
TECHNICAL PAPER

Selection of HAZOP or PHR for Retrospective Hazard Reviews (RHRs)



Many companies in the high hazard process industries have a requirement to carry out regular revalidation of their Process Hazard Analyses (PHA) in order to achieve continuous improvement in process safety.

Such studies need to address the types of failings at the Texas City refinery that led to the explosion in 2005, with the quote from the subsequent Baker Report on the incident that 'the passing of time without a process accident is not necessarily an indication that all is well'. In some cases PHA revalidation is required to meet corporate requirements, in others to comply with legislation such as the COMAH Regulations in the UK or the Process Safety Management (PSM) standard in the US. The objective should be to address common issues found on ageing facilities such as operating procedures not being up-to-date or the basis of safety being compromised by many changes over a period of time.

Some form of Retrospective Hazard Review (RHR) is required involving a team of experienced and knowledgeable technical and operations personnel, led by a competent process safety specialist. The overall objective is to identify the potential for significant hazardous events causing harm to people or the environment, assess the current safeguards and determine the need for improvements to reduce risks to a tolerable level. In most cases companies are using Hazard and Operability (HAZOP) studies or a higher level technique such as ABB's well proven Process Hazard Review (PHR) that has gained support from the UK HSE.

HAZOP studies have the benefit of potentially being very thorough but are challenging to complete in a reasonable timescale. PHR provides a higher level approach which focuses on the potential for Major Accident Hazards (MAHs) and can therefore be completed in a much shorter time, but may not be a suitable approach in some situations.

The choice of HAZOP or PHR for PHA revalidation work can have a significant effect on the overall timescales, with PHR typically being 4-5 times quicker for a similar facility with cost savings and greater chance of key operations personnel being available. A number of factors need to be carefully balanced when deciding on a suitable approach for a specific study, and this technical paper provides guidance to assist in this decision making process.



The requirement for RHR

Process plants undergo detailed hazard identification and risk assessment during the design stage, often using a combination of Hazard Identification (HAZID) studies on the preliminary design followed by HAZOP studies at the detailed design stage. During the operational stage there is a need to periodically review and update this PHA documentation to take account of new information that has been gained on the process and to ensure continuous improvement in reducing risks. These reviews need to take account of changes including; creeping change caused by many modifications, loss of experienced staff, ageing or obsolete equipment, new understanding of hazards from inside or outside the company.

Companies operating on-shore in the EU need to comply with the MAH Directive (COMAH Regulations in the UK), which requires all MAHs to be identified and a demonstration that 'all measures necessary' have been taken to prevent and mitigate these hazards, with similar requirements in place for off-shore facilities. RHR have been routinely carried out during the preparation of safety reports (on-shore) and safety cases (off-shore), and to meet the need for thorough reviews every 5 years.

In the US, companies handling hazardous chemicals must comply with the PSM Standard which includes a requirement for PHA's to be revalidated every 5 years for existing major hazard installations. A number of methods are proposed in the standard, with PHR meeting the requirements of the final option; what-if, what-if / checklist, HAZOP, FMEA, fault tree analysis, or an appropriate equivalent methodology.

Description of HAZOP and PHR methods

The layers of protection or barriers built into a process design can deteriorate over time such that they no longer provide the required level of risk reduction. This is characterised by holes in the 'Swiss cheese model' which can affect the hierarchy of prevention, control and mitigation measures and emergency response as shown on the diagram below for the 2005 Buncefield accident. A key requirement for any RHR team is to identify the potential hazardous events on the process and look for existing holes in the barriers so that these can be addressed before a serious incident occurs.

