RETROSPECTIVE HAZARD IDENTIFICATION AND ASSESSMENT OF AGEING PLANT

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Just over a decade ago a catastrophic failure of a heat exchanger occurred at Esso's Longford gas plant in Australia killing two workers and injuring eight others. One of the contributory causes of the accident identified in the Royal Commission report was the failure to carry out a Hazard and Operability (HAZOP) study of the plant (built in 1969), a study which had been planned but not executed. Since then many companies have implemented programmes for retrospectively reviewing ageing plant to formally identify hazards and assess risk.

This paper draws on experience from implementing programmes for the retrospective identification and assessment of major hazards within a UK-based, multi-national energy company. These programmes have entailed the application of two widely-used techniques (HAZOP and Process Hazard Review) to a variety of plant (offshore installations, gas terminals and gas-fired power stations), at a variety of levels (individual units and whole facilities) in both the UK and overseas. It also draws on the wider experience of the two consulting organisations which supported these programmes.

The paper assesses the comparative benefits of the two hazard review techniques, the context in which they were applied and their success in achieving the desired outcomes. The paper then draws out the wider lessons for industry in terms of:

- the triggers for when to carry out a retrospective hazard study;
- the scope and timing for such studies;
- suitable methodologies; and
- linkage with other initiatives such as safety system obsolescence, decommissioning and performance standards review.

BACKGROUND

On 25 September 1998, a heat exchanger (GP905) fractured at one of Esso Australia's Longford gas plants (GP1) releasing hydrocarbon vapour and liquid. Explosions and a fire followed in which two workers – Peter Wilson and John Lowery – were killed and eight others injured. Supplies of natural gas to domestic and industrial users in the State of Victoria were halted for 19 days. The causes of the Longford gas plant accident were investigated in a Royal Commission report (Longford Royal Commission, 1999) and have been discussed by Hopkins (2000).

The immediate cause of the Longford accident was the restarting of warm 'lean oil' flow to GP905, which had become abnormally cold following a plant trip. The reintroduction of the warm oil caused brittle fracture of the heat exchanger. One of the contributory causes identified in the Royal Commission report was a failure to carry out a Hazard and Operability (HAZOP) study of the plant. Esso's Operations Integrity Management System (OIMS) included provision for retrospective HAZOP studies, in particular for ageing plant, and a study of GP1 had been planned for 1995. For various reasons however, none considered satisfactory by the Royal Commission, the HAZOP did not take place, either in 1995 or in subsequent years when budget provision was also made. The Royal Commission concluded as follows:

> *Whatever the reason for failing to carry out a HAZOP study for GP1, the failure to do so carried with it the risk that hazards would remain unidentified and uncontrolled. The events of 25 September 1998 demonstrated the existence of such hazards. Had a HAZOP study of GP1 been conducted, as Esso initially believed it should, Esso would have acquired knowledge of those hazards which, as it transpired, were critical. In due course that knowledge would have been disseminated by way of training, the development and use of procedures and the adoption of protective control systems. In short the failure to conduct a HAZOP study of GP1 contributed to the disaster which occurred on 25 September 1998.*
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> [Longford Royal Commission, 1999]

This paper discusses experience within Centrica of retrospective hazard identification of ageing plant. This covers application to a variety of types of plant, in the UK and US using various methodologies. Whilst the focus of this paper is on hazard identification, it also extends to risk assessment though discussion of such techniques as

Preliminary Hazards Analysis (PHA) and ABB's Process Hazard Review (PHR) methodology.

OVERVIEW OF CENTRICA PLC AND OUR RETROSPECTIVE HAZARD IDENTIFICATION PROGRAMME

OVERVIEW OF CENTRICA

Centrica is an integrated energy company, formed from the demerger of British Gas in 1997 and comprising various businesses for the sourcing, storage and supply of gas, electricity and associated services, to customers. Centrica employs around 33,000 people, the majority in the customer-facing businesses in the UK. Our upstream activities include exploration, hydrocarbon production and storage (onshore and offshore), power generation (including gas-fired power stations and wind farms), LNG trading and pipelines operation, spanning the UK, US, Canada, Belgium, Norway and Nigeria.

