Streamline Your Process Hazard Analysis

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A little creativity during preparation — developing checklists, grouping similar processes, pre-populating worksheets, and considering possible deviations and safeguards before meeting face to face — goes a long way toward improving the efficiency and effectiveness of your PHA efforts.

The U.S. Occupational Safety and Health Administration (OSHA) process safety management (PSM) standard *(1)* requires facilities that handle hazardous chemicals to conduct process hazard analyses (PHAs) to identify and address potential process hazards. PHAs are conducted by multidisciplinary teams, because a group typically identifies more problems — and solutions — than individuals working separately. PHA employs such techniques as what-if analysis, checklists, and hazard and operability (HAZOP) studies *(2)*.

Every process covered by the PSM standard is required to have a baseline PHA, and the PHA must be revalidated every five years. The revalidation process can be handled as a new baseline PHA, which is often referred to as a "redo," or it can be a review and update of the prior PHA based on changes, incidents, and new information, which is considered a "revalidation."

Keeping PHAs current is a time-consuming and resource-intensive endeavor, and can be particularly challenging for a small company or facility. This article provides tools and techniques that can help to streamline the PHA process, and suggestions for reducing the time and cost associated with PHA-team meetings. It also discusses how to significantly simplify the PHA validation cycle through continuous revalidation.

The approach described here is based on lessons learned during a PHA redo project at a small plant (about 30 employees) that makes more than 50 different products, over half of which involve highly hazardous chemicals (HHCs). This method allowed us to redo PHAs for the manufacture of 31 products in a multitude of vessels. The work was completed in less than a year, and provided a model that is being adopted at other locations throughout the company.

Effective preparation by the team leader before a PHA meeting, including methodology selection, checklist development, and grouping of similar processes, can reduce the total PHA resource hours required for a typical one-week PHA by up to one-third. Substantially more time — up to one-half — can be saved if the completed PHA is used as the basis for PHAs at other facilities that use similar process equipment.

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Choose the software

An important first step in preparing for a PHA is selecting software to capture the PHA discussions and create the final documentation for each PHA. Many software packages are available, each with its own advantages and limitations. Some of the criteria for evaluating software include ease of use (*e.g.,* the ability to customize checklists and risk matrixes, ease of reporting results), wide availability to multiple personnel, and the ability to accommodate multiple languages.

Significant engineering resources are needed to conduct and document a PHA, and time is often not available for lengthy software training sessions. A Microsoft Excel-based package is a good choice for many teams. Excel is standard software used by many chemical process industries (CPI) companies, so team members are probably already familiar with the basic features of Excel-based PHA software. Embedded macros that streamline the recording process during the PHA meetings and accelerate the compilation of the recommendations for the final report can be very helpful.

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After the PHA meetings, the files can be made accessible to other plant or company employees without the need for a special software license. This is very important for information sharing among plant engineers and throughout the company, and for continuous revalidation (which will be discussed later).

Select a PHA technique

The most common methodologies employed for PHAs include HAZOP, what-if, and checklist analyses (or some combination of these). When choosing, consider which method is most appropriate for evaluating the hazards of the process being analyzed, and that also meets regulatory requirements.

Processes that take place within a single, multipurpose batch reactor often use the same or similar raw materials. Consistency in the safeguards provided for these processes, especially those handling highly hazardous substances and flammable liquids, is important. These safeguards should be determined according to recognized and generally accepted good engineering practices (RAGAGEPs), which are commonly available in the literature provided by the chemicals' suppliers. RAGAGEPs provide a good basis from which to develop checklists for materials that are handled in bulk and common types of process equipment.

Beyond these basic commonalities, other issues — such as concerns related to reactivity and the process itself — are too complex to be covered adequately with a checklist. HAZOP is a good baseline methodology for evaluating issues related to chemical reactions within the individual processes by guiding the team in identifying potential critical deviations. Additional streamlining can be achieved by grouping related processes and supplementing the HAZOP study with what-if analysis.

Table 1. A checklist for raw material handling should incorporate (among other things) the chemical supplier's recommended practices.

