

REDUCING THE POTENTIAL FOR MAJOR ACCIDENTS WITHIN THE POWER GENERATION SECTOR BY UTILISING OPERATIONAL EXPERIENCE

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Accidents at Texas City and Buncefield in 2005 have increased awareness of the potential for similar accidents in the UK Power Generation sector. The importance of process safety has been recognised, and the need to focus on the potential for major accidents associated with the release of flammable substances or release of energy from high speed machinery or high voltage electrical systems.

Many companies have been implementing Process Safety Management (PSM) systems to assess the risks from their existing operations and improve the performance of risk control systems. This has been a challenge due to the wide range of technology within the sector, with energy sources from fossil fuels to renewable sources, plus many ageing assets within the UK fleet of power stations.

This paper will describe how a hazard identification and assessment methodology developed within the chemical sector has been applied to operational Power Stations. The Process Hazard Review (PHR) technique was originally developed in the 1990's by ICI to identify process safety concerns on operational plants following several serious accidents within the company on older plants.

A team of knowledgeable operations and technical staff led by a process safety specialist consider each process system and use guidewords to identify credible hazardous events. The severity of the event is assessed, and the reliability and robustness of existing risk control measures judged against site experience and relevant good practice. The overall aim is to utilise the knowledge of staff to identify gaps or weaknesses in the risk control measures, including procedural controls, and make recommendations to address these shortcomings.

Many Power Stations have been assessed using PHR in the last few years and the paper describes typical process safety issues that have been identified. It is typical for a relatively large number of recommendations to be raised. The paper will describe a methodology developed to help develop recommendations into clear actions, using a risk based approach and simple cost-benefit analysis.

KEYWORDS: Process Hazard Review, Process Safety, Risk Assessment, Power Sector

INTRODUCTION

The accident at BP's Texas City refinery has created increased awareness of the potential for major accidents on high hazard facilities. Many companies manage safety performance by focussing on injury rates without realising that control measures for process safety may have become seriously impaired.

The causes of these accidents are dreadfully familiar, nearly always involving multiple failures in the layers of protection. The Baker report [Ref 1] on the BP Texas City accident states that "The passing of time without a process accident is not necessarily an indication that all is well and may contribute to a dangerous and growing sense of complacency".

Improving process safety performance requires an understanding that a different approach is needed. As shown in Figure 1, process safety relates to low frequency and high consequence events that are outside the experience of most facilities. By comparison, personal safety relates to "slips, trips and falls" type injuries that occur on a fairly regular basis. Process safety requires a risk management approach with the following essential elements:

- Credible hazardous events identified
- Severity estimated in terms of harm to people or environment
- Key risk control systems to reduce risk to an acceptable level identified
- Testing and inspection arrangements in place to ensure the reliability of safety critical equipment
- Weaknesses in risk control systems identified and improvement plan developed

INCREASED RISKS ON AGEING ASSETS

Many power stations are being operated beyond their original design life increasing the risk of a process safety accident due to the following factors.

- No hazard analysis during the design phase or records not available to the operating team.
- Process safety information incomplete, missing or out-of-date. For example; process P&ID's, hazardous area drawings, relief system design calculations, design basis for safety instrumented systems, emergency procedures.
- Lack of information on major accident hazards and basis of safety adopted at the design stage.
- Organisational changes resulting in poor understanding of the key risk control systems.