OVERVIEW OF CENTRICA'S RETROSPECTIVE HAZARD IDENTIFICATION PROGRAMME

Retrospective hazard identification within Centrica comprises various types of study, the precise scope, timing and objectives of which are set within businesses, according to the business-specific needs. Table 1 gives examples of the various studies which have been undertaken, or are ongoing. It is emphasised that these studies are in addition to those carried out routinely to assess plant modifications and projects.

The techniques which Centrica has used for retrospective hazard identification include HAZOP as well as hazard-based approaches such as HAZID, PHA and ABB's PHR methodology, which derives from ICI's six stage hazard study process. These techniques have been applied to various types of plant including offshore installations, gas processing terminals, gas-fired power plant, pipelines and a tank farm. Within these facilities the studies have addressed a variety of types of hazard including those associated with dangerous substances, high energy sources (such as pressure systems, high voltage equipment and rotating machinery) and operation in extreme and/or sensitive environments. The hazard reviews have been undertaken at various levels including individual operating units and whole facilities. In some cases the studies have started from a 'blank sheet', representing a considerable commitment of resources to re-establish and document a baseline level of knowledge of the plant hazards and safeguards. In other cases the studies have taken the form of periodic reviews and updates of previous studies, perhaps in support of statutory COMAH safety report or offshore safety case re-submissions.

Overall, the studies which have been undertaken have met the objectives set. Indeed, in many cases, other benefits have accrued such as sharing of experience and learning amongst team members, improved understanding and ownership of existing risk controls and the opportunity to engage widely on options to improve safety. The main point of contention has been the balance of the effort required to undertake such studies in relation to the outcomes achieved, taking into account other priorities for driving safety improvement. This is particularly the case for HAZOP studies which are time-consuming and may require specialist consultancy support. On the other hand, within Centrica, we have found HAZOP to be the most rigorous form of hazard identification, scrutinising as it does Piping and Instrumentation Diagrams (P&IDs) and operating procedures line-by-line and developing detailed understanding of hazards and their potential causes. It also provides a record which can be readily reviewed and updated as the reference documents for the study are reviewed and updated. Hazard-based techniques (such as PHA) provide a less resource-intensive alternative to HAZOP which we have found readily applicable internally to a variety of types of facility where a team-based risk assessment is additionally beneficial.

In undertaking retrospective hazard identification we have found the following factors important in maximising the benefits in relation to the effort required:

- Set clear objectives for the study, linked to other initiatives (eg COMAH or offshore safety case reviews, safety instrumented system (SIS) obsolescence projects etc) and obtain buy-in at all levels. This is important in ensuring that the study is focused, adds wider value and that there is support for any recommendations which may arise;
- Provide competent leadership. It is important for the study leader to be fully competent in the technique to be applied (and thus maintain the study focus) and have sufficient technical background to ask probing questions of the team;
- Involve the right personnel, in particular operations personnel. This is where retrospective hazard identification can add value by involving those who understand how the plant actually operates and can share learning from any incidents which have occurred.
- Schedule to the study sensibly to maintain enthusiasm and momentum, eg no more than 3 half day sessions per week
- Prioritise and follow-up on the findings, and feedback to those involved. Related to this we have also found it important to track action close-out through asset governance arrangements.

DISCUSSION

CURRENT REGULATION AND GUIDANCE

In Europe, Framework Directive 89/391/EEC, implemented in the UK through the Management of Health and Safety at Work Regulations, 1999 (MHSWR), places a variety of duties on employers relevant to managing risk. Regulation 3 specifically requires employers to carry out an assessment of the risk to their employees and the public stemming from their work activities. The Approved

