Session No. 570

Process Safety: It’s Rocket Science, But It Doesn’t Take a Rocket Scientist

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Introduction

The safety of highly hazardous processes has been dramatically affected by the implementation of process safety management principals. Implementation of process safety standards by OSHA and EPA, as well as preceding state standards, have helped to apply rigorous management principals to control hazards for processes that use large quantities of flammable or toxic substances. However, the concepts of process safety can, and should be, more broadly applied to manufacturing processes, which may not be subject to strict regulatory requirements, to minimize the potential for catastrophic incidents. Recent examples of incidents that could have been prevented through the implementation of process safety elements include the CAI/Arnel explosion in 2006 and the Kleen Energy explosion in 2010. These incidents reflect the common threads of any significant incident: lack of hazard awareness, lack of adequate process controls, and the inability to recognize the potential for multiple infrequent events to cause a catastrophic loss.

Safety professionals have a number of formal tools at their disposal to help identify and communicate hazards; some more involved than others. One of the most involved and comprehensive tools is the Process Hazard Analysis (PHA). The process hazard analysis is an element of process safety, used to dissect and identify elements of process hazards incorporating both the engineering (structural) and human factors (operational) elements that can have both a positive or negative impact on the overall safety of the process. Facilities covered by OSHA Process Safety Management are required to conduct PHAs every five years, or more frequently in situations where the process changes. PHAs are conducted during process changes to analyze the consequences of these changes and verify that the changes do not impact the overall safety of the system.

A process hazard analysis is a tool that can be broadly applied to almost any process. It is an important tool to consider for processes that could have catastrophic consequences involving significant property damage, off-site impacts, multiple injuries, or fatalities. While PHAs are more commonly used for chemical processes involving flammable, explosive, reactive, radioactive, or highly toxic chemicals, PHA concepts can just as easily be applied to processes that have solely physical hazards.

The General Duty Clause of Section 112(r) of the Clean Air Act Amendments of 1990 states that facilities "have a general duty to identify hazards which may result from (such) releases using appropriate hazard assessment techniques, to design and maintain a safe facility taking such steps as are necessary to prevent releases, and to minimize the consequences of accidental releases which do occur." This implies that facilities have a "general duty" to conduct formal hazard reviews for processes that use highly hazardous or flammable chemicals to minimize the potential for catastrophic loss.

Challenges

Despite all the benefits of conducting a PHA, it remains the heavy hammer for the safety professional; seldom wielded and only when it is absolutely necessary. The reasons for this are clear; outside of the chemical industries few safety professionals have formal education in conducting a PHA. Many safety professionals are leery about getting involved in a process where they may have only rudimentary knowledge of how the process works.

Safety professionals come from all walks of life, experiences and education. Many safety professionals have limited engineering backgrounds, making it difficult to grasp a process in a manner that allows them to identify hazards and apply appropriate controls before an incident occurs. There is an obvious concern about not conducting the process properly or completely and letting significant hazards go unfounded.

A PHA is a rigorous and time-consuming process that involves significant resources at multiple levels and roles within an organization. Most PHAs take a day or more to perform, depending on the breadth of the analysis and the complexity of the process. Because of this, the safety professional should carefully consider the situations where it is appropriate to conduct a PHA. PHAs should be considered for processes that could have disastrous consequences or those that are highly complex. These kinds of situations make conducting a PHA a daunting task.

The safety professional may be concerned by perceived lack of management involvement or commitment to resolution. These are constant and ever-present struggles for the safety professional that will exist whether or not the hazard analysis is conducted. Conversely, conducting a PHA shows proof of commitment at many levels within the organization and establishes a leadership role for the safety professional. The PHA results should be highly visible, so that all personnel can learn and potentially contribute to the solutions documented in the analysis.

Solutions are expensive. There may be concern in the organization that the solutions derived from the PHA may be difficult or impossible to implement with existing resources. Unrealistic solutions are an indication that the safety professional has not adequately facilitated the process, or has selected a PHA team with limited authority. The safety professional must ensure that he has selected the right team to guard against unrealistic or impossible-to-implement recommendations. It should be a team that has the right knowledge, authority, and resources to help make appropriate selections.

