Implementing safety assessments and management systems – a parallel between high and non-high hazard industries

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ABSTRACT

Hazard Identification and Risk Assessment studies, such as HAZOP, HAZID and FMEA, among many others, are broadly recognized and widely applied by the industry as effective methods to ensure compliance with legislation and are industry best practice techniques to enhance plant safety and operability. As a result, they also drive performance and operational excellence. High hazards industries, driven by COMAH regulations (and other equivalent regulations for Offshore, as well as outside the UK), are required to perform a number of such safety assessments to comply with regulatory requirements, as well as company standards in some instances, in order to demonstrate effective management of safety risks. Less hazardous, smaller scale industries (i.e. not governed by COMAH) on the other hand, are not necessarily mandated to undertake such rigorous approaches to managing safety. As a result, these organisations are generally less aware of the advantages and potential benefits not only to safety, but also to business performance, of implementing a structured, systematic and rigorous approach to managing safety. Additionally, most of these organisations have generally little understanding around the various hazard identification and risk assessment studies that drive effective safety management and, ultimately, what are the benefits they can obtain from these studies, as well as what is required to undertake them. When the various elements of safety, including the numerous safety assessments that can be undertaken by an organisation, are not managed in isolation but embedded into a comprehensive and integrated safety management framework, organisations can maximise the benefits obtained from these studies and the vast amount of results they can generate. The objective of this paper is to demonstrate the potential benefits, particularly to non-high hazard industries (i.e. not highly regulated), of adopting a rigorous and systematic approach to managing safety. The paper will provide an overview of a number of industry best practice safety studies and outline key elements of each technique, describing their goals and roles within a safety management framework. The paper also discusses on what is required from such industries and the steps to undertake the studies, as well as the potential challenges organisations can face when building these systems for managing safety. The discussions presented herein, however, can be naturally extended to any industry such as those regulated by COMAH, since they provide a number of good practices for the implementation of safety studies and structured safety management systems in the industry.

INTRODUCTION

The Control of Major Accident Hazards (COMAH) Regulations, based on the Seveso III Directive, was first applied in the United Kingdom in 1999. After the occurrence of a number of major accidents in Europe during the 1970s, it was observed a real need for the development of a new regulation with the main intention to prevent the risks from major accidents involving dangerous substances. The COMAH Regulations are applicable to any establishment storing or otherwise handling large quantities of industrial chemicals of a hazardous nature and it operates on two levels which depend directly on the establishment's status with regard to its inventory capacity: 'Lower Tier' and 'Upper Tier' categories. Employers' duties under the Regulations will depend on which tier their facilities are categorised.

Non-high hazard industries are not part of any of these categories and therefore do not have the legal obligation to demonstrate compliance with COMAH regulations. The absence of such legal duties under COMAH should not however be interpreted as though these industries do not present hazards with a potential for significant harm. As a matter of fact, they may have similar hazards as of COMAH sites, such as loss of containment of flammable or toxic substances with potential for fatalities and significant asset losses. The main overall difference is that the extension of the potential consequences from an accident is generally reduced due to the lower quantities of dangerous substances stored on site.

As part of their legal obligations under COMAH, high hazard industries need to implement a wide range of reputable, well stablished industry best practice techniques in order to identify hazards, and implement measures to control their risks; and, as a result, to be able to ultimately demonstrate to the Regulator that compliance with COMAH Regulations has been met. Implementation of such techniques is required from early stages of design through to the end of the facility lifecycle. In line with their duties under COMAH, high hazard operators are also mandated to put in place structured management systems, with a number of defined internal processes including, among others, the procedures, systems, competences and defined roles and responsibilities to ensure that all aspects of safety (site-wide and organisation-wide) are effectively managed.

Non-high Hazard industries, as any other, are legally obliged to assess workplace risks to demonstrate broad compliance with The Health and Safety at Work Act 1974. However, without duties under COMAH, these industries are generally much less aware of the best practice techniques available for process hazard identification and risk assessment, and how operators can benefit from the implementation of such techniques in systematic and rigorous approaches to managing safety. Moreover, experience has shown that these operators are generally unaware that the benefits derived from implementing such safety assessment techniques and management systems do include not only improvements to safety, but also to plant reliability and operability, and as such drive excellence in operational performance, which can ultimately lead to enhanced business and financial performances.