Table 1. Examples of retrospective hazard identification studies in Centrica

Type of study		Application and scope	Objectives
Hazard-based ('top down')	PHR	Offshore installations (2) and gas terminal Retrospective PHR of entire asset Duration: 1–2 weeks per facility	• Revalidate major accident scenarios, initiating events and safeguards; • Identify opportunities for further risk reduction; • Support COMAH and offshore safety case statutory reviews • Support performance standards review
	PHR	UK gas-fired power station portfolio (7 stations) Retrospective PHR of process safety hazards at each station, eg fuel supply systems, gas/steam turbines and generators, heat recovery steam generator, high voltage electrical systems etc Duration: 3 days per station	• Develop understanding and provide systematic review of process safety hazards at power stations; • Assess risks associated with above hazards; • Identify necessary risk reduction measures in accordance with ALARP requirement*.
	PHA	US gas-fired power plants (3) Scope and duration similar to above	Similar to above
	COMAH risk assessment	UK 'lower tier' COMAH sites (3) PHA/PHR-type reviews	• Similar to above but focused on major accident hazards, as per COMAH definition
	HAZID	Gas terminals (2) HAZID review of gas terminals as part of 5-yearly COMAH review and revision. Duration 2–3 days per terminal	• Revalidate major accident scenarios, initiating events and safeguards; • Validate assumptions in Quantified Risk Assessment (QRA); • Identify opportunities for further risk reduction; • Update Hazard Register.
Deviation-based ('bottom up')	HAZOP	Gas terminal Full retrospective HAZOP of gas terminal – approximately 100 P&IDs Duration: 8 weeks spread over 6 months	• Revalidate hazards, initiating events and safeguards; • Identify opportunities for further risk reduction; • Support Safety Integrity Level (SIL) study and Emergency Shutdown (ESD) system obsolescence project; • Support ongoing terminal simplification projects; • Support upcoming major project by providing baseline hazard identification record; • Support COMAH review; • Support review and update of terminal P&IDs.
	HAZOP	Sour gas terminal Full retrospective HAZOP of gas terminal Duration: similar to above	• Support terminal design and operability review following a series of incidents during commissioning; • Critically review Terminal Piping and Instrumentation Diagrams; • Identify opportunities for further risk reduction.
	HAZOP	Individual operating units (offshore installations or gas terminals) Retrospective HAZOP study as part of annual audit programme Duration: 3 days (typical)	• Re-appraise hazards, initiating events and plant safeguards; • Review and update previous HAZOP studies and action close-out; • Identify opportunities for further risk reduction.

* Requirement to reduce risk as low as reasonable practicable (ALARP)

Code of Practice for MHSWR (HSC, 2004) states that such an assessment '*should usually involve identifying the hazards present in any working environment or arising out of commercial activities and work activities, and evaluating the extent of the risks involved, taking into account existing precautions and their effectiveness*'. Regulation 3 also requires that the risk assessment is reviewed and updated as appropriate to ensure its continued validity.

MHSWR provides a link to the requirements of other legislation such as that specific to the major hazards industries, including the COMAH Regulations, 1999 (which implement the EU 'Seveso II' Directive), Offshore Installations (Safety Case) Regulations (SCR), 2005 and the Pipelines Safety Regulations (PSR), 1996. Identification of hazards is mentioned in all these pieces of legislation in particular in the context of the demonstrations required in statutory safety documentation. Thus, for example, the COMAH Regulations require that an operator's Major Accident Prevention Policy (MAPP) document take into account various principles including '*identification and evaluation of major hazards – adoption and implementation of procedures for systematically identifying major hazards arising from normal and abnormal operation and the assessment of their likelihood and severity.*' A common feature of COMAH, SCR and PSR is the need to review and revise as appropriate the statutory safety documents – at least every 5 years in the case of COMAH and SCR.

In the US, hazard identification for facilities handling highly hazardous chemicals is mandated by the Process Safety Management (PSM) standard of the Occupational Health and Safety Administration (OSHA), in particular part (e)(6) of 29 CFR 1910.119 covering PHA. Similar to UK major hazards legislation, this includes a requirement to update and revalidate the PHA at least every 5 years.

In Australia, onshore major hazards legislation in the State of Victoria, ie the Occupational Health and Safety Regulations (OHSR), 2007 (Section 10) – introduced following Longford – closely follows the EU Seveso II approach.