Raw Material Handling Checklist	
All terminal (end-point) valves and fittings should be plugged to reduce likelihood of an accidental exposure. (Dow Product Stewardship Manual, p. 13)	☑
Measures that prevent exposures should be utilized, including dry-disconnect fittings for transfer hoses. (Dow Product Stewardship Manual, p. 15)	☑
A closed-loop gas return line of sufficient diameter (2 in. minimum) from the storage tank gas phase to the tank truck is the preferred configuration. (Dow Product Stewardship Manual, p. 20)	☑
Storage tanks should be constructed of carbon steel or Type 316 stainless steel (Dow Product Stewardship Manual, pp. 31, 39) and built per API 620.	☑

In some cases, the best way to ensure a thorough, efficient analysis is to employ a variety of techniques within the same PHA. Combining multiple study methodologies provides several benefits. The use of checklists ensures that the processes incorporate as many RAGAGEPs as possible. The HAZOP analysis permits a very thorough review of reaction hazards. A supplemental what-if study enables the team to consider a variety of concerns that may not get captured by checklists or HAZOP methods.

Establish study nodes

The team leader structures the PHA by examining piping and instrumentation diagrams (P&IDs) and dividing the process into sections (or nodes) for analysis. A node is a section of the process where a physical or chemical change occurs. By choosing appropriate nodes that are neither too large nor too small, the leader can organize the analysis so that it is both thorough and efficient. If completed in advance of the first team meeting, this effort can save hours, possibly even days, of face-to-face meeting time.

Nodes are often defined by grouping similar processes that use the same or similar equipment. For example, a node may consist of a reactor and key associated equipment, or the raw materials supplied to that reactor system.

It is important for the leader to review this process breakdown with the PHA team (or at least the key process engineer) to ensure that the proposed partitioning is logical. In addition, the leader needs to remain flexible and be willing to modify the proposed study nodes if the team gets bogged down during the meeting.

Table 2. A checklist for flammable liquids can contain generic questions about handling flammables in general plus specific questions related to the particular equipment under review.

Flammable Liquid Handling Checklist	
Loading and unloading of tank cars and railcars	
Is bonding/grounding (to protect against static accumulation) provided at the loading and unloading facilities and tested to validate minimum resistance to ground on at least an annual basis?	☑
Storage tanks	
Are tank fill pipes that enter the top of a tank designed to terminate within 6 in. (150 mm) of the bottom of the tank? If not, is inerting provided for the tank?	☑
Process vessels	
Does the liquid-knockout vessel (used in vapor-collection service) have a means to detect liquid level and sound an alarm?	☑
Is automation or a fire-actuated valve provided at key exit lines from any vessel that handles flammable liquids?	☑

Develop checklists

Take advantage of the expertise of your chemical suppliers. Many provide excellent engineering documentation for the safe handling of their products, such as manuals with details on appropriate piping specifications, unloading facilities, storage, instrumentation, maintenance, and more.

These vendor documents are useful for creating checklists for hazardous raw materials that are handled in bulk. (This is a good project for a summer intern.) Since many processes use the same raw materials, the checklist section for the bulk raw material handling can be completed once and incorporated into the PHA for any process that uses the same raw material. Table 1 is an excerpt of a checklist for one such raw material. The checklists can be pasted directly into the PHA software to document that the hazard analysis considered the relevant RAGAGEPs.

Numerous references, including Center for Chemical Process Safety (CCPS) books *(3, 4),* National Fire Protection Association standards *(5, 6)*, and Factory Mutual Data Sheets *(7, 8)*, describe safeguards for flammable-liquid handling. These can serve as the basis for developing a generic checklist with questions about handling flammable liquids in general plus more-specific questions related to different types of equipment, such as reactors, storage tanks, distillation columns, pumps, piping, valves, etc. (Table 2). If a flammable liquid is used in the process under review, the PHA team can use the portions of this generic checklist that apply to the equipment being studied.

Group similar processes

Facilities that house a large number of similar batch processes that share equipment are good candidates for PHA streamlining. A matrix that highlights the similarities (Table 3) can be used to determine which process/equipment combinations are enough alike to be grouped into a single family. Within each family, the combination that has the highest chemical reactivity or toxicity hazards is selected for the baseline PHA for that family. (Flammability hazards are not criteria for this selection because they can be addressed with a checklist.)