The intent of this paper is to demonstrate through real project examples – discussed herein as two case studies – and sound experience in the subject matter, that the benefits from implementing rigorous and systematic approaches to managing safety, founded on standard industry best practices, are also applicable to non-high hazard industries. Ultimately, it is intended to discuss reasons why operators outside COMAH duties should look to embrace and implement such systems within their organisations with a view to maximising safety as well as business performances.

CASE STUDIES

The case studies presented in this paper are based on recent projects undertaken by Bureau Veritas for non-COMAH sites. The first case presented here is a "Plant Safety and Operational Resilience Review" undertaken for a chemical manufacturing plant. The second is a "Pre-Operation Safety Review" for a gas test laboratory.

Plant Safety and Operational Resilience Review Studies

The operator in this first case study consisted of a chemical manufacturing plant which produced synthetic crystal components for specialised technological applications. The synthesis processes consisted of a set of complex reactions involving a number of different gases (among them, flammable and toxic gases) which had to be maintained under very strict operational conditions (pressure, temperature, gas compositions, reactant ratio, among others) to ensure the final products would meet the required specifications.

The main business and operational challenges faced by this operator consisted of the fact that the facility was experiencing a number of unplanned shutdowns, which culminated in significant production losses, due to plant equipment failures and mal-operability of the process systems (e.g. operator errors, misalignments, mal-operation of valves or equipment, failures of utility systems and general process equipment, etc.). Also, owing to such failures, there was a rising concern that process hazards associated with the operations of the site which could pose a risk to people or the environment had not been effectively identified during design stage.

The plant under concern was originally designed to operate as an R&D facility. Having grown and expanded its capacity over the years, however, it had achieved industrial scales of production. With a number of top-notch end customers, the operator needed to ensure their production outputs would meet contractual demands; and therefore such unplanned failures and shutdowns posed, in addition to safety risks, a significant threat to business performance. Through this expansion and increase in production scales, the plant had never undergone any form of formal structured process hazard identification review. Moreover, another key concern was that the plant expansion had not been properly documented (i.e. not reflected on the P&IDs and process safety information), with a number of key safety management documentation and processes being out-of-date or even inexistent.

In order to tackle these challenges and develop a plan to enhance the plant safety and operability, with a view to minimising any process failures and plant shutdowns, a structured review of the process for hazard identification and risk assessment was undertaken through a combination of techniques, described as follows.

<u>HAZOP & FMEA</u>

Qualitative assessments such as Hazard and Operability (HAZOP) studies are commonly used by COMAH operators as primary means for identifying hazards posed by process facilities and operations with the intent of minimising, when not possible to eliminate, scenarios which could lead to an event with undesirable outcomes. These reviews are mainly focused on safety, however not only limited to it, and different aspects such as environmental impacts, property damage and operational losses can also be taken into consideration as part of the assessment.

HAZOP studies are essentially structured and systematic investigations of processes to identify hazards associated with the plant operability resulting from deviations from the design intent. Due to the nature of its methodology, the HAZOP was selected in this case as the primary technique to drive the hazard identification and risk assessment review for the process systems of the facility under concern.

In order to be able to effectively implement a technique such as a HAZOP on the facility's process systems, the operator was advised to, as a first step, develop and update their documentation to a suitable and sufficient level, in order to reflect the plant's current design and operational status.

After such documentation was in place, a series of workshop sessions were undertaken. These workshops were facilitated by Bureau Veritas and involved a multidisciplinary team with key operator personnel, including Process Engineering, Operations, Equipment Eng., Maintenance, Facilities Management and Health & Safety.

For the success of the study, it was essential that the key personnel, described above, who have the right level of knowledge and experience on the process systems, were made available for the workshop sessions. This was ensured as part of the project through early conversations and agreement with the facility's Director of Operations (sponsor of the study) who was responsible for allocating the required resources accordingly, and was supported by the development of a detailed workshop schedule, which allowed for the sponsor to plan and ensure personnel availability. The support from the leadership in this case was also an important factor to promote the importance of the study among the team.