Economic challenges persist in any recommended measure, but these criticisms can be reduced or eliminated by finding creative solutions that improve efficiency, quality, operability and comfort, and reduce overall liability for the company. The key to getting endorsement, approval, and cooperation during the PHA is to focus on the practical aspects of the PHA, and ensuring that each member of the team focuses on their unique abilities, knowledge and experience.

Practical PHA Implementation

There are a variety of methodologies to consider when proposing to conduct a PHA. Probability analysis systems like Fault Tree Analysis (FTA) use Boolean logic to identify a probability of an event occurrence. This quantitative analysis relies on a significant level of background knowledge by the team, since the probabilities of each lower=level event must be known or reasonably estimated.

Qualitative analyses such as Hazard Operability (HAZOP), Failure Mode Effect and Criticality Analyses (FMECA), “what-if” scenarios, and checklists are typically more straightforward and typically less time consuming with the right level of preparation. However, because these types of studies rely on subjective information, the selection of the PHA team is critical. Team members that are new to the process or organization will not have the experience necessary to make a subjective evaluation regarding the frequency and the consequence of a particular event.

Less rigorous, qualitative methods should be considered in situations where the level of risk is lower and the available resources make quantitative analysis challenging or impossible. These types of analyses can be beneficial for relatively simple or commodity processes such as refrigeration or chlorination systems. Such techniques involve a checklist, what-if analysis, or a combination of both.

The checklist method relies on a series of pre-populated questions for the PHA team. These questions are typically derived from applicable codes and standards, as well as consensus or trade organizations. Although the checklist methodology does not require a significant level of process knowledge by the PHA team, it also does not take into account the unique attributes of a facility’s process. The checklist method of analysis is a low-engagement methodology since inquiry can involve a seemingly endless series of questions that are typically directed at one or two specific roles at a time.

The what-if analysis is a qualitative PHA method that identifies process hazards and controls through a series of process scenarios that identify situations that could cause unintended events and determine the consequences of such events. A number of process scenarios are typically “pre-populated” into the model before the date of the hazard analysis to get the process moving. However, with high involvement, the number of potential scenarios can increase rapidly.

Many “what-if” analyses combine applicable components of the checklist and HAZOP methodologies while using FMECA concepts to prioritize events and the need for corrective action. A “what-if” analysis should be flexible enough to consider the best elements of these other qualitative analyses.

There are a number of benefits to the “what-if” PHA methodology. By nature, the process requires a high level of inquiry and participation by the PHA team. Team members are constantly challenged with the question “what happens if?” The answers often require responses from multiple team members, based on their individual roles. As such, this type of method encourages (nee requires) a high level of participation and teamwork.

The “what-if” methodology is simple enough that decisions and feedback are presented in real time, during the actual conduct of the analysis. Conflicts and questions are typically resolved immediately by the team during the analysis. In the event that controls are determined to be inadequate for a particular scenario, the team is usually asked to provide conceptual recommendations at that moment, instead of tabling the problem or passing the solution onto someone else.

While initially seeming chaotic, the “what-if” PHA method is intended to be a logical, rigorous analysis focused on outcomes. The information is presented in a succinct manner that shows the connections between process, scenario, outcome, resolution and recommendations. The PHA team must carefully consider each scenario, judge whether or not the controls provided are adequate and make recommendations if not. All of these steps are typically done in sequence, and the team rarely moves onto the next scenario until all facets of the current scenario are decided upon.

The “what-if” PHA method is not solely focused on the equipment and the engineering behind the process. Each scenario inherently considers the engineering aspects of the process and the behavior of the people that need to operate and interact with it. Both engineering and human factors are considered in this scenario.

In order for the “what-if” PHA method to work effectively, a high level of involvement is required at all levels of the organization. The makeup of the PHA team should include personnel from engineering, operations and facilities. Personnel representing other roles, such as suppliers, contractors, quality and finance, should also be considered. This high degree of involvement is both a blessing and a curse. It sets the stage for a high degree of interaction and interoperability between various roles in the organization, but success relies on ensuring that the right team is present, ready to act, and engaged in the process. Additionally, the safety professional needs to ensure that the right information is captured during the analysis and that it is presented in a logical and organized manner.

One significant benefit of the “what-if” PHA method is that it allows each member of the PHA team to focus on their area of expertise. It relies on each of the team members to bring their full knowledge of the process and its operation. The safety professional does not need to have extensive knowledge of the process and can focus on facilitating the PHA to achieve maximum benefit.

