PROCESS SAFETY MANAGMENT AUDITS – LESSONS LEARNT FROM SOUTH AFRICA

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PROCESS SAFETY MANAGEMENT (PSM) is relatively new to the chemical and allied industries in South Africa. With the introduction of the IChemE "Fundamentals" Course knowledge and interest has mushroomed. The author has audited several companies using methodology based on the principles highlighted in the Fundamentals Course and on managing for 30 years in hazardous materials manufacturing.

The audit methodology has proved sound, allowing a company to have a benchmark for PSM activities and standards. The approach has also to be modified to cope with companies using many raw materials and producing multiple products (>1000). The use of photographs has proved to be very valuable.

The audits have shown a number of significant common trends with lessons to be learnt by the company and the auditor. These include :

- Preoccupation with Occupational Safety
- Reliance on safety management systems and minimal understanding of Human Factors
- High standard for some PSM elements like "Legal compliance" and "Major hazard management" and low standards for many other elements
- Virtually no PSM performance indicators particularly leading indicators
- Little understanding of inherent safety and few practical applications

The author will describe the PSM auditing approach used. The common findings, issues and suggested actions will also be tabled. Practical examples and photographs will be used to illustrate important points.

INTRODUCTION

Process safety management is a relatively new concept and system for South African managers in the process industries. From about 2004, consultants who were familiar with the process industries in the UK and USA started introducing aspects of process safety management. Some multinational companies (oil companies based in the USA) also started applying the OSHA PSM[1] system at about the same time. A number of major incidents in Sasol, the major South African petrochemicals company, influenced the company to adopt the OSHA PSM approach.

Interest and momentum in process safety took a major step forward when the IChemE course "Fundamentals of Process Safety[2]" was presented in South Africa for the first time in 2009. The course has been oversubscribed every year since and this year, even with two courses, there has been such demand to fill both courses.

Companies with some knowledge of process safety principles now became interested in where they stood in terms of standards and how large the "gap" was to being "acceptable", "good" or "excellent". They also needed to know what their weakest or most vulnerable areas were. The need for Process Safety Management audits was thus established.

Those companies who followed the OSHA PSM system used audit protocols specified by the global body – with the PSM system being in place in the USA since 1992 there was considerable experience in this particular approach.

However, the IChemE approach to process safety is a broader one than specified by OSHA for the USA. There are a number of topics and concepts not covered by OSHA. It was considered a sound idea to be able to audit companies or units using the "IChemE" definition of process safety as developed in the 5-day "Fundamentals" Course.

Rod Prior, organiser of the South African "Fundamentals" Course developed an audit protocol which has been used in several companies since mid 2011. This paper illustrates lessons learnt from this auditing experience. With reference to a number of practical cases the author will illustrate a number of findings and issues that have arisen and what solutions might be useful. There are learning points for all.

Audits started in September 2010 and six have been completed with the most recent in November 2011. The companies are briefly described in the Table below. The reference to a Major Hazards Installation[3] is a classification under the South African Major Hazard Installation Regulations 2001(MHI). This is equivalent to a COMAH Top Tier Site.

THE "ICheme" AUDIT PROTOCOL AND THE OSHA AUDIT PROTOCOL

The PSM audit protocol was developed around 18 elements. These are shown in the table below.

The 14 element OSHA System contains an element "Trade Secrets" which was not found meaningful in the 18 element auditing system. The OSHA System has an element called "employee participation". This is covered by the ICHEME safety culture section. The IChemE

Company	Main products	Type of process	Hazards	MHI status	Comment
C-1	Fatty acids, rosins, vegetable oils	Batch & continuous	Fire	Yes	Cramped site – 100 people
C-2	Sulphuric acid, sulphur dioxide, oleum	Continuous	Toxic, fire (sulphur)	Yes	Old site with standard plants
C-3	Insecticides, herbicides, veterinary products	Simple batch with little instrumentation	Toxic, fire	Yes	Lack of systems & modern equipment
C-4	Phosphoric acid, construction chemicals	Continuous using phosphorous	Toxic materials (phosphorous pentoxide gas)	Yes	Modern plant – 100 people
C-5	Coinage	Batch & continuous.	Metal smelting, electroplating	Yes	Use hypochlorites, cyanides, hydrogen
C-6	Chemical formulator – 1500 chemical mixtures	Simple mixing. Major storage of materials	Fire & toxic materials	Yes	3000 raw materials – cyanides, hydrofluoric acid