Among the vast amount of aspects considered as part of the study, a number of highlights can be listed, as below.

Identification of process deviations

Through the application of HAZOP deviations such as "No Flow", "Low Flow" or "Low Pressure", for example, it was possible to identify a number scenarios of specific equipment failures as well as operability issues (for example, an operator error when inadvertently closing a valve), which resulted in either a reduced or total loss of gas supply to the reaction with subsequent shutdown (and therefore in production losses) and/or loss of containment of flammable or toxic gases (e.g. due to leakages) with potential for personnel injuries or fatalities. Along the same lines, the use of "Low Temperature" or "High Temperature" deviation allowed for the identification of failure scenarios that could cause the reaction medium to operate outside the set temperature, which could also culminate in an unplanned shutdown and thus production losses.

Failure Modes

Another crucial aspect of the study, since it also wanted to look into aspects related to the reliability and availability of the plant, was that the HAZOP also included high-level discussions on the potential failure modes of a number of scenarios discussed (i.e. integrating features of a traditional Failure Modes and Effects Analysis – FMEA). This analysis uncovers the specific areas that are more likely to fail and why, and provides guidance on the development of controlling processes so failures can be avoided when not possible to be eliminated. This was not done through a formal implementation of a full separate FMEA, supplementary to the HAZOP, but by taking scenarios discussed within the HAZOP and detailing specifically which failure modes were taken into consideration for each scenario, and then the assessment of causes, consequences, safeguards, and ultimately the generation of any specific recommendation was undertaken accordingly. For example, the scenario of a "pump failure due to mechanical failure" (e.g. the failure of a specific pump component) was discussed as a separate scenario from "pump failure due to electrical supply failure". A proposed modified HAZOP worksheet to include the elements of an FMEA analysis is depicted below in Figure 1.

Deviation	**Cause**	**Key FM**	**Consequence**	**Safeguards / Detection**	**Freq**	**Sev**	**Category**	**Risk**	**Recommendation**	**Owner**
No flow	e.g. "Pump failure"	e.g. "Mechanical"					Health / Safety			
							Env.			
							Production			
		e.g. "Electrical"								

Figure 1: HAZOP modified worksheet

Moreover, the risk ranking (discussed below) was also used as a 'flagging tool' to determine specific elements (e.g. specific equipment) which needed to undergo thorough failure-modes focused discussions to identify and evaluate more complex failures, usually when in higher risk scenarios.

Risk Ranking

To deliver the "risk assessment" feature of the study, the HAZOP included risk ranking for all scenarios discussed in the workshop. In order to do so, the operator was required to develop a calibrated Risk Matrix, which effectively had to include consequence severity categories not only for 'health / safety' and 'environment', but also in terms of 'production losses / availability'. Bureau Veritas advised the operator on calibrating their existing risk matrix in order to enabling it to be used in the study. The calibrated consequence category of 'production losses' allowed the operator to identify and list specific failure scenarios which could then be ranked based on their critically in terms of plant availability / production impacts.

Risk-based Prioritised Action Plan

Finally, the ultimate outcome from the hazard identification and risk assessment was the development of a prioritised action plan, following the generation of a number of recommendations from the HAZOP/FMEA. Essentially, using the risk ranking results for each scenario, it was possible for the operator to list all recommendations and plan their implementation according to the risk levels. This way, it was possible to identify scenarios and recommendations associated with the higher risks and, as a result, prioritise the implementation of the respective actions, while being able to plan in a longer term to implement the ones associated with the lower risks.

Reliability Centred Maintenance (RCM)

After completion of the study, general discussions were held with regard to further approaches which could be used to improve the plant availability. BV advised the operator on the application of a technique called Reliability Centred Maintenance (RCM), which focuses on the development of a proactive maintenance strategy with aims to increase the probability of an equipment or component to function in a required manner over its design lifetime while requiring minimum maintenance intervention. The RCM technique seeks to devise cost effective and proactive maintenance strategies in conjunction with the implementation of cost effective real-time monitoring systems, when possible, to alert and prevent the occurrence of failures. Moreover, further analyses can be performed to evaluate feasible and cost effective design solution aiming to permanently eliminate the machine or component failure causes.