Each modeled scenario in the analysis results in a description of the process hazards, consequences of the scenario, and controls used to prevent the scenario from occurring. This is familiar territory for the safety professional. Once the output is generated, the safety professional is in a good position to provide input as to whether or not the controls are appropriate for the given consequence. Multi-point failures can also be modeled to determine the impact of such scenarios and ensure that catastrophic events are properly controlled.

While the knowledge of the PHA team is a significant benefit in this process, it can also be one of the greatest challenges. As facilitator, it is the safety professional's job to unlock the potential of the PHA team and ensure that each member is fully involved and engaged in the process. In this circumstance, the PHA is only as good as the knowledge and input from the entire team. As such, the safety professional must identify and remove barriers to involvement and commitment leading up to the date of the hazard analysis.

Roles and Responsibilities

The safety professional should be the facilitator of the process and should coordinate all aspects of the PHA including preparation, scheduling and execution. The safety professional is not the process expert and is typically the person who is least familiar with the process. While this situation may initially seem problematic, the lack of knowledge can work to the advantage of the process. By communicating this fact to the PHA team, the safety professional is indicating his dependence on each of the team members. Also, this lack of specific process knowledge may enhance the overall creativity of the process, since the safety professional may ask questions that the rest of the team might overlook due to familiarity.

Even though the safety professional is likely to be the least knowledgeable person about the process, he must have sufficient knowledge about the process to participate in the hazard analysis and to ask the right questions. In short, the safety professional needs to be smart enough to be dangerous.

Certainly, the safety professional must be knowledgeable of the safety codes and standards that apply to the process. As such, the safety professional should review process components and interview engineers familiar with the process to identify the applicable codes and standards. The safety professional should review and document the applicable federal and state regulatory safety standards as well as list the applicable consensus standards. The safety professional should be aware of the currently recommended controls for the process through a review of the most up to date versions of the consensus standards.

The most current consensus standards should be reviewed by the safety professional in preparation for the hazard analysis. These consensus standards may include controls that were not part of the code during the installation of the process. For example, a flammable chemical process that was installed in early 1990 relied on the 1987 version of NFPA 30 ("Flammable and Combustible Liquids Code"). The current version of this standard was updated in 2008, and includes process safety controls that were not incorporated into the 1987 standard. These "state of the art" codes should be considered as a resource for the safety professional to determine if current controls are adequate given the consequences of a particular scenario. If not, then the safety professional also has a resource to consider for additional controls that will meet modern consensus standards. This increases the validity of the control when presented to the PHA team for consideration. The safety professional can indicate "if this process was built today it would have…"

While the safety professional has basic knowledge of the process, his primary role is to be the leader, organizer and facilitator of the PHA. During the PHA, the safety professional will maximize his organizational skills to synthesize the ideas of the PHA team into a logical output that highlights the hazards, consequences, and controls in the process.

It is the safety professional's mission to energize the creative talent of the PHA team by ensuring that each member of the team is prepared to provide input and has a voice in the discussion. The safety professional needs to carefully select the members of the team based on their expertise in a variety of roles to ensure success of this process.

The success of the PHA is highly dependent on the input of the PHA team. As such, the safety professional must select a team that represents a diversity of knowledge in the process and that the collective interests in the team are given a voice. Team member selection should consider these roles as well as personnel who have the greatest level of process knowledge. Minimally the PHA team should be made up of personnel within the following roles:

> <u>Process Engineering</u> – Process design personnel with significant knowledge of the science behind the process including operating limits, material flow and energy balance. These personnel will likely provide the greatest input regarding structural (engineering) controls used to mitigate the hazards of the process.

> <u>Operations</u> – Personnel who operate the process on a regular basis. These personnel will likely provide the greatest input on operational controls for the process including procedures, human factors, siting, and ergonomic elements.

> <u>Facilities</u> – Personnel who maintain and troubleshoot the process during abnormal events. These personnel will be familiar with the more frequent abnormal events, as well as "near hit" incidents.

Personnel in these three groups should be considered the core of the PHA team. However, the following roles should also be considered:

> <u>Quality</u> – These personnel typically have significant involvement in process deviations and corrective action for the purposes of maintaining product quality. They will have knowledge related to the operating conditions of the process and can be consulted to determine if operations are maintained within the document operating parameters of the process.

