal a history of repeat findings indicating chronic problems. Therefore, audit findings should always be seen as calls for action and should be addressed in a timely manner.

6. Conclusions

A process safety management system (PSM) is most effective when it is consistently applied and thoroughly integrated within the organization. Third-party audits are key in helping companies with the PSM implementation, continuous monitoring and improvement, and therefore, in overcoming this challenge.
Audits reveal a history of repeat findings indicating chronic problems which can only be effectively achieved by addressing the technical and cultural root causes. Thus, key audit findings are a valued source of information for understanding current weaknesses and lessons learned.
The results from the statistical analysis highlights trends and provides detailed conclusions on how to potentially link actual industry weaknesses (audit findings), via maximizing the importance of implementing a sound Process Safety Culture (supported and followed from top Management, through operations and maintenance, to all facility workers). In this context, the statistical analysis confirms that the most cited elements in the study are: Mechanical Integrity, Process Safety Information, and Operating Procedures.
In order to minimize the number of findings and to ensure proper implementation of the OSHA PSM standard, it is necessary to focus the efforts in conducting proper training, improving process safety culture in the organizations, conducting third party audits, and considering the implementation of enterprise software solutions.

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