The first step of this methodology involves a thorough investigation of the equipment or component failure causes and subsequently their consequences to the system. Therefore, the results of the HAZOP & FMEA undertaken in the first part of the study can be directly used as a spot-on input for devising the plant RCM study. As an example, the scenarios identified with the potential to generate loss of production / plant availability events, as a result of the risk ranking step, could then be selected and used as the starting point for the RCM study. Thus, it is worth reinforcing the importance of using a calibrated risk matrix when conducting the risk assessment, as it enables the generation of valuable information in terms of risk-based priorities for maintenance strategies.

Pre-Operation Safety Review

In the second case study, the facility under concern was a recently built test laboratory of gas filtering mediums, in which a number of toxic and flammable chemicals (for example, Cl_2 and CH_4) were employed in various small scale operations using controlled inventories (e.g. limited number of gas bottles). Although the lab testing facility was automated to a certain extent, most of the tasks in the laboratory required manual operation of the substances by the laboratory personnel in a frequent basis. Moreover, the laboratory was installed within a normally manned administrative building, which was also adjoining to other external populated areas. Therefore any undesired events in the facilities (e.g. a fire/explosion or a release of toxic gas) had the potential to harm a considerable number of people.

The operator in this case was a well reputable, worldwide known organisation. In order to protect safety of its employees and the local community, as well as the reputation of the business, they needed to ensure that hazards associated with the design and operation of laboratory were appropriately identified and measures put in place before the start-up of the unit.

The review in this case consisted of two integrated approaches:

- A UK Health & Safety Regulations compliance review, in which the main obligations of the facility under the UK H&S law were identified and the compliance maturity level of the design against these obligations were evaluated; and
- A Hazard Identification workshop, to identify hazards associated with the design of the facility, which was undertaken via a Structured 'What-If' Technique (SWIFT).

UK Regulations Compliance Review

An independent review of the Test Laboratory was undertaken with aims to identifying potential gaps between the facility's operational arrangements (processes, procedures and installed equipment) and the relevant UK Health & Safety (H&S) statutory requirements. In summary, the main goals of this work were to:

- Identify the relevant UK H&S Regulations which were applicable to the facility;
- Determine the key requirements under the Regulations which the facility needed to comply with;
- Perform a gap assessment to evaluate the compliance maturity level of the site against the applicable regulatory requirements; and
- Identify improvement opportunities, and propose recommendations in cases where remedial actions were required to drive compliance with the UK H&S law.

The work methodology consisted of a series of activities including: the review of key H&S management documentation; interviews with key site personnel; and site walk arounds for physical observation of the operations and equipment.

A resulting list of applicable UK H&S Regulations was generated, which outlined the key requirements under the legislation which the site needed to comply with, and the results of the gap assessment with the observed actual compliance status against those requirements. Based on the results of the gap assessment, a list of recommendations was proposed to improve the overall compliance status of the facility, enhancing assurance that operations could go ahead in a safe and compliant manner, and therefore lowering the risks to the business.

HAZID via SWIFT

Hazard Identification (HAZID) Studies are high-level reviews of plants and operations for general identification of hazards. Although having structured methodologies, which to a certain extent are similar to a HAZOP, these are usually more generic in terms of approach and scope. Most types of HAZIDs are usually deployed through the use of a set of Guidewords for which specific hazards are identified and discussed.

For the case under discussion, owing to the nature of the process, the 'Structured What-If Technique' (SWIFT) was selected as the best technique for the identification and analysis of the hazards associated with the laboratory design and operations.

The SWIFT combines the uses of Checklists or pre-selected Hazard Categories with a brainstorming 'What if?' approach. It is a highly effective hazard identification assessment, undertaken via multi-disciplinary workshops, in which the team has a greater degree of freedom to generate specific hazard questions. This approach significantly facilitates targeting particular hazards and areas of concern.