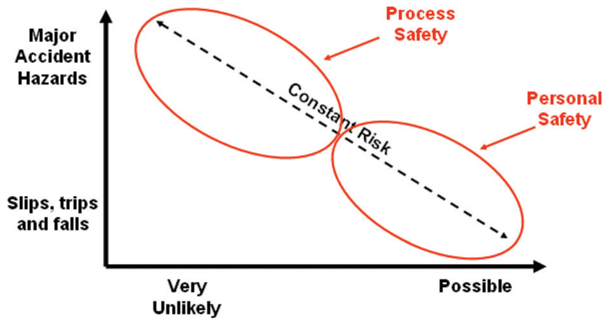

Figure 1. Comparison between different types of safety

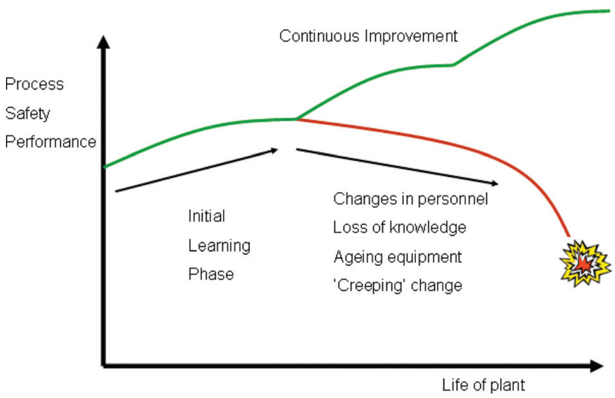

Figure 2. The need for periodic process safety reviews

- Changes to the process and operating procedures not properly assessed for process safety.
- Poor identification of process safety incidents and lack of investigation to identify the root causes.

If no action is taken to tackle these issues it is possible that a serious process safety accident may occur, as shown in Figure 2. An intervention is required on a periodic basis, typically every 5 years, to identify the main process safety related concerns and implement targeted changes to hardware and procedures to achieve continuous improvement.

PROCESS SAFETY IN THE UK POWER SECTOR

Safety in the Power Generation sector was traditionally controlled by the Central Electricity Generating Board (CEGB). Fragmentation of the industry has occurred since privatisation, with existing power stations split between companies including; EON, RWE npower, Scottish Power, Scottish & Southern Energy and EDF Energy. Each of these companies own stations using a range of power sources such as; natural gas, coal, fuel oil, nuclear, wind and water.

Traditionally, the sector has focussed safety improvement efforts on personal safety performance. This is evident when visiting power stations, with example such as signs at EON site entrances stating "We do not hurt people", boards with safety statistics, and clearly marked walkways on-site. The accident at the BP Texas City refinery and the subsequent investigation of management failings chaired by James Baker, has greatly increased awareness of the need for the Power Generation sector to focus equally on process safety.

There have been several "process safety" type accidents in the UK Power Generation sector, mostly involving the sudden rupture of high pressure steam pipework due to various deterioration mechanisms. This has highlighted issues with ageing plant that is being addressed by a cross industry working group, Coal Safety and Generators Programme (GENSIP). More dramatic accidents have occurred outside of the UK, including an explosion at a hydro-electric plant in Russia in 2009 that killed nearly 70 people, and an explosion at a gas fired power station in the US in 2010 during commissioning, that killed nearly 20 people.

Typical process safety hazards on power stations with the potential for multiple fatalities include the following:

- Releases of fuel (e.g. gas, oil or coal) with fire and explosion hazard
- Sudden rupture of high pressure steam systems
- Catastrophic failure of high speed machinery (e.g. turbines, compressors) with missile hazard
- Electrical explosions on HV equipment (e.g. Transformers, HV switchgear)
- Chemical reaction hazards with water treatment systems (e.g. strong acids and alkalis)
- Blade failures on wind turbines with missile hazard
- Release of anhydrous ammonia with toxic hazard (ammonia is now being used for emissions control on coal fired power stations)

Most companies in the Power Generation sector have active programmes for Process Safety Management (PSM) to increase awareness of process safety and improve the management systems needed to control this type of hazard. A key element of an effective PSM system is Process Hazard Analysis (PHA), requiring identification of potential process safety hazards, assessment of potential consequences, and analysis of the risk controls measures required to reduce risks to as low as reasonably practicable. This knowledge is essential in order to shape the rest of the PSM system to maintain these risks at an acceptable level.

Several companies have looked outside of the sector to find well established and effective PHA techniques. The Process Hazard Review (PHR) methodology described in this paper was developed by the multi-national chemical company ICI in the early 1990's following several serious accidents on ageing chemical plants within the UK. A key development for the Power Generation sector was to extend the focus from "loss of containment" incidents involving dangerous substances, to include "release of energy" incidents. The latter provides a focus on the potential for serious accidents with high pressure steam, high speed machinery and HV electrical equipment.

PROCESS HAZARD REVIEW METHODOLOGY

Many companies carry out retrospective HAZOP studies on existing facilities. These are difficult due to the lack of accurate design data and can take excessive time due to the detailed nature of the study. They often result in an excessive number of actions focussed towards hardware changes to improve operability rather than more effective actions aimed at reducing risk.