> <u>Suppliers</u> – Chemical and material suppliers have knowledge of the quality control processes for the feedstock and can provide input regarding potential chemical contaminants that could cause abnormal events, and the methods used by the supplier to minimize and test for these contaminants. Chemical suppliers are also typically involved in chemical delivery activities at the facility.

Contractors – Contractors may be involved in more extensive maintenance activities or during process changes and can provide input into the methods of construction and post-construction testing. In the event that the PHA is modeling a change in the process, the contractor designated to perform the change should participate in the process.

Finance – Recommended process controls identified and documented during the PHA must realistically reflect the resources available in the organization. The entire PHA is a waste of time if resources are not allocated effectively. Finance personnel participating in the PHA can provide input or track the cost of process recommendations, so that these recommendations accurately reflect a realistic allocation of financial resources. This is not to say that recommendations should be discounted solely due to cost, but in many cases there is more than one particular control that can satisfy the identified mitigation measure and that the cost of the control should be considered in the context of all the decisions made by the PHA team.

The safety professional should consider these roles as part of the PHA team or include these personnel in interviews during preparation activities.

The members of the PHA team are united in a common goal to identify process hazards and to ensure that adequate controls are applied to prevent unintended consequences. The safety professional should leverage and communicate that common goal to all of the team members. The safety professional should ensure that the aforementioned roles are addressed when selecting the PHA team, but also consider the qualities of the personnel selected for the team.

It is best if all of the PHA team members are energized, enthusiastic and engaged in the process. The safety professional should consider the personnel who are best suited for their roles and that will provide a balanced approach to the task. The PHA team should have a balance of experienced and inexperienced personnel, of senior and junior staff, since these attributes are likely to produce different perspectives when reviewing the process scenarios.

The safety professional should select team members that are naturally inquisitive and value and embody the benefits of safe operations and behavior. It is also helpful if team members have demonstrated success in working with multi-disciplinary teams in the past. Having skeptics on the team can provide balance to the process as long as the skeptics are engaged in this process and are focused on the core mission.

Do Your Homework

Prior to engaging in the PHA it is important for the safety professional to know as much as possible about the process to be analyzed, so that he can act within his role as the safety expert. This includes not just the aforementioned codes and standards that apply to the process, but also include knowledge of the process technology and operations.

The safety professional should set aside time to observe the process, including routine and non-routine operations. During observation of the process, the safety professional should review and discuss operating procedures with the process operators. The safety professional should also inquire to see how operators would detect and respond to process deviations or unintended outcomes. The safety professional should also interview a cross-section of process operators to get their perspective on the hazards of the process including any recent or unreported "near-hit" incidents.

The safety professional should have a good basic understanding of the technology of the process to produce the intended result. Interviews with engineering staff at the process area can shed light on process bottlenecks and other possible deviations. Process engineering staff can also provide the safety professional with reference documents on the process including background information on process technology that can be used as a reference during the PHA.

The conduct of a PHA is highly information dependant. Nothing stops a PHA in its tracks quicker than a lack of information. Having the right information available during the PHA can mean the difference between resolving an issue on the spot or deferring a particular issue due to lack of information.

As the facilitator of the process, the safety professional must ensure that appropriate information on the process is available prior to the PHA, which should minimally include:

- Process drawings – including current layout of operating equipment, piping and instrumentation diagrams
- Operating limits – Information on the intended and safe operating limits of the process
- Operating procedures – Routine and non-routine operations should be considered
- Material and energy balances – Information on material flow, chemical reactions and resultant byproducts should be documented

A gap analysis should be conducted on this information before the PHA is scheduled to verify that the information is accessible and up to date. Action should be taken to prepare or update this information if it was determined to be insufficient during the gap analysis.

Prior to the PHA date, the safety professional should prepare the data table used during the what-if analysis by pre-populating a set of kickoff scenarios for each process to be modeled. These "kickoff" scenarios are the result of the safety professional's interviews with operations and engineering personnel at the process, as well as a review of process operating limits. Operating limit information on the process is absolutely critical since many of the scenarios are based on process deviations outside of their intended operating limits.