System has a number of elements that are essentially not covered by the OSHA System. These are:

- PSM Strategy, plans, organisation and goals
- Inherent safety
- Design procedures/capital project review
- Human Factors and safety culture
- Legal, Standards and Codes
- Performance Measures

Performance management is not covered by OSHA. Clearly the reward system for process safety performance is an important factor. Process and equipment integrity is a broader concept that OSHA's "Mechanical Integrity". Permit to Work is again a broader element than OSHA's Hot Work Permit. By adding the Learning part to "Incident Investigation and Learning" this element incorporates the vital aspect of learning from incidents (own and others).

The questions used in the audit were generated solely from the author's own practical experience and the content of the IChemE's "Fundamentals" Course. An example of the questions in one element of the audit is shown in Table 2. The entire audit comprised 352 questions.

Table 1. Audit Protocol Elements

	AUDIT ELEMENT
1	PSM Strategy, plans, organisation and goals
2	Inherent safety
3*	Process knowledge and documentation
4	Design procedures/capital project review
5*	Process hazard analysis/risk assessment
6*	Emergency response planning and response procedures
7*	Management of change
8*	Process and equipment integrity
9*	Permit to work
10	Human Factors and Safety Culture
11*	Training and performance
12*	Operating and maintenance procedures
13*	Pre-Start up Safety Review
14*	Contractors
15*	Incident investigation and learning
16*	Audits and corrective action
17	Legal, Standards, Codes
18	Performance measures

*denotes an element where there is an OSHA PSM element which either fully or partially equates with the "IChemE" element.)

AUDIT APPLICATION

On the plant audits the plant manager and safety professional usually accompanied the author, whilst for the systems audits the appropriate specialists attended when needed i.e. maintenance, designers, R&D, project and SHEQ.

Audits were done over 2 days with physical inspection taking a day and systems auditing taking a day. Documents were reviewed, people were interviewed, plants and warehouses visited. Where possible, verification of the audit questions was sought in practice. In some instances issues were analysed in depth by "drilling down" into the detail.

The detailed scores for the PSM audits of the 6 companies are shown in Table 3.

PROCESS SAFETY AND OCCUPATIONAL SAFETY

All of the audited sites had occupational safety programmes of varying sophistication and longevity. Most grappled with the difference between the two types of hazards, preventative measures for process hazards and the resulting risks that have to be managed.

An interesting and illustrative example of the two approaches to safety arose from auditing a company using thousands of raw materials, mixing and storing thousands

Table 2. Schedule 2 – Inherent Safety questions

Sch 2 - Inherent safety	
(Audit - 27.10.2011)	***Review included Product Development Managers***
1. Is this concept understood at least in principle? By whom?	***Partially only – some knowledge from previous international companies.***
Eliminate/substitute – minimise – moderate – simplify	***The hierarchy is known in principle***
2. Has there been effort to avoid the hazards?	***In evaluating alternative speciality chemicals safer options are considered. Environmental risk reduction tends to dominate – safety informal.***
3. Is this captured in procedure or any other document?	***Informal process – could use the Hazard Study1 and 2 questionaires. NPI document some references.***
4. Can safer raw materials, reagents be used? Can the form be changed to make it safer?	***There are possible alternatives.***
5. Can safer products be made? (form change?)	***Not really, products are standard commercial requirements.***
6. Can smaller quantities of hazardous materials be stored or used?	***Yes – but not formally considered.***
Does the Economic Order Quantity overrule this?	***Use of KANBANS has impacted this as a byproduct***
7. Can temperatures / pressures be reduced?	***Not applicable(N/A)***
8. Any examples of 4–7?	***Replacing chlorinated hydrocarbons – customer driven***
9. Are these ideas known by plant designers?	***The PDMs understand these ideas.***
10. If package plant is used are these concepts used?	***No***
11. Is there an attempt to get the ideas in early?	***Yes***
12. Does the organisation see safety as "add on" only?	***No***
13. Are hazardous raw materials stored and segregated to minimize incompatibilities	***No – oxidizers are stored close to other hazard groups, incompatible plant batches are placed on a pallet, receiving bays are uncontrolled.***
14. Are hazardous final products stored and segregated to minimize incompatibilities	***No – oxidizers are stored close to other hazard groups, acids are stored above oxidizers. Corrosives not well stored.***
	Score : 8 /13