The regulations referred to above are supported by various guidance documents, which includes guidance on hazard identification, eg.,

- UK COMAH: Guidance on Regulations, L111 (HSE, 2006a), Safety Report Assessment Manual – Section 10 (HSE, 2007)
- UK SCR: Guidance on Regulations, L30 (HSE, 2006b), Guidance on risk assessment for offshore installations (HSE, 2006c)
- US OSHA PSM standard: 1910.119 Appendix C – Compliance Guidelines and Recommendations for Process Safety Management (Non-mandatory)
- State of Victoria, Australia OHSR – Section 10 (Major Hazard Facilities): GN13 – Hazard Identification (Worksafe Victoria, 2006), FR11 – Safety Case Hazard Identification (Worksafe Victoria, 2007)

The above guidance is concerned predominantly with the generalities of hazard identification and does not address the specific case of retrospective application, although the Australian guidance identifies one of the factors for successful hazard identification as '*it is regularly maintained and used as a live document*'. Retrospective hazard identification is mentioned in a UK research report (HSL, 2005) in the context of lifecycle assessments, but no further discussion is provided. It is also mentioned in an HSE report of findings from a voluntary loss of containment reporting initiative (HSE, 2005). One of the findings of this study, in the context of a runaway chemical reaction incident, is that '*when performing retrospective HAZOPs it is important to validate that control measures are in place and work correctly*'.

Hazard identification is a key component of national and international standards on safety management systems, eg HSG 65 (HSE, 2003) and BS OHSAS 18001 (BSI, 2007). It is also specifically addressed in BS EN ISO 17776 (BSI, 2002) and BS IEC 61882 (BSI, 2001). BS IEC 61882 refers to the need for periodic HAZOP reviews to '*counteract the effects of creeping change*'.

Elsewhere in the literature there is numerous good practice guidance on hazard identification, eg CCPS (2008), EPSC (2008), EPSC (2003), Kletz (2001) and CIA (2000). Again this is predominantly generic in nature, but for example, the CIA and CCPS guidance briefly addresses retrospective application:

> *Whilst MOC [management of change] reviews provide a record of incremental changes over a period of time, it may become necessary to review a system as a whole. Such a review is particularly important if any changes to operating procedures, feeds or products and/or modifications have been made. There are several techniques available for such studies and HAZOP should be considered as a preferred approach if the following have occurred: major incidents, many modifications, the original studies were inadequate, significant design deficiencies have been revealed, the plant has not run smoothly.*
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> [CIA, 2000]

> *Even as process changes never end during the life of a facility, there will always be the necessity to continue hazard evaluations. Periodic updating or revalidation of the hazard study to incorporate facility changes is the method used to maintain adequate safeguards. The timing of these cyclic reviews depends on factors such as regulations, the rate of process changes, and the nature of those changes . . . A significant change outside the fenceline can also trigger the need for a hazard review.*
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> [CCPS, 2008]

HAZARD IDENTIFICATION THROUGH THE LIFECYCLE OF FACILITIES

Hazard identification is an exercise that ideally should be carried out, reviewed and updated continually throughout the lifecycle of a facility, from conceptual design through to decommissioning. BS IEC 61882 describes this process for HAZOP, which is summarised in Table 2.

Techniques such as HAZOP can establish an approach to risk control either 'strategically', through inherent or passive methods, or 'tactically' with active or procedural controls. Any final outcome however is ultimately reliant on a company's management to adopt and support the approach to any recommendations made. Inherent and passive approaches must be implemented early in the lifecycle and this can have a significant impact on process design. It is therefore, important to make a clear connection with the overall business case to support the safety life cycle approach and avoid the potential penalties of lost time, money and injury. At the conception stage of projects therefore there is an opportunity to influence the level and detail of inherent safety that is built into a new facility. To put this into a financial perspective it has been suggested that, if it costs $1 to eliminate a safety-related problem at conception stage, it would cost $10 to eliminate it at the flowsheet stage, $1000 at the production stage and $10,000 at the post-incident stage.

Whilst there may be a financial or time constraint leading a preference for active or procedural controls, which can be implemented later in the design, such forms of risk control tend to be characterised by repetitive actions and viewed at a later date as 'short-sighted'. Furthermore, this repetition has the potential to be associated with high OPEX costs in addition to giving a higher likelihood of human error. Herein lies a problem, as currently there are operators that have to manage the significant 'built in' risks created by a failure to adopt inherently safer design recommendations arising from HAZOP and similar studies at an early stage in the lifecycle. The approach of designers, management and engineers therefore significantly influences not only the safety of processes, but also the resulting behaviour of those who are asked to operate them. Clearly if equipment is designed or built with a lack of inherent controls and layers of protection there is always going to be a potential, later on, for an undesirable impact on plant integrity and people.