Areas of focus of the SWIFT workshops for the case under discussion included:

- Loss of containment;
- Human error;
- Particular hazards associated with the use of substances (e.g. reactivity of chemicals);

- Storage and segregation of substances;
- Equipment malfunction;
- Instrument malfunction;
- Hazards arising from maintenance activities;
- Health issues and injuries (e.g. asphyxiation, burns);
- Power / utility failures; and
- General emergency situations;

The SWIFT template used as part of the work is presented below in Figure 2.

Hazard Category	What if…	Consequences	Safeguards	Recommendations	Owner

Figure 2: SWIFT worksheet

What-if Questions

The application of the 'What-if' questions prompted the discussions among the members of the workshop regarding the potential hazards in the facility, their consequences and the existing safeguards installed. Some examples of general 'What-if' questions used to investigate the hazards in the laboratory are given below:

- What if Valve "A" is left in a faulty position following maintenance?
- What if Equipment "B" fails resulting in excessive flow of gas?
- What if Valve "C" is inadvertently operated by the operator?
- What if there is moisture left in the gas lines?
- What if the incompatible reactants are inadvertently mixed during operation?
- What if operator connects the wrong cylinder to the gas supply panel?
- What if power / utility supply fails during operation?
- What if gases are out-of-specification and incompatible with (e.g. corrosive to) pipework material?

As overall results, the application of the SWIFT challenged the design and the effectiveness of controls of the lab against the potential risks to safety from its operation and design. A number of hazards were uncovered and key areas of concern were discussed. This allowed for a list of recommendations to be generated with aims to review particular items of the facility design and operating procedures.

Some examples of hazards and areas of concern that were identified included, among others:

- Interfaces between the laboratory control and emergency systems and the overall building emergency systems.
- Potential risks arising from human errors in operations not covered by standard operating procedures.
- Particular equipment failure modes that had the potential to result in unexpected undesired events, including the potential for release of toxic or flammable gases within the laboratory.
- General weaknesses in procedural and engineering controls.
- Need for further detailed assessment of the consequences of scenarios (e.g. via consequence modelling) resulting from loss of containment of flammable or toxic substances.

IMPROVEMENTS TO SAFETY MANAGEMENT SYSTEMS

This chapter will provide further details and discuss how the outcomes from the hazard identification and risk assessment studies undertaken on both case studies enabled operators to develop and improve their organisational arrangements for managing safety.

Safety Management Systems and the Roles of Hazard Identification and Risk Assessment

A safety management system is a structured and systematic approach to effectively identifying and managing safety issues, and includes series of organisation-wide processes, such as organisational structures, accountabilities, competences, documentation and procedures, which provide a framework to organise and manage the myriad aspects of safety that can exist within an organisation.

In line with international industry standards, and to foster continual business improvement, Safety Management Systems are commonly developed and implemented using a cyclical PDCA (Plan, Do, Check, Act) approach:

- **Plan** – The organisation identifies what needs to be done to effectively manage safety. Key elements of the planning phase include the organisation undertaking Hazard Identification and Risk Assessments, identifying the Legal and other requirements to which the organisation subscribes, and setting the organisation objects with regard to managing safety.
- **Do** – After identification of the key elements that form part of their safety management plan, the organisation devises the strategy for implementing the controls required to manage the risks and achieving the established objectives. This includes, but is not limited to, developing the procedures, documents, delivering training and competence requirements, and assigning the required organisational roles and responsibilities for managing safety.
- **Check** – Throughout the implementation of the plan, systematic checks need to be performed to monitor the performance of the safety management system on a regular basis. This includes monitoring any deviations to plan, investigating incidents, revisiting Hazard Identification and Risk Assessment when required, conducting periodic Audits, and developing corrective and preventative actions.
- **Act** – Following the 'Check', the needed corrective actions are implemented to ensure the effective delivery of the plan and the achieving of the organisation's objectives.

Based on the above, it can be seen that Hazard Identification and Risk Assessment play a key role during the very earliest stage of an SMS development and set the framework / foundation for its implementation, during the 'Plan' phase. One can argue that, and in fact, hazard identification and risk assessments are the very cornerstone of any system for managing safety. Figure 3 below depicts, not exhaustively, a number of typical elements of an SMS which revolve around hazard identification and risk assessment, and as such demonstrate the importance of this core element.