of final products. Many of the materials are toxic and/or flammable. The final products, in particular, were stored in a modern high rise warehouse with excellent physical standards. The products were in drums, isotainers and glass containers. From an occupational safety perspective the pallets were neatly stored, there were no leaking containers, marking was clear and housekeeping was outstanding (see pictures). A locked-out section contained cyanide products. The warehouse staff were very proud of the facility and the standards. A complete set of MSDSs was available.

A form of product segregation was implemented based on an inappropriate road transport segregation chart. When compatibity issues were looked at more closely in the audit a number of serious issues were detected. These included:

- Oxidizers such as hydrogen peroxide, sodium hypochlorite and sodium nitrite stored with other chemicals including acids and toxic compounds.
- Oxidizers and acids (hydrofluoric acid) stored above each other with the worst case of acid being directly above the oxidizer. The risk was unrecognised.
- Sodium nitrite stored on wooden pallets. This combination has been responsible for at least one major incident in South Africa.
- Failure to identify chemicals as oxidizers when the hazard label showed them to be corrosive. Sodium hypochlorite is one such example.
- Ammonium hydroxide considered to be an oxidizer when it is not. However, it is very corrosive and reactive and must be kept apart from a large number of chemicals.
- Large stocks of combustible oils/greases in a 'chemical store'.
- The marshalling area in the Raw Materials Store (receiving area) is not managed for incompatibities – some poor combinations were seen
- Incompatible raw materials (mix for plant batch) on same pallet – temporary storage before transport to plant. Mix included hydrogen peroxide, sodium nitrite and ether.
- Corrosive materials (acids, alkalis and other) should be stored at least three metres from any other material including toxics. Some were stored within 20 cm.

See Pictures 1 and 2 for some of these aspects.

There was a clear lack of understanding MSDSs and the information contained to correctly identify the hazards of materials. The use of internal identity numbers did not help. There was no real understanding of the principles of

Table 3. PSM Audit Scores

Company	C-1	C-2	C-3	C-4	C-5	C-6	Av
Element	%	%	%	%	%	%	%
PSM Strategy, plans, organisation,goals	32	39	25	32	29	71	38
Inherent safety	38	54	54	42	54	62	51
Process knowledge & documentation	38	74	32	50	41	53	48
Design procedures/capital projects	53	65	48	48	63	58	56
PHA/Risk Assessment	62	74	68	59	68	65	66
Emergency Response Planning	75	93	84	73	78	80	81
Management of Change	41	78	56	50	19	75	53
Process & equipment integrity	45	65	23	30	48	70	47
Permit to Work	70	95	88	55	40	85	72
Human Factors & safety culture	52	53	42	47	45	59	50
Training and Performance	41	71	41	59	59	71	57
Operating/Maintenance Procedures	57	69	43	56	51	37	52
Pre-startup Safety Review	49	77	43	50	18	54	49
Contractors	50	83	67	46	46	75	61
Incident investigation and learning	52	55	55	57	48	48	53
Audits and corrective action	21	29	36	36	50	57	38
Legal, standards and codes	74	89	80	81	81	88	82
Performance measures	7	10	7	7	10	17	10
Audit %	51	67	52	51	49	66	–

chemical separation. Inherent Safety in storage situations requires an in-depth knowledge of compatibility and segregation rules. The audit protocol for Inherent Safety requires amendment for companies where storage and mixing are the prime activities.