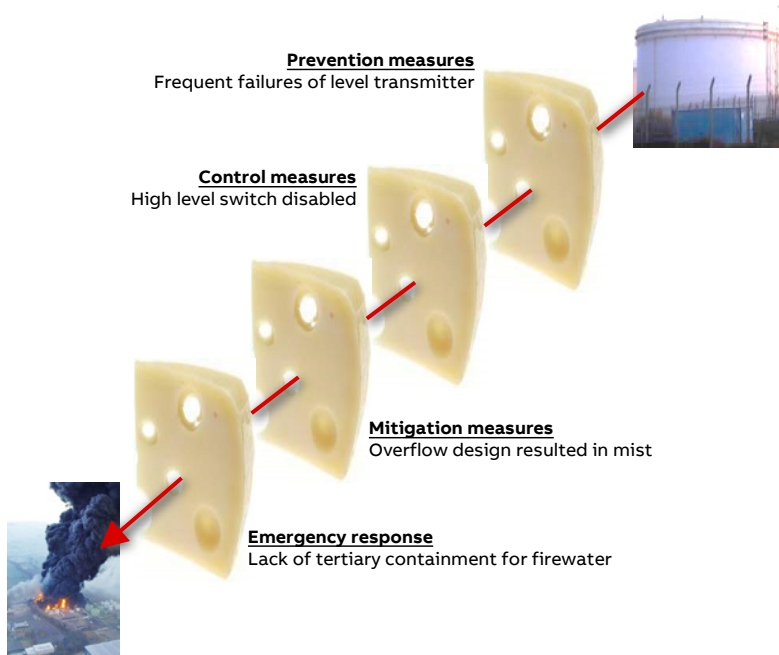
A number a common features of a RHR need to be considered, whether the approach is HAZOP, PHR or some other equivalent method.

- Typically carried out 5 yearly on existing facilities
- Team of experienced operations and technical staff
- Facilitated by a competent process safety specialist
- Considers real experience on the facility
- Assesses the robustness of barriers
- Identifies deviations from standards
- Generates a risk prioritised improvement plan

HAZOP studies were originally developed by ICI in 1964 for the detailed design stage of projects to ensure that the facilities installed as shown on the Piping and Instrument Diagrams (P&IDs) are fit for purpose and meet the applicable standards. The process design is split into nodes as individual lines on the P&ID (continuous processes) or steps in the operating sequence (batch processes), and a series of guidewords such as 'no flow' or 'high pressure' used to identify all the causes of deviations from the design intent.

The team considers if these deviations can escalate into a serious event, and then assesses the risk and need for improved safeguards, such as; alarms / trips, pressure relief, procedural controls, secondary containment, etc. HAZOP studies have been used extensively for retrospective studies on existing facilities, sometimes at a higher level than for design based studies with larger node sizes than a design stage study and a focus on hazardous events with serious consequences.

Below: Swiss cheese model.



PHR was originally developed by ICI in the early 1990's for periodic reviews of existing facilities, to address the following challenges experienced when trialling HAZOP studies on existing plants; excess time required involving busy operations staff, excess number of actions many related to operational issues, failure to see the bigger picture related to hazardous events, and the need for fairly accurate and up-to-date P&ID's.

PHR also takes a broader view of the facility than HAZOP, considering various issues including; neighbouring facilities, incident history, observations from site tours. PHR is quicker than HAZOP as it splits the process into larger nodes at the system level, and looks directly for hazardous events (in middle of bow tie diagram) with guidewords linked to loss of containment or release of energy such as 'internal explosion' or 'puncture'.

The differences between the HAZOP and PHR approaches are shown on the bow tie diagram above. The efficiency of the PHR method comes from moving more quickly through the process system-by-system, and only searching for detailed initiating causes where a significant hazardous event has already been identified, for example an internal explosion in a storage tank. In comparison HAZOP is more structured and results in more complete records with all potential initiating causes by considering every line / step on the process and going through all potential deviations.

However, HAZOP teams often go down blind alleys of deviations which do not escalate into a process safety issue, with time required for this assessment and making a record of 'no serious consequences'. There are also occasions where HAZOP teams working at line / step level fail to recognise a hazardous event at the system level, which can be characterised by 'not seeing the woods for the trees'.

