Evaluating the Quality of a *Process Hazard Analysis*

Focus Article

Process Hazard Analyses (PHAs) are widely used in the process industries. The intent of these studies is to identify process deviations that could lead to a catastrophic fire, explosion, and/or toxic release. Their use predates OSHA's Process Safety Management regulation. Over the past 40+ years, PHA techniques have been improved to include a review of a wider range of information, better documentation, and a more thorough consideration of risk. Sometimes, we see PHAs that have not kept up with these improvements or are lacking critical information. When revalidating PHAs, PHA leaders, typically, choose one of three paths. If the previous PHA is sound, including all elements in accordance with Best Practices, the PHA can be reviewed and updated with current information and process changes. If the PHA is missing a few critical elements, it may be possible to retrofit the previous study to include these elements. Lastly, due to defects in the previous study, redoing some studies from scratch is the best course of action.

The question then becomes "What constitutes a 'good' PHA?" The activities undertaken to conduct the study are, of course, critically important; nearly as important is the documentation of the study. Remember that the study will be used in the future, by individuals who were not on the study team, and during the next revalidation. For these reasons, the documentation of what was done and the outcomes are very important. This article reviews the elements of a sound PHA, including both the study actions and the documentation.

PHA Study

Every PHA study should begin by identifying what is included in the study and, equally important, what is not. This is often accomplished by marking the study boundaries on the P&IDs. For example, a pipe from a storage tank may be bounded by drawing a line through the outlet valve on the tank, showing that the outlet valve is within the scope of the study, while the storage tank is not.

Study Objective

While this may seem obvious, documenting the objective of the study is important to understanding the intention of the study and the report. Without it, it is difficult to judge the completeness of the study. Is the study intended to identify deviations that can cause process safety incidents? Are environmental incidents and/or personal injuries included? What about operational issues? Remember that "HazOp" stands for Hazard and Operability.

Study Scope

All equipment within the process boundary must be reviewed during the study. Taken together, the study nodes must include each pipe, valve, tank, instrument, etc., that is within the boundary of the scope. The operating modes should also be included in the study scope. If items are missing from the scope or have not been evaluated, they must be added.

Study Methodology

There are many established methods of conducting a PHA. While HazOp and What-if studies are common, other such methods as FMEA, Event Trees, LOPA, and QRA, are sometimes a better choice. The method used must be appropriate for the process and adequate to identify deviations at the appropriate level of detail. HazOp evaluates every line, pump, vessel, etc., in fine detail, using guidewords and parameters to provide a very thorough analysis. What-if analyses can accommodate larger nodes and tend to review the process at an intermediate level of detail. There may be several different methods that would be appropriate, and different processes within the study boundaries might be evaluated using different PHA methods.

Operating Modes

Many, if not most, process incidents occur during abnormal operations. To identify critical process deviations, the study must include all operating modes. This includes startup, normal operations, shutdown, emergency, and temporary operations. Process parameters and operating conditions often differ between operating modes. The upset conditions, process deviations, and even the potential consequences can be different as well. These must all be accounted for during the study.

Study Nodes

During most PHAs, the process is divided into nodes that are studied individually. This allows the team to focus on smaller parts of the process instead of trying to identify deviations that could occur anywhere in the process. If the nodes are too large, deviations may be missed because there is too much to consider at once. The nodes should each be evaluated to ensure that they were not too large to effectively evaluate. There should be no gaps between nodes; where one node ends, the next should begin.

Design Intent

Each node must be defined to include its purpose and the acceptable process variables. If the purpose is not agreed upon among the team, the consequences of a deviation may be misunderstood. If the normal pressure range is not known, how is the "high pressure" deviation defined? It is also prudent to distinguish between the normal operating limits and safe operating limits. Exceeding the normal operating limits, which are often set for quality purposes, may not create a hazard unless the safe operating limits are reached.