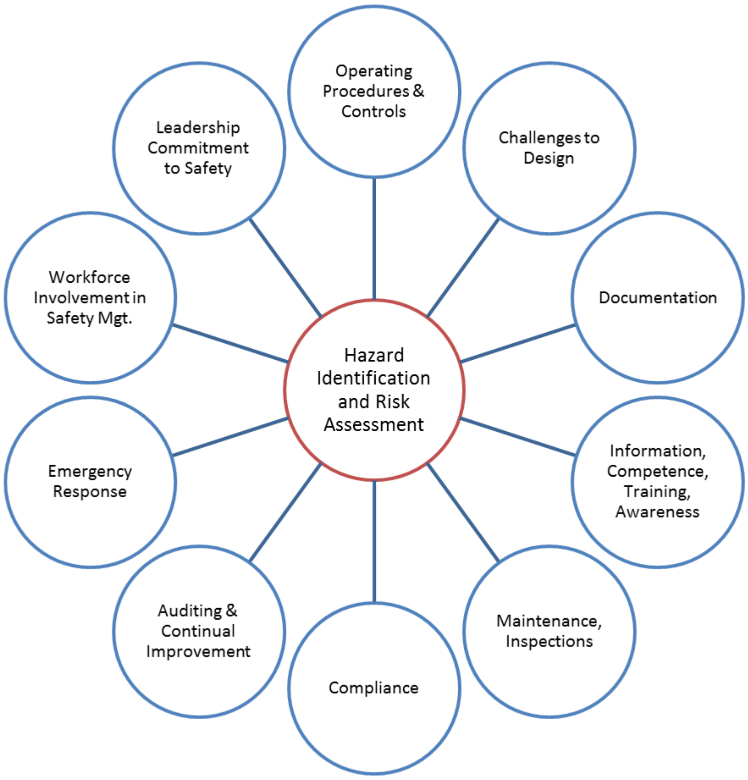

Figure 3: SMS elements (not exhaustive) which are connected to Hazard Identification and Risk Assessment

Safety Management Systems: Areas of Improvement Identified in the Case Studies

In line with the elements depicted in Figure 3, the implementation of the Hazard Identification and Risk Assessment techniques discussed in both case studies resulted in a number of improvement opportunities to the operators' management systems. Some examples of such areas of improvement are discussed in further details below. Note that the list presented below is limited to a few examples only, which are in addition to the general points already discussed under each case study in the previous sections of this paper.

Competence, Work Instructions and Operating Procedures

Throughout both case studies, various scenarios were identified in which undesired events could occur due to operator errors, for example in an inadvertent operation of a manual valve, or equipment left in an erroneous state following a maintenance activity, etc. For a number of these scenarios, it was found that the operators heavily relied on the competence / experience and judgement of the person operating the system to perform it correctly, and no formal operating procedures were in place (including e.g. procedures to operate valves/equipment, post-maintenance checklists prior to re-starting operations, etc.). The results of the hazard identification and risk assessment processes allowed for the targeted development of work instructions and operating procedures, the identification of safety-critical competences and training requirements.

Compliance with Regulations

Specifically for the second case study, the overall purpose of the UK Regulations compliance review was to improve the organisation's understanding of their obligations under the H&S law, identify areas of potential non-compliance risks, and recommend remedial actions when necessary in order to ultimately provide enhanced regulatory compliance assurance. The assessment itself and its results provided the facility with a valuable evidence of on-going evaluation and commitment to H&S management, which provide basis for informed decision-making for improving operational safety compliance.

The HAZOP study undertaken in the first case study also identified regulatory compliance concerns, and as such was used to develop recommendations to ensure Health & Safety obligations were met.

Documentation improvements and management of change

The case studies discussed in this paper stand on different project phases; however, both significantly benefited in terms of documentation improvements as a requirement for and a result of implementing the hazard identification and risk assessment techniques. The deployment of techniques such as HAZOP, FMEA and HAZID require that up-to-date information and documentation, such as P&IDs, process safety information, calibrated risk matrix, among others, are available prior to commencing the studies, in order to ensure an accurate and effective identification of hazards and assessment of the risks.