THE TRIGGERS FOR RETROSPECTIVE HAZARD IDENTIFICATION

Rigorous adherence to the lifecycle approach to hazard identification, as per BS IEC 61882 (Table 2) and similar standards, should ensure that there is always a clear link between the hazards present at a facility and the risk controls in place. In reality however, especially for ageing plant, it is likely that a disconnect will exist.

This links to one of the key demonstrations expected of operators, for example, under COMAH, namely to describe not only *what* safeguards on are in place but *why*,

Table 2. HAZOP through the lifecycle (from BS IEC 61882)

Lifecycle phase	Application
Concept and definition	In this phase of a system's life cycle, the design concept and major system parts are decided but the detailed design and documentation required to conduct the HAZOP do not exist. However, it is necessary to identify major hazards at this time to allow them to be considered in the design process and to facilitate future HAZOP studies.
Design and development	During this phase of a life cycle, detailed design is developed, methods of operation are decided upon and documentation is prepared. The design reaches maturity and is frozen. The best time to carry out a HAZOP study is just before the design is frozen. At this stage the design is sufficiently detailed to allow the questioning mechanism of a HAZOP to obtain meaningful answers. It is important to have a system that will assess the implications of any changes made after the HAZOP has been carried out. This system should be maintained throughout the life of the system.
Manufacturing and installation	It is advisable to carry out a study before the system is started up, if commissioning and operation of the system can be hazardous and proper operating sequences and instructions are critical, or when there has been a substantial change of intent in a late stage. Additional data such as commissioning and operating instructions should be available at this time. In addition, the study should also review all actions raised during earlier studies to ensure that these have been resolved.
Operation and maintenance	The application of HAZOP should be considered before implementing any changes that could affect the safety or operability of a system or have environmental effects. A procedure should also be put in place for periodic reviews of a system to counteract the effects of 'creeping change'. It is important that the design documentation and operating instructions used in a study are up to date.
Decommissioning or disposal	A study of this phase may be required, due to hazards that may not be present during normal operation. If records from previous studies exist, this study can be carried out expeditiously. Records should be kept throughout the life of the system in order to ensure that the decommissioning issues can be dealt with expeditiously.

ie how do they relate to the hazards and the potential initiators of such hazards? This works in reverse too in that it should be possible to trace appropriate risks controls from all the hazards which have been identified through a formal hazard identification process.

They may be many reasons why such a disconnect exists, for example:

- a hazard identification study was not done originally for the facility;
- a hazard identification study was done but has been lost, eg due to poor record-keeping or changes in facility ownership;
- the recording of the original hazard identification exercise was poor, eg by exception;
- a hazard identification was done during the plant design process but not updated to reflect the 'as-built' or 'as-operated' status of the plant;
- the plant has accumulated a number of 'minor' changes which were not judged significant enough to warrant a review of the hazard identification study but which, cumulatively, may be significant;
- the plant has been subject to modifications which were incorrectly categorised as insignificant (or not assessed at all);
- the plant is not operated as per the design intent;
- incidents have happened which have caused the operator to question the quality of the plant design and the supporting hazard identification studies;
- the underpinning knowledge of hazards (and their initiators) has improved;
- hazard identification techniques have advanced since the original studies

Figure 1 illustrates how a gap can develop between actual plant safety performance and stakeholder expectations for one or more of the above reasons. It is such a situation in which retrospective hazard identification can help plug the gap, confirm (or otherwise) the suitability of current risk controls and drive improvement.

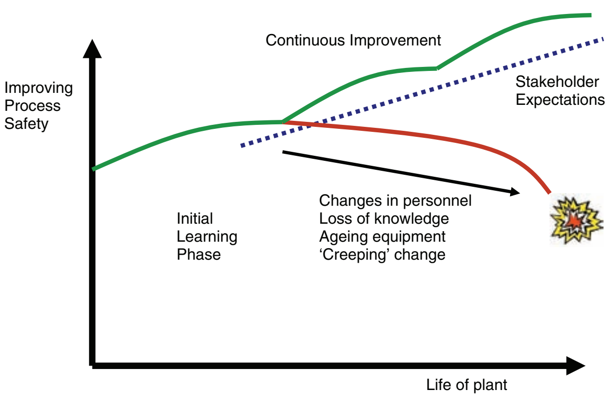

Figure 1. The need for periodic safety reviews

SCOPE AND TIMING OF RETROSPECTIVE HAZID IDENTIFICATION STUDIES

At a typical major hazard facility, hazard identification studies are likely to be taking place on an almost continuous basis, due to ongoing modifications, projects, equipment decommissioning etc. A key question therefore is how retrospective hazard identification fits in with these ongoing requirements.