The Process Hazard Review (PHR) methodology [Ref 2] was developed by ICI for the petrochemical industry during the early 1990s and has since been used widely in many sectors including Oil & Gas and Power Generation. Unlike HAZOP studies, PHR reviews each process system on a plant in sequence, such as a fuel storage system, and identifies credible hazardous events. PHR is therefore much quicker than HAZOP whilst being better at finding detailed concerns relating to process safety.

The essential requirement for an effective PHR is a team of knowledgeable operations and technical staff from the site led by an independent and experienced process safety specialist. The process drawings are reviewed, ideally P&ID's if available but otherwise Process Flow Diagrams. For each system the team use the guidewords in Figure 3 to identify credible "loss of containment" or "release of energy" events, utilising direct experience from the site under review.

The PHR team assess the immediate and ultimate consequences in terms of harm to people or environment, using modelling data if available. It is important at this stage to ignore any safeguards such as trip systems, in order to identify what might happen when all the layers of protection have failed.

For major accident hazards events the team identify the current measures for prevention, control and mitigation, including passive, active and procedural safeguards. The experience of the team is used to identify weaknesses on the plant, for example a level sensor on a safety critical trip system that is known to regularly fail. The essential elements of procedural controls are tested with the PHR team, and further checks carried out on site to confirm that the procedures are being applied.

Recommendations for improvements are raised focussed towards major accident hazards and known problem areas. These fall into the following generic categories, with a bias towards making procedural controls more robust rather than costly hardware changes.

- Simple risk reduction measures, for example fitting blank flanges to drain valves on hazardous lines.
- Improvements to operating or maintenance procedures to ensure that key elements are being followed and that best practices are followed
- Improved inspection and testing of safety critical equipment, for example vent lines on storage tanks liable to blockage
- New layers of protection for high risk events to meet current company or international standards
- Research into poorly understood hazards such as static control measures or consequence modelling to determine the extent and severity of fires, explosions or toxic releases.

Plant tours are regularly made by the team leader accompanied by an experienced operator. This provides an opportunity to check the condition of safety critical equipment in the field and confirm procedural controls discussed at the team meetings. For example, the road tanker offloading valves at and acid/alkali bulk storage systems were specified to be fitted with a padlock to prevent offloading to the wrong tank in error. It was found during the plant tour that the padlock was missing from the valve as shown in Figure 4, increasing the risk of an error resulting in a reaction hazard within the tank.

Most companies have a process safety risk matrix similar to the example in Figure 5. All the identified events are placed on the matrix by estimating the event severity and likelihood using suitable word models and the judgement of the PHR team. The completed matrix showing the risk level for each hazardous event is a powerful tool to indicate the areas of concern and allow for prioritisation of the recommendations.

Internal Explosion
Reaction
Extreme Pressure
Extreme Temperature
Puncture
Excess Loading
Long term weakening
Overfill
Opening
Leak