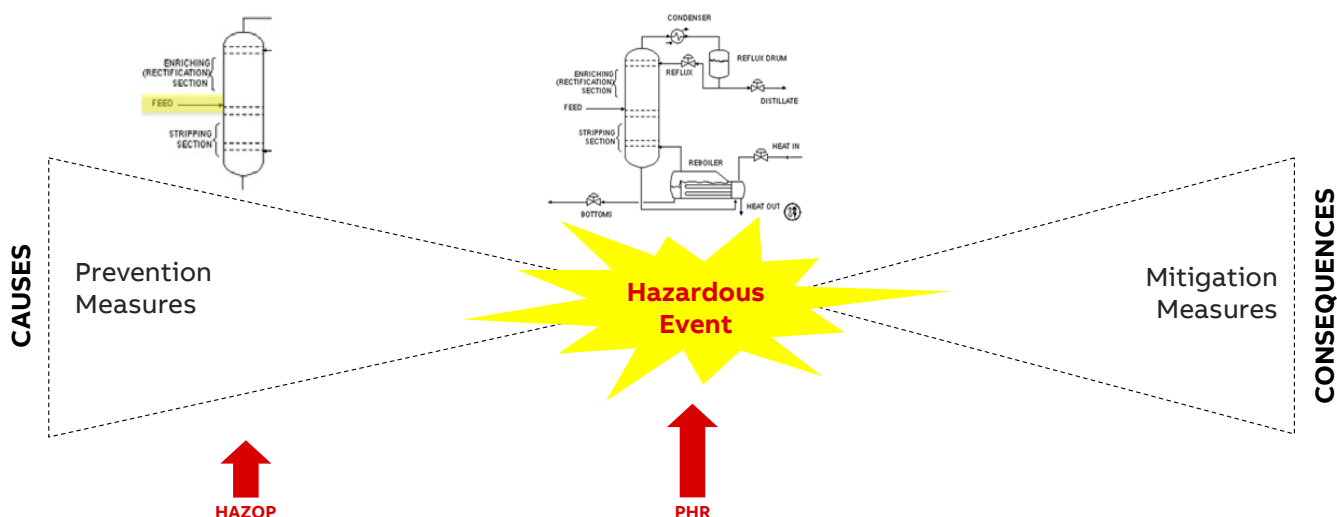
Factors affecting choice of method

ABB routinely carries out PHA revalidations on existing facilities using both HAZOP and PHR methods, and has developed delivery tools that allow a common approach and recording methods in all aspects other than splitting of the process into larger nodes for PHR and use of different guidewords as described above.

The choice of HAZOP or PHR often depends on meeting regulator requirements, client corporate preferences or previous practices on the site. In the table overleaf, a number of factors are discussed that should be considered before embarking on a PHA revalidation, providing an improved justification for the choice of HAZOP or PHR.

ABB's PHR methodology has been used extensively by ABB in the UK for the hazard identification and risk assessment aspects of COMAH safety reports, and had gained acceptance from the UK HSE. In their safety report assessment manual for instance, criterion 11.17 can be met by providing an 'explanation of the formal hazard identification and risk assessment techniques used to provide continuing review (e.g. PHR, PHA etc.)'.

Below: HAZOP and PHR approaches are shown on the bow tie diagram.



Factor	Comments
Company standards / regulator requirement	In some companies there is a corporate requirement for either HAZOP or a PHR style approach written into their standards, in which case this method is mandatory. Regulators have directed companies towards HAZOP based on their preferences or perceived compliance with the US-PSM standard which explicitly mentions HAZOP. ABB has helped companies challenge the regulator and support the use of PHR if this has been chosen as the preferred method.
Recent process safety incidents / no or poor design stage HAZOP	The higher level approach for PHR works well if there are no known serious deficiencies in the basic process design. The structured and thorough approach offered by HAZOP may be required if there have been serious process safety incidents, or where there are concerns about the basic process design due to no design stage HAZOP or evidence of poor quality in this HAZOP.
Complexity of process	PHR at system level works effectively for relatively simple processes such as storage systems and continuous processes. The more thorough approach to identifying initiating causes offered by HAZOP may be appropriate with more complex processes, such as batch reactors with multiple steps or at HP/LP interfaces on oil & gas facilities. ABB can offer a flexible approach where PHR is used for most of the review with an option to use HAZOP where required to provide additional 'thoroughness'.
Availability of operations based staff	RHRs place a great demand on busy operations based staff, and yet input from knowledgeable plant based staff is key to the success whether using PHR or HAZOP. For some companies the use of the more time efficient PHR method is the only viable option given limited staff availability. There are examples where reviews using HAZOP have not been completed due to the excess time required.
Quality of design data including P&ID's	On many operating plants the accuracy of the P&ID's is poor, especially those beyond 10 years old where many modifications have been carried out. The nature of HAZOP using structured line-by-line approach based on the P&ID's can lead to problems on existing facilities where the P&ID's are out-of-date. PHR provides an increased flexibility with the higher system level approach, and allows progress on risk assessment without the need to wait for P&ID updates to be carried out.
Need for quick results	The increased time for HAZOP can result in delays between the start of the study and the results being finalised and improvement actions taken. Based on ABB experience, an offshore platform may take a total of 6-9 months to complete, compared with 1-2 months for a PHR of the same facility. Some companies with concerns about current performance may be looking for a quicker identification of improvement actions in order to reduce risks as offered by PHR.
Availability of skilled facilitators	PHR is a more demanding technique for the leader, requiring hazardous events at a system level to be identified with more of a 'helicopter view' of the process, with the experience of knowing when to dive deeper into specific issues. By comparison HAZOP provides a more structured approach for less experienced leaders, and may be the preferred route if such internal resources are to be used.
Limit number of actions / focus on major accidents	The additional time required for HAZOP often results in a proportionate increase in the number of actions or recommendations raised, which can present challenges for the company in effectively closing out with an adequate justification. Experience has shown that the PHR approach with greater focus on major accident hazards generally results in recommendations that are better risk prioritised.