In deciding on a course of retrospective hazard identification, key issues to be addressed include:

- How fast should a retrospective hazard identification programme be implemented? Should the operator commit to analysing the whole facility over a set period and, if so, what should this be, eg 2 years, 5 years or 10 years? Alternatively should such studies focus on particular plants or operating units of concern? Within Centrica, our approach has been the latter, which gives flexibility in determining where retrospective hazard identification studies will add most value and allows cognisance to be taken of the many other hazard studies which may be ongoing.
- At what level of documentation should the retrospective hazard identification study be addressed, eg P&ID or Process Flow Diagram (PFD)? This links to the previous question in that, for example, a HAZOP study at the PFD level can be executed much more rapidly than at the P&ID level. Within Centrica however our approach as been to re-HAZOP at the P&ID level. This is because P&IDs comprise part of the key plant documentation which is maintained continually up-to-date. Such documents are in use frequently, for example by design engineers in assessing potential plant modifications and operations personnel in logging and controlling isolations. It is useful therefore to have an up-to-date HAZOP study which cross-references 'live' plant documentation familiar to most personnel.
- To what extent should the retrospective hazard identification study be used to challenge the original design assumptions? This may be viewed as one area which retrospective hazard identification studies should not stray as it may be impossible or, at best, costly to uncover the original design assumptions. However this may become an area of increasing importance given the general shift away from prescriptive design approaches (with large factors of safety applied) to risk-based design, in which the assumptions made may not have been appropriate or may have been exceeded in the course of plant operation.

One of the key benefits we have found of retrospective hazard identification within Centrica is that it captures actual experience of operation and maintenance of plant, including learning from any incidents which have occurred. Such studies therefore fulfil an important role in translating the original 'theoretical' design hazard identification studies into useful, up-to-date references for use by plant personnel.

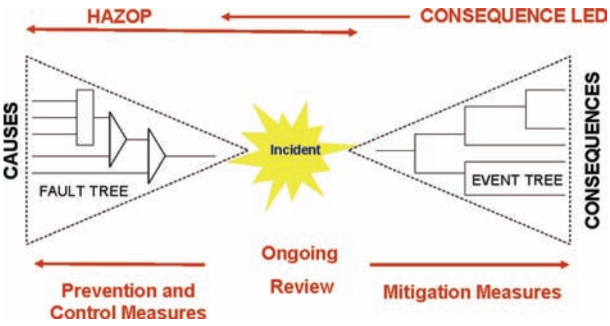

Figure 2. Hazard identification – PHR vs HAZOP

Table 3. Typical guidewords

HAZOP	PHR
• High/low/no flow	• Internal explosion
• Reverse flow	• Runaway reaction
• High/low pressure	• Extreme pressure
• High/low temperature	• Extreme temperature
• High/low mixing	• Puncture
• High/low concentration	• Excess loading
• High/low reaction	• Long term weakening
• High/low level	• Overfill
	• Opening
	• Leak

ageing plant. A number of these methodologies have been published in the open literature whilst some are proprietary in nature. Many are supported by software packages from a variety of vendors.

Centrica has used two principal techniques, namely HAZOP and PHA, in particular ABB's PHR methodology. PHR is a development of the hazard study methodology designed for use on existing and ongoing operations. It was originally developed specifically for the effective and efficient safety assurance of ICI's assets world-wide. This was prompted by difficulties experienced in trying to retrospectively apply HAZOP. The PHR technique is broadly based on the Hazard Study 2 approach but has additional sections and guidewords that focus on losses of containment. PHR concentrates on significant consequences to people and the environment, as a result principally of losses of containment, and uses semi-quantified risk assessment techniques to rank identified hazards. Figure 2 contrasts the HAZOP and PHR approaches whilst Table 3 shows typical guide words applied in the two techniques.

Table 4 shows the advantages and disadvantages of HAZOP and PHA based on Centrica's experience. In deciding an appropriate approach key considerations include the motivation for the study and desired outcomes, resource availability, documentation requirements and the characteristics and hazard profile of the plant to be studied. Also important is linkage with other studies, which is discussed below.