Figure 3. PHR guidewords

Figure 4. Missing lock on road tanker offloading valve

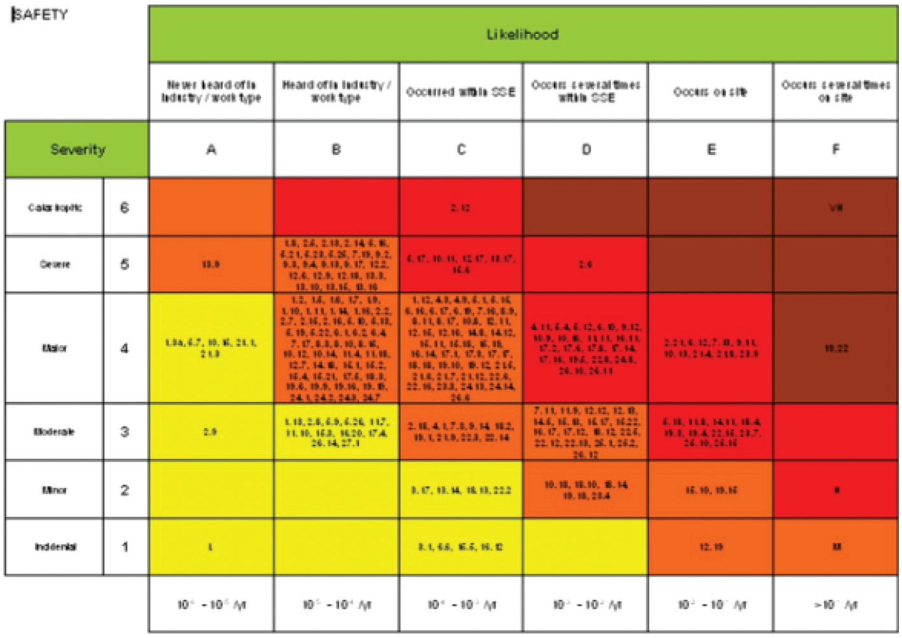

Figure 5. Risk matrix showing all hazardous events identified

CASE STUDY: POWER STATION PHR

A PHR was carried out on a large gas and oil fired power station to address company concerns about the time likely to be required using conventional PHA techniques such as HAZOP studies. The PHR took four weeks and covered all the operating facilities on the site, involving a team of experienced operating and technical staff.

The events identified during the PHR were positioned on the company standard risk matrix, as shown in Figure 5. This helped to prioritise the recommendations raised by the team. The results were 1 scenario rated "very high" risk, 61 "high" risk, 214 "medium" risk, and 81 "low" risk. High risk issues were raised on the following systems reflecting the high hazard potential.

- Gas supply and pressure reducing station
- Heavy fuel oil receipt from jetty and circulation
- Fuel gas supply to gas turbines
- Hydraulic and lube oil systems
- Steam raising systems and steam turbines
- Fuel gas and oil burner systems
- Hydrogen system
- Water treatment chemicals
- Site transformers and LV/HV switch rooms

The company is working through a prioritised action plan for the site that will provide an assurance that process safety risks are under suitable control. The key benefits from the PHR were considered to be:

- Rapid identification of process safety hazards across the entire power station.
- Assessment of current safeguards and development of a list of prioritised recommendations for reducing risks to as low as reasonably practicable.
- Efficient use of busy operations staff whose detailed knowledge was essential in ensuring that concerns were identified.
- Agreed review methodology that can be applied consistently across all power stations owned by the company.
- Use of the structured PHR technique that is well proven throughout the process industries and valued by the regulatory authorities.

IMPLEMENTING IMPROVEMENTS

Completing a PHR is the first stage of the improvement process and it is essential that the recommendations raised are then addressed promptly. From experience a number of challenges exist for companies trying to resolve recommendations:

- Continuity, does the person responsible for action understand what is required?
- Workload, are suitable resources available, can the recommendations be prioritised?
- Execution, can the recommendation be resolved and necessary action taken in a timely manner and how is the work to be paid for?

Simple low cost improvements should be implemented at the earliest opportunity to reduce risks and show a commitment to the improvement process. Technical assessments are then required to identify practical improvement options and carry out some form of cost-benefit

Medium Risk	A	A	B
Low Risk	A	B	B
Very Low Risk	B	C	C
	Low Cost Minor changes or procedural improvements	Medium Cost Improvements within existing OPEX budget	High Cost Improvements requiring new CAPEX

A - Implement with high priority unless not practical

B - Implement unless cost is disproportionate to benefit

C - Low priority based on process safety risk

Figure 6. Risk based cost-benefit analysis tool

analysis. This is required to convert the recommendations into a series of specific actions with owners and completion dates.

The cost of making changes to an operational site is higher than those made during the initial design stage. A common problem is making decisions on expenditure where the benefits are limited to reducing risks. Events judged to be at high risk require urgent attention and changes to reduce risk regardless of cost.

A simple cost-benefit tool such as that shown in Figure 6 can be used to determine the priority of events at medium or low risk, where risk is judged tolerable if relevant good practice is being followed. The approach is helpful for screening with the option for a quantified cost-benefit analysis for high cost improvements.

CONCLUSIONS

Reading investigation reports on accidents such as the explosion at Texas City, it is easy for site managers to think that such accidents could never happen on their facilities. To be confident that process safety risks are in control, it is important to have identified potential major accident hazards, assessed the status of the safety critical risk reduction measures based on operational experience, and monitored the status of planned improvements.

In this paper a methodology has been outlined to efficiently carry out reviews using knowledgeable operations staff to identify concerns. This is followed by targeted changes and monitoring of the effectiveness of the key risk control systems, including key elements of procedural controls. Such reviews can be carried out on a regular basis, typically every five years, to revalidate the assessment based on new experience.

The approach can provide senior management of high hazard facilities, such as Power Stations, with the opportunity to demonstrate continuous improvement in process safety performance. It can also increase confidence that all reasonable steps are being taken to control the risk of a serious process safety accident.

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