We used a matrix such as this to conduct a single PHA for each family of similar processes. First, we reviewed all of the applicable checklists (raw materials, flammable liquids, facility siting, and/or human factors). Next, we performed a HAZOP of the main process (to provide a baseline for the vessel). Finally, we added a what-if analysis for each of the other processes within the same family to address differences between that process and the main (worst-hazard) process.

Each PHA report covering a family of processes typically had two to three checklists, one HAZOP section (for the baseline process), and four to five what-if sections (for each of the related processes). This proved to be a very thorough, efficient, and systematic way to evaluate the process hazards with minimum resource requirements.

Preparation is key

The quality of the hazard analysis depends heavily on the effectiveness of the PHA team. However, the team leader significantly impacts the amount of time and resources required during the actual PHA sessions. Although efficient meeting facilitation is critical (*e.g.,* not using meeting time for design), up-front preparation work completed by the PHA leader prior to the meeting(s) is the biggest meeting time-saver.

Although a PHA is a team effort, some questions and responses can be scouted out by the leader (or another team member) in advance. For example, rather than all of the team

Table 3. Summarize processes, equipment, and operating conditions in a matrix to identify commonalities, and group those that are similar.

	Primary Process Vessel	Vessel Size, gal	Pressure Rating, psig	Relief Valve Size, in.	Raw Material			Handles ≥10,000 lb of Flammable Liquids	PHA Grouping
					A	B	C		
Process 1	9	4,000	100	4			X		A (Main)
Process 2	9	4,000	100	4			X		A
Process 3	9	4,000	100	4			X		A
Process 4	12	8,000	100	4	X	X		X	B
Process 5	12	8,000	100	4		X			B
Process 6	12	8,000	100	4	X	X		X	B
Process 7	12	8,000	100	4	X	X		X	B
Process 8	12	8,000	100	4		X		X	B
Process 9	12	8,000	100	4	X		X	X	B
Process 10	12	8,000	100	4	X	X	X	X	B (Main)
Process 11	12	8,000	100	4	X	X		X	B

members spending time in the meeting mulling over whether the site or process complies with each checklist item, it is much more efficient for one person to go into the field to check each requirement on the list. This type of up-front effort not only saves meeting time, but it also reduces the number of action items that need to be verified after the meeting.

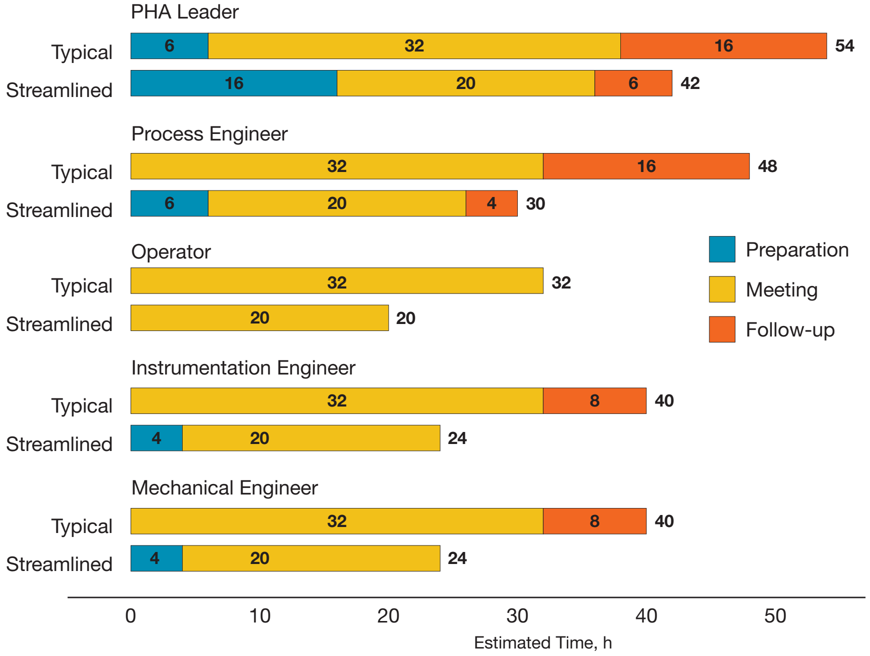
The leader can ensure quick and accurate answers regarding possible consequences of a scenario during the meeting by informing the other team members in advance of the deviations that are likely to be discussed. This enables the engineer to give thought to many deviations and worst-case scenarios prior to the meeting. This approach is particularly useful for reaction-related deviations, such as reactants being added in the wrong order or at the wrong temperature, because the consequences of such deviations may not be easy to envision.