METHODOLOGY FOR RETROSPECTIVE HAZARD IDENTIFICATION

A wide variety of methods are available for hazard identification (eg CCPS, 2008; HSL, 2005; EPSC, 2003), many of which are applicable to retrospective hazard identification of

LINKAGE WITH OTHER INITIATIVES

As noted above, the effort involved in retrospective hazard identification can be offset by ensuring linkage with other safety initiatives which may be ongoing or planned for the same facility. In fact effective hazard identification forms

Table 4. Comparative experience of HAZOP and PHA/PHR in retrospective hazard identification within centrica

Methodology	Advantages	Disadvantages
HAZOP	• Provides rigorous, line-by-line scrutiny of P&IDs and operating procedures • Develops detailed understanding of hazards and potential initiators • Provides a record which can be readily reviewed and updated when the reference documentation for the study is reviewed and updated. • Readily links to SIS obsolescence projects through validation of required functionality of the new SIS • Addresses operability issues as well as hazards	• Time-consuming and expensive • Requires experienced practitioners • May require specialist consultancy support (in particular for major retrospective programmes) • Additional guidewords required for unusual hazards
PHA/PHR	• Applicable to a wide variety of types of facility (not just process plant) • Cost-effective and straightforward to apply using in-house resources • Readily extendable to include team-based, semi-quantified risk assessment	• Checklist-based, therefore may miss hazards and potential causes • Not suited to detailed scrutiny of P&IDs and operating procedures

the basis of a number of other initiatives which operators of ageing plant are typically engaged in. These include:

- SIS obsolescence projects. An up-to-date hazard identification study is critical to ensuring that the new SIS has the required functionality and is a key requirement of the relevant standards, eg BS EN 61511 (BSI, 2004).
- Review and update of performance standards for safety-critical equipment. Hazard identification assists in this context in identifying safety-critical systems and components and their required functionality.
- Quantified Risk Assessment (QRA) review and update. Hazard identification is an essential pre-cursor to risk assessment by informing the selection of representative scenarios for the risk assessment and assessment of the likelihood of these scenarios materialising.
- Risk-based inspection (RBI) programmes. Hazard identification studies provide a useful reference in identifying, for instance, plant degradation mechanisms (eg corrosion) and fire threats, hence informing the scope of RBI programmes for pressure systems and fire-protected structures.
- Plant modification and decommissioning projects. An up-to-date hazard identification study forms a useful basis on which to identify and assess the hazards associated with proposed modification and decommissioning projects.

CONCLUSIONS

It is fundamental to the operation of major hazard facilities to maintain a thorough up-to-date understanding of the hazards associated with such facilities. Indeed it is often stated that identifying the hazards is half the battle to effective risk management. Frequently however it is not possible to establish a complete linkage between the risk controls in place and an up-to-date, formal identification and assessment of hazards.

There may be many reasons for this including for example the accumulation of a number of 'minor' modifications, operation outwith the design intent and improvements in the understanding of hazards and their initiators. This is where a programme of retrospective hazard identification (irrespective of any studies to address plant modifications) can help plug the gap, confirm (or otherwise) the suitability of existing controls and drive improvement.

Retrospective hazard identification can be a time-consuming and costly exercise therefore common sense needs to be applied to ensure that the best value is obtained from such studies. Our approach within Centrica has been to ensure clarity and buy-in to the objectives of the study and then set the scope, timing and methodology accordingly. Leadership of such studies, and involvement of the right personnel, are also critical success factors, as well as follow-up of any recommendations made.

Within Centrica, we have used a variety of study methodologies, including PHA and PHR, which provide a rapid, hazard-based approach, suitable for different types of facility, and HAZOP where a more detailed focus on P&IDs is required. We have included retrospective hazard identification within our planning and audit processes to ensure linkage with related studies and activities such as obsolesence and decommissioning projects, safety report reviews, performance standard updates and risk-based inspection programmes.

A significant value from carrying out retrospective hazard identification is that it provides an operationally-focussed assessment, drawing on experience of operation and maintenance of plant, including any incidents which have occurred and providing an opportunity for critical review of risk controls and knowledge transfer.

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