Study Worksheets

The findings of the PHA team are documented on a worksheet, sometimes using software designed for this purpose. In most studies, a list of guide words, hazard considerations, or a checklist is used to guide the team, ensuring a thorough study. If it is determined that a deviation, such as high pressure, cannot occur, this should be documented in the study (e.g., no credible cause identified). Similarly, if a deviation cause does not result in a credible safety-related consequence, this should also be documented (e.g., no credible hazardous consequence identified). If not, a review of the study may lead the reader to ask, "Did the team consider this, or did they not find a process risk?" It may lead the revalidation team to reconsider items because they aren't sure if the previous team completed an evaluation.

The study documentation should use identifying information for each piece of equipment considered. Using valve numbers, for example, clearly communicates which valve sticks open or fails to close. Within a process, and often within a node, there can be multiple valves, tanks, etc. It can be difficult for future reviewers, and even team members, to recall precisely which equipment the study is denoting.

Risk Assessment

Many PHAs use a method of qualitatively estimating risk. This may be a risk matrix, risk ranking, or another scheme. Whatever method is used, it should be documented and explained within the PHA report. Providing details or definitions of the descriptions used is very helpful. While it is difficult to second-guess a PHA team, a portion of the ranked study lines should be reviewed to be sure that the team was not grossly miscalibrated to the definitions. One should also ensure that the risk ranking was completed for all credible consequences.

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Study Consequences

The study must provide a complete understanding of the event consequences. Consequences written such as "fatal injury," "release of tank contents," or even "pool fire" are usually incomplete. The sequence of events leading to the ultimate consequence must be identified. For example, "release of tank inventory to the dike. Flammable vapor cloud ignited by nearby unclassified electrical equipment resulting in a vapor cloud explosion. Fatal injuries to nearby lunchroom occupants due to overpressure and flying shrapnel." With a better understanding of the consequence, the effect of the recommendation(s) is more clearly understood.

Process Incidents

OSHA's PSM standard explicitly requires that the PHA include a review of previous incidents. In the past, many PHAs limited this review to incidents occurring at the facility. With the communication and data-sharing opportunities available today, it is easy to expand the scope in order to review incidents within the company and within the industry. Many companies have a centralized, searchable database of incidents that can be consulted. Industry organizations often report on significant incidents, and there are several publicly available information sources for process incidents. The wider the net is cast, the more likely your opportunity to learn from others.

Process Changes

When a PHA Revalidation is conducted, it is necessary to review changes made to the process that have occurred since the last PHA. This includes changes to any of the Process Safety Information, such as operating procedures, newly installed (or removed) equipment, and chemical changes. If the facility has a robust Management of Change program, this review is easily accomplished. If not, discovering changes may require some digging (e.g., P&ID comparison, operator interviews, review of work orders). In any event, each change must be evaluated independently to ensure that any new process hazards were identified and adequately minimized.

Recommendations

Recommendations are one of the critical outputs of a PHA. If the recommendations are not resolved or implemented, the intended reduction in risk is not achieved. The PHA team can influence the implementation decision, as well as ensure that the correct actions are taken, by clearly documenting what the recommendation entails and what it is intended to achieve. While no recommendation should be implemented without a full understanding of the intention of the recommendation, the recommendation should include basic information. Take the recommendation to "Install a block valve downstream of the pump." Those reviewing the recommendation will not understand the goal without further explanation. The engineer may think that he or she figured out what is needed, only to find that the team meant a different pump or that an emergency shutoff valve was needed instead of a manual valve. This is where the use of equipment and instrument numbers are useful. If we provide additional information in the recommendation (e.g., "Install an automated valve downstream of PMP-267"), the reviewer and implementer will be more likely to install what is needed. The simple addition of "to prevent backflow" to the recommendation can be very helpful. While a recommendation should not be a page long, it should give a clear understanding of what is to be done and why. Where questions still exist, a PHA team member or the PHA leader may be consulted. There should also be a link between the recommendation and the location(s) in the study from which it originated. This will help locate the recommendation when questions arise.