As reported for the first case study, the facility's expansion had not been properly documented, and as such resulted in outdated, or in some cases inexistent, P&IDs and process safety information. Several risks are associated with the use of non-updated documentation; and lessons learnt from past accidents in the industry have already shown the potential severity of hazards derived from process changes (creeping changes) that are originated over the facility lifecycle and are not properly documented neither risk assessed. Therefore, in this case a work effort was required prior to the commencement of the study with the purpose of achieving the minimum documentation requirements to perform the study, while further changes were made after its completion by implementing the generated recommendations as wells as general document update requirements flagged during the workshops. This fostered the development of a management of change culture in the organisation, where future changes to process and plant would be subject to a more rigorous control.

On the other hand, the process facility in the second case study was still on pre-operation stage and as such a number of operational procedures and internal safety processes were still under consolidation. In this case, the application of the methodologies described in this paper supported the identification of weaknesses and gaps in the facility documentation and as a result improved the safe start-up of the process.

SUMMARY AND CONCLUSIONS

This paper described the context in which hazard identification and risk assessment techniques, widely used by High Hazard Industries, were applied into two Non-High Hazard sites and discussed the various safety, operational and financial related benefits obtained from them. The summary below highlights some of the key benefits identified to the businesses and the improvements to safety management systems:

- Enhanced understanding and management of process risks - with the development of a structured process to manage hazard identification and risk assessment, including the internal processes to manage the implementation of recommendations from such assessments (following a PDCA process).
- With the combination of traditional Risk/Safety assessments (e.g. HAZOP) and reliability assessments (e.g. FMEA) an integrated approach was applied to investigate a process facility with aims to identifying key failures and deviations resulting not only in undesirable outcomes to safety of people, but also in terms of plant uptime (availability) and production losses.
- Clear identification of 'high risk' areas and critical items in relation to safety, operability and production/availability (resulting from the risk ranking), together with the development of a risk-based prioritised plan for the implementation of the recommendations generated in the HAZOP/FMEA study to support achieving a safer and more reliable process facility.
- The application of Hazard Identification technique via SWIFT in addition to a UK H&S Regulatory Review provided a holistic approach to the identification of hazards and assessment of control measures in the design to ensure a safe start-up and operation of the site and also the identification of potential regulatory compliance weaknesses, and the development of remedial actions to enhance compliance assurance.

- Development and implementation of sound process safety management documentation (e.g. P&IDS, standard operating procedures, emergency response, training and competency requirements, etc.), and embedding rigorous processes for the management of change.
- Definition of optimised, risk-based maintenance strategies – including risk-based preventative maintenance and inspection regimes, list of critical items and spares, among others, following the outcomes of the HAZOP/FMEA.
- Increased operator knowledge around the various Risk & Safety and Reliability studies, their associated benefits and added-value to the business, which provides the organisations with guidance and support to the decision making processes on how to improve further areas within the process facility and across organisation.

Another point worth mentioning, the first case study discussed in this paper was a sound example of how the costs of the application of these techniques can be considerably higher if only applied after the design phase, when the process plant is already in operation. Given the higher costs to implement corrective actions to a plant in full operation, the operator in this case has decided to undergo similar a process of systematic hazard investigation and rigorous safety management implementation for other of their new facilities which are still in design phases.

In summary, the use of industry best practice techniques for systematic identification of hazards and management of risks, aligned with the development of structured management systems covering internal processes and documentation, such as P&IDS, process and control philosophies, audits, management of change and control of creeping changes, among others, is applicable to every industry - High or Non-high Hazard. Regardless of being or not governed by stringent regulations such as COMAH, process facilities are generally subject to hazards which have the potential to pose significant risks to personnel, property, the environment and business reputation and; therefore, should endeavour to apply the industry best practice techniques available to identify and manage risks accordingly. Both case studies presented in this paper demonstrated the significant potential for Non-High Hazard operators to benefit from the application of a number of hazard identification, risk assessment and compliance review techniques, and the benefits of integrating these under a structured safety management system. It should be noted, however, that such benefits are not limited to those described in this paper, as a wide variety of further qualitative as well as quantitative methodologies, in addition to the ones discussed herein, are also available to enhance organisations' safety, operations and business performances.

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