PSM STRATEGY, PLANS, ORGANISATION AND GOALS

Only 1 of the 6 companies had an acceptable strategy and plans to implement and manage PSM. This is reflected in this element ranked second lowest at 38%. The knowledge of PSM was very superficial with at best one person having attended some training. PSM at the time of the audits did not feature in the strategic plans of the companies. No goals existed in this area except to have an audit done. There was a general feeling that the audit would trigger awareness and action at all levels.

On one site an informal PSM programme had been started. This was driven by an enthusiastic manager working on his own.

The interest in process safety seemed to depend, in some measure, on the history of incidents experienced on the site. Where no significant release of flammables,

Figure 1. Picture 1-Warehouse – good stacking and housekeeping

Figure 2. Picture 2-Warehouse – oxidizers/acids adjacent & overhead

explosives substances or toxic materials had occurred in recent times, the interest in the topic was less than those who had current experience to reflect upon. There was a limited ability to relate to the major historical process safety landmark events such as Texas City, Bhopal, Flixborough etc.

PERFORMANCE MEASURES

This element scored the lowest (10%) by some margin. None of the companies actually had process safety performance measures either lagging or leading and therefore could not be sure how sound their "layers of protection" were against loss of containment. Some of them had excellent measures for occupational safety performance.

During the audit suggestions were made about some initial process safety performance measures. Most of the companies had reasonable maintenance systems and carried out preventative maintenance. Data was available on actual maintenance carried out against the planned maintenance schedules. However the data was not necessarily easily available and needed to be collected and processed to give meaningful information. There was a positive response with starting with this measurement.

"ISLANDS OF EXCELLENCE"

One of the interesting observations arising out of the audits was the high standard of certain elements, sometimes uniformly so, across the 6 companies. Elements fitting into this category included:

- Legal compliance – all 6 scored well (average score 82%)
- Emergency Response Planning and response procedures – (average score 81%)
- Permit to Work – 4/6 scored well (average score 72%)
- PHA/Risk Assessment – all 6 scored reasonably (average score 66%)

All the companies conducted legal compliance audits using 3rd parties to do the audits. Whilst this does not ensure good management of process safety (SA has no direct process safety legislation except for the Major Hazards Installations Regulations 2001) there are requirements to carry out risk assessments etc.

As part of the MHI Regulations there is a requirement to have both internal and external Emergency Plans. These have to be spelt out in submissions to the Regulator, the Department of Labour. The audit found the plans to be reasonable except for a consistent lack of an effective external Emergency Plan which should be initiated by the Local Authority but where the company has to provide significant input. The Local authorities lack capacity and experience in this area.

Whilst the companies are small to medium sized, some are part of larger chemical companies. Aspects like Permits to Work (PTW) have been introduced many years before and have been well entrenched. The quality of these systems is variable.

Risk Assessments are standard in the chemical industry. The HIRA (Hazard Identification and Risk Assessment) is a legal requirement under the Occupational Health and Safety Act of 1993. These HIRAs cover all hazards, not specifically process safety aspects. The MHI Regulations require a QRA of the major risk/risks. In general the HIRAs don't result in good systematic analyses of process safety aspects.

HUMAN FACTORS AND SAFETY CULTURE

All the audits showed scores around 50%. There was no understanding of the three related areas (Job, Individual, Organisation). A number of basics were in place like dealing with violations differently to human errors. In general, process safety critical communications were well dealt with. Stressors leading to errors were not very prevalent.

Human Factors (HF) were not taken into consideration in risk assessments and incident investigation. HAZOPs did not really include the possibility of human mistakes. Incident investigations showed the human contribution to be either human error (unspecified) or a violation with only the remedies of training or punishment being offered. This is a very simple view of HF.