This pre-meeting work does not take the place of the team's brainstorming. Each consequence must still be discussed in the meeting. However, it does help to keep the discussion focused and on track.

Another valuable type of preparation is to pre-populate consequences and typical safeguards. This information can be found in references such as CCPS's Guidelines books *(3, 4)*. Pre-population is similar to creating a checklist of the most common deviations and consequences, and it helps to ensure that these are not forgotten. Pre-populating some of the standard safeguards also provides a starting point for recommendations if the team identifies a gap during the meeting.

A review of past incidents associated with the process under analysis is a required component of all PHAs. Instead of the entire team spending time trying to remember past incidents, the PHA leader (or another individual) can research related incidents and near-misses contained in the onsite incident reports as well as in publicly available incident reports for similar industries. Deviations can be entered into the PHA worksheets in advance of the meeting, as can the potential worst-case consequences and the safeguards identified as a result of incident investigations. The team must still discuss these pre-identified scenarios, but the time spent doing so will be much less.

Figure 1 compares the estimated time requirements for various PHA team members to conduct a typical week-long PHA and a streamlined PHA.



▲ **Figure 1.** By spending more time preparing for the PHA, the team leader can substantially reduce the time required of the other members of the team.

Extending the concept

This streamlining concept can easily be extended to other company facilities. The completed PHA worksheets for a process at one plant can be used as the baseline starting point for a similar process at a different plant. This is, in a sense, analogous to creating a customized checklist for the new facility or conducting a revalidation for an existing PHA.

Having data to reference, such as possible deviations, consequences, and safeguards, saves many person-hours of meeting time relative to starting with a blank PHA worksheet. However, it is critical to understand that a team approach is vital to a successful PHA.

Before the PHA meetings, the worksheets need to be updated to reflect the equipment and instrument numbers at the subsequent facility. This can often be done with a simple find-and-replace operation.

The PHA team compares the information in the completed worksheets to information on the hazards associated with the second facility, and makes any needed corrections to ensure that the PHA reflects the new facility's unique equipment and operations. If necessary, the original set of PHA worksheets can be augmented with new what-if questions or nodes to address specific differences in facilities or equipment. This technique is very similar to revalidating an existing PHA, for which the team members review the accuracy of old data and update information based on new experiences, or just fresh thinking by a different PHA team.

Several caveats apply to the use of PHA worksheets containing data entered in this manner. First, the PHA documentation must be very thorough. If it is not clear, the new PHA team will waste time trying to interpret the thought process that went into the initial PHA to determine how it applies to its process.

Second, the new PHA team must be vigilant in its review. Despite having possible consequences, safeguards, and risk rankings already listed, the new PHA team must conduct its review with a critical eye to ensure that all the hazards have been addressed and that the risk-reduction safeguards have been adequately identified.

Third, the PHA team must ensure that the consequences and safeguards in the pre-populated worksheets really do apply to the facility under review. For example, if one location has a quench tank for emergency relief and another facility does not, the consequences of deviations can be dramatically different.

Virtual efficiencies

In some cases, key people, such as research and development (R&D) and engineering personnel, or even the PHA leader, may not work at the facility where the process is located, and traveling may be cost-prohibitive. Fortunately, the entire PHA team is not required to be in the same conference room. PHAs have been conducted successfully by video conferencing.

All participants, whether attending in person or remotely, must have access to all of the key drawings and the risk matrix that are used in the PHA. The worksheets can be shared by video conferencing so that all participants can see what is being recorded and ensure that their comments are properly captured.