One should also ensure that the recommendations address the scenario of concern and that they actually reduce risk. Sometimes, a team will make recommendations in accordance with good engineering practice that may not address the specific risk they identified. Misunderstandings about the process operation, sequence of events, or capabilities of the recommended change can lead to recommendations that don't reduce the specified risk.

The PHA Report

The narrative of the PHA report provides valuable information not found in the PHA worksheets. This information is critical to understanding the quality of the process.

Basis for PHA Methodology Selection

An evaluation of the PHA should include assuring that an appropriate methodology was used. The Hazard Study leader should have considered several factors when selecting the study type. This may include the material properties, process parameters (e.g., temperature, pressure), and process complexity. These considerations must be documented in order to justify the method(s) used. For each of the factors considered, the outcome should be documented. For example, when considering material properties, one might document that the materials are Class 1A flammable liquids, non-toxic and with the potential for vapor cloud generation.

PHA Team Information

The assessor should ensure that the PHA team included members with the appropriate experience and expertise to properly evaluate the process. The report should document who was on the PHA team and the expertise of each team member. This assures readers that the team composition includes all required/prudent points of view (e.g., process engineering, process operation, maintenance). A list of study sessions, what nodes were reviewed during each session, and who attended each session should be included, as some team members will be needed only for selected portions of a study. Members with process knowledge may change for different parts of the process. The documentation should show that an appropriate team was present at each session.

Process Safety Information

Process Safety Information (PSI), typically, changes over time. Changes to process operations, equipment configuration, and operating procedures all result in changes to the PSI. The team must use the most up-to-date PSI for the study. Documenting the version, drawing number, revision number, etc., will demonstrate that this was done. This will also help the next revalidation team determine what process changes may have occurred and understand the PHA after PSI has changed. Factors to consider include whether all required PSI was made available to the team, and whether the PSI was up to date.

Process Description

The design intent of each node documented in the PHA study record provides a detailed description of process operation. The PHA report should provide a high-level description that includes descriptions of the hazardous materials used, product ingredients, final products, and process heating and cooling, etc. Often, report writers present a process-flow diagram in this section of the report. The process description should contain a similar level of detail as in the process-flow diagram.

Summary of Recommendations

Recommendations are documented throughout the PHA worksheet, which can be hundreds of pages. This makes them very difficult for others to find when reviewing and approving. The report should include a list of all study recommendations in one location. As this is the most often-used source of recommendations, clear descriptions are needed.

Summary

Reviewing a PHA to gauge the quality of the study is to understand if the study met the objectives of identifying deviations, estimating the consequences, assessing risk, and, where needed, making sound recommendations. These objectives are accomplished if the PHA team conducted and documented a thorough study based on the sound practices established over decades' use. Ideally, the study can be reviewed and revalidated or retrofitted in order to add missing elements. However, do not be afraid to conclude that the study should be repeated from scratch. This may be the best, and most efficient, way to ensure that the new study achieves the desired objectives.

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Process Safety Management (PSM) Programs

- Design and creation of relevant PSM programs
- Support the implementation, monitoring, and sustainability of PSM programs
- Audit existing PSM programs, comparing with best practices around the world
- Correct and improve deficient programs

Process Safety Information/Data (Laboratory Testing)

- Flammability/combustibility properties of dusts, gases, vapors, mists, and hybrid atmospheres
- Chemical reaction hazards and chemical process optimization (reaction and adiabatic calorimetry RC1, ARC, VSP, Dewar)
- Thermal instability (DSC, DTA, and powder specific tests)
- Energetic materials, explosives, propellants, pyrotechnics to DOT, UN, etc., protocols
- Regulatory testing: REACH, UN, CLP, ADR, OSHA, DOT
- Electrostatic testing for powders, liquids, process equipment, liners, shoes, FIBCs

Specialist Consulting (Technical/Engineering)

- Dust, gas, and vapor flash fire and explosion hazards
- Electrostatic hazards, problems, and applications
- Reactive chemical, self-heating, and thermal instability hazards
- Hazardous area classification
- Mechanical equipment ignition risk assessment
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