The process safety culture was obviously not well developed in any of the companies. There was knowledge and awareness of general safety culture arising from Behavioural Based Safety programmes which are common.

INHERENT SAFETY

Understanding of this aspect was poor. Apart from some exceptions there was an acceptance of the hazards imposed by package plants (e.g. units such as boilers which are sold complete with all its ancillary equipment), historical situations and a pre-occupation with "matters of the day". Two sites revealed interesting applications of the concepts of Inherent Safety. The lowest scoring site has a small R&D section which designs, develops and formulates some of its products. Systematic approaches to reducing toxic risk were employed largely driven by changes in European legislation and an understood need to reduce toxicity where possible. In the other site example Product Development Managers are employed who react to customer's environmental and safety concerns. In addition there is a New Product Introduction (NPI) System which helps enforce checking of SHE aspects.

ASSET INTEGRITY

Preventative Maintenance is unsophisticated. Safety critical equipment and systems are not identified and standards like IEC 61508/IEC 61511[4]are not used. Interlocks are not formally identified as safety critical items. Accordingly no reliability, availability and survivability standards have been set for the critical items. Experience has been the major factor in setting inspection and testing schedules. Engineering drawings, particularly with the older sites, are not always up to date. There are few Asset Integrity plans.

PROCESS HAZARD ANALYSIS

This is largely restricted to HAZOP studies, QRA analysis (MHIs) and qualitative/semi-quantitative risk assessments. A notable feature of Hazard Analysis of new projects/products is the sole use of HAZOPs as a tool for identifying hazards. This is, of course, the same as HAZARD Study 3 in the well-known series of 6 HAZARD[5] Studies used internationally. The Studies apply to different phases of a new project as it evolves. The consequence of this limited approach to hazard analysis is that hazards only get identified at a developed stage of the project (P&I Diagrams available) with the resultant inability to make significant changes. Failure to do hazard studies at later stages of construction and operation could result in hazards introduced at late stages not being detected. In addition the use of HAZOP at too early a stage is very ineffective.

DISCUSSION AND CONCLUSIONS

The PSM auditing protocol based on the IChemE "Fundamentals" training course has proved to be useful in providing a benchmark for sites/companies to understand what their standard is in PSM management. The audit also exposes the elements most in need of development. The audit is arbitrary in terms of scoring but is probably adequate to rate the site as sub-standard, average, good or outstanding.

PSM has not been seen as the logical framework linking many different elements together with the objective of managing process hazards to acceptable levels. Some "islands of excellence" exist such as Legal Compliance, Emergency Planning, Permit to Work and Process Hazard Analysis. These islands exist because of requirements other than PSM management.

The interest in implementation and improvement of PSM, if not legislated for, is related to recent incident experience, training and existence of champions. There is more experience and emphasis on Occupational Safety in the audited companies and they are struggling to migrate to a PSM culture.

There was also no appreciation of process safety being important from new product/process concept to plant operation i.e. "from cradle to grave". There needs to be a use of techniques other than HAZOP at appropriate stages of a project. In particular the HAZARD STUDY 2 technique should be used when the process flow is known. It is important in early phases of a project to detect major hazards.

In the case of multi-raw material/multi-product storage, chemical compatibility is a major aspect of Inherent Safety and the PSM audit protocol needs to be modified to accommodate this feature.

As with many companies operating in the process industries, the audited companies found difficulty with Performance Measures and Inherent Safety. The proposal on Measurement was to use existing data and start simply with basic Preventative Maintenance performance measures. Inherent Safety is dependent on the nature of the operation. The philosophy of the approach needs to be accepted first and then the generic steps of Minimize, Eliminate, Moderate and Simplify can be applied as appropriate. The resulting process needs to be formalised.

The application of Human Factors is basic. Two areas where, in particular, benefit can be obtained in the short-term from a more insightful knowledge of the facets of human error will be in doing risk assessments and incident investigation.

The experience of doing process safety audits has helped the audited companies and the issues arising and lessons learnt are, hopefully of interest to others in the field.

REFERENCES

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