This approach works best if the remote attendees have previous PHA experience and are willing to speak up and share their thoughts. The leader's facilitation skills will be tested by not being able to see all of the team members, so it is preferable to have a very experienced leader for such PHAs.

When participants are in distant time zones, the need for off-hour meetings can be challenging. But the savings in terms of travel costs and time are usually worth it.

Continuous revalidation

Although it does not make the initial PHA easier, continuous revalidation significantly reduces the resource requirements when the revalidation comes due. Continuous revalidation involves one person reviewing and revising the PHA file whenever a change or a process safety incident occurs. When it performs the five-year revalidation, the PHA team needs only to confirm that all information is correct. By spending a little time keeping the documentation up to date, you can turn the PHA file into a living document, similar to P&IDs.

Management of change (MOC) requires some sort of assessment of the change's impact on safety and health. Although this can often be accomplished by key people meeting briefly to discuss the change and document the discussion with the appropriate MOC paperwork, the assessment could easily be conducted as a PHA update. If the PHA software is user-friendly and readily accessible, capturing the MOC discussion within the PHA documentation framework is not cumbersome. If the original file clearly shows which nodes include which sections of the process, you can quickly find the portions of the PHA affected by the change, then update the file to reflect changes to existing line items, or add new lines as needed.

This method of documenting the health and safety impact of a change also facilitates a more thorough review, because the current PHA report probably already contains the detailed information needed to understand the change's impacts. Be sure to add a dated comment summarizing the update along with the MOC number to the PHA report.

In theory, PHAs should capture all of the potential incidents that could occur in a process. However, sometimes an incident or near-miss that was not anticipated and analyzed by the PHA team does occur. If this happens, add a new line item to the PHA file (or update an existing item) to reflect the problem and capture the recommendations of the incident investigation. Add a comment to the PHA file regarding the lines that were added or modified, including the incident date and/or MOC number.

If the PHA file is updated for each change or incident investigation occurring throughout the five-year revalidation

Literature Cited

1. **U.S. Occupational Safety and Health Administration,** "Process Safety Management of Highly Hazardous Chemicals," 29 CFR 1910.119, www.osha.gov.
2. **Center for Chemical Process Safety,** "Guidelines for Hazard Evaluation Procedures," 3rd edition, American Institute of Chemical Engineers, New York, NY, and John Wiley and Sons, Hoboken, NJ (2008).
3. **Center for Chemical Process Safety,** "Guidelines for Engineering Design for Process Safety," American Institute of Chemical Engineers, New York, NY (1993).
4. **Center for Chemical Process Safety,** "Guidelines for Process Safety in Batch Reaction Systems," American Institute of Chemical Engineers, New York, NY (1999).
5. **National Fire Protection Association,** "NPFA 30: Flammable and Combustible Liquids Code," NFPA, Quincy, MA (2012).
6. **National Fire Protection Association,** "NPFA 77: Recommended Practice on Static Electricity," NFPA, Quincy, MA (2007).
7. **FM Global,** "Property Loss Prevention Data Sheet 7-14: Fire and Explosion Protection for Flammable Liquid, Flammable Gas, and Liquefied Flammable Gas Processing Equipment and Supporting Structures," FM Global, Factory Mutual Insurance Co., Johnston, RI (2004).
8. **FM Global,** "Property Loss Prevention Data Sheet 7-88: Flammable Liquid Storage Tanks," FM Global, Factory Mutual Insurance Co., Johnston, RI (2011).

cycle, the revalidation is mostly complete. When the next one is due, the PHA team just needs to ensure that all of the changes and incident investigations have been incorporated and verify that the information contained in the file is still correct and complete.

Closing thoughts

PHAs are a vital component of any PSM program, but providing the necessary personnel to conduct them is often a challenge, particularly in small organizations. By implementing the suggestions presented in this article, a PHA leader can significantly reduce the burden on the team. It is much more cost-effective for the leader to spend additional time in the preparation stage in order to minimize the PHA meeting time. Proper documentation and sharing of PHAs in a user-friendly format saves time for other PHA leaders and teams. CEP

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