Case study comparison

The table below, provides metrics on typical reviews carried out by ABB using the HAZOP and PHR techniques respectively, to illustrate the differences. It is stressed that these were different in a number of ways including the facility and the leader, but were both led by ABB on similar types of facilities in the oil & gas sector.

Factor	Case 1: HAZOP	Case 2: PHR
Facility type	UK gas reception terminal	UK gas reception terminal
Number of units	15	11
Days of study	105	10
Total recommendations	498	90
High priority items	14	45

In these cases PHR was almost eight times faster than HAZOP per unit, partly explained by a wider focus on SHE issues for the HAZOP case, but supports the more typical advantage of PHR being 4-5 times faster. Another clear difference is the much greater number of recommendations for HAZOP, whilst PHR has less overall but more aimed at higher priority issues.

Although this can partly be explained by different risk ranking approaches it also reflects the greater focus on significant hazardous events with PHR.

Linkage with LOPA studies

As a follow up to PHA revalidation work many companies are carrying out Layer of Protection Analysis (LOPA) studies, either to provide target SIL's for their Safety Instrumented Systems (SIS), or to more broadly verify the required reliability for all independent protective layers.

ABB has experience of carrying out LOPA studies following both HAZOP and PHR reviews, and in both cases there can be issues requiring a degree of rework for the LOPA team. HAZOP should in theory identify all initiating causes, but these are identified at line / step level and it can be difficult to link these to a specific hazardous event at system level. As LOPA is based around a hazardous event at system level, the LOPA team often needs to check back through the HAZOP records over several nodes to gain a full understanding of the overall scenario.

Unlike HAZOP, PHR works at system level and looks to identify specific hazardous events, and where these are significant works backwards to identify initiating causes. In principle and in practice this helps the subsequent LOPA process by providing clear hazardous events with better thought out consequences. With PHR there can however be some further work for the LOPA team to ensure that all initiating causes have been identified.

Conclusions

When planning PHA revalidations a key decision is required on the use of either a HAZOP or PHR approach, which can have a major impact on the time required based on PHR being typically 4-5 times quicker than HAZOP. ABB has a wide experience of using both methods and this paper has captured some of the factors that may influence the decision on the use of HAZOP or PHR. Key factors are that PHR requires a more experienced leader to ensure that hazardous events are identified effectively, and HAZOP is likely to be the best option where there are concerns about the basic design of the process or quality of previous PHA documents.

In recent years ABB has streamlined the guidance for RHRs and delivery tools to allow a flexible approach when carrying baseline reviews or subsequent revalidation reviews. This allows both PHR (system level) and HAZOP (line / step level) approaches to be used on a single facility, with a decision on PHR or HAZOP at the system level based on factors such as; level of complexity, quality of current PHA documents, history of near misses / incidents. This flexible approach allows the efficiency of the overall process to be optimised, with PHR used to make faster progress where possible, and more detailed HAZOP used where required to provide greater thoroughness.



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