In identifying scenarios to model, the safety professional should ensure that this list includes any known incidents including injuries, material damage or near-hit incidents. In the event that the facility does not have a process for capturing near-hit incidents, members of the PHA team, as well as process operators, should be interviewed to identify these incidents for the benefit of the process.

Set Proper Expectations

Once the PHA team is established and the background information is obtained, the stage is set to schedule and prepare for the date of the hazard analysis. When scheduling the hazard analysis, it is important to clearly communicate the commitments and expectations of the PHA team. Even simple processes take the bulk of a day to fully analyze and more complex process may take multiple days to address the most relevant scenarios.

Conversely, any process could have multiple deviation scenarios, including scenarios involving combinations of multi-point failures. It is important that the team models the most relevant scenarios that could lead to catastrophic results, so that the available time of the team is used wisely. The PHA must have a start and an end, and it is up to the facilitator (the safety professional) to maximize the available time allocated for the analysis.

Make sure that PHA team members commit to the date, time and duration of the analysis, so that there are no surprises. Consider production schedules and the business impact of the scheduled date when proposing the date of the analysis. There is no benefit to the process, if key members of the PHA team need to frequently step out to address other operational concerns.

When organizing the team, the safety professional should identify himself as the facilitator of the PHA. The analysis is not meant to be performance art, with the safety professional identifying control recommendations for endorsement by the team. Quite the opposite, the safety professional's role is to help the PHA team draw appropriate conclusions during the analysis. The PHA team should be aware that the success of the process relies on a high degree of engagement and participation by each of the members.

Setting the Stage

The "what-if" PHA method is a brainstorming exercise that relies on the collective knowledge, engagement and creativity of the PHA team. Distractions must be minimized to get the best results from the team. Setting realistic expectations from the start minimizes PHA team member distractions and the need to be somewhere else during the process.

The room where the PHA will be conducted should be sufficient size for all team members, the necessary equipment, and paperwork. There should be a projection surface in the room as well as a whiteboard for mind mapping and to post ideas and concepts. Process drawings should be posted in the room for reference purposes. Ideally the PHA should be conducted in a suitable conference room that is as close to the process as possible. It is likely that the team will need to refer to specific process components in the field and it is a benefit if these components can be referred to immediately when needed.

The facilitator should also make arrangements for refreshments and pace time for suitable rest breaks. A PHA is a high intensity effort, requiring significant concentration. Therefore it is essential that team members get a chance to take short breaks, approximately every 60-90 minutes.

Prior to initiating activities, the facilitator should introduce each team member and their role in the process. This is especially important for teams that have not worked together in the past or in situations where contractors or outside vendors are present. Familiarizing members of the team with each other at the beginning of the process will help establish responsibilities and provide cohesion as members rely on each other in their individual areas of responsibility.

Icebreakers

Members of the team who have not been involved in a prior PHA will need to be familiarized with the process before it begins. It is important to have success and full engagement at the start so that sufficient effort and energy is provided throughout the process.

In unifying the PHA team toward a common goal, it is helpful to provide case studies showing unintended consequences in similar processes (if available). Multiple resources can be used to this effect including news articles, safety journals, and information provided by the Chemical Safety Board. Showing the consequences of what the team is trying to avoid through the PHA aligns the team's purpose and provides motivation.

The case study also helps set the stage for the level of detail for the PHA team to consider. Case studies of catastrophic incidents often involve a combination of minor and improbable events coming together at once. The safety professional should impress upon the PHA team that little details are often overlooked and that focusing on the little details that will yield the greatest benefit. Conducting a PHA requires a more intense level of thinking than normal for a process to identify the overlooked hazards that could cause catastrophic consequences.

The facilitator may also want to consider doing a simple "warm up" exercise by modeling a simple scenario. It is important for the PHA team to understand how the PHA works before the real work begins. Common activities such as baking a cake or washing dishes can be modeled to demonstrate the techniques used in the PHA and the documentation produced. Whatever scenario modeled, the process should be common, relatively straightforward, and easily modeled within a few minutes.

The "warm up" exercise will also help demonstrate the concept of the PHA and the expectations of the team. The exercise will also show an example of the end-result for a simple scenario.

Publish It/Show It

In order to make decisions in real time, the results of the analysis musts be shown in real time. The results of a PHA are typically documented in a data table or other specialized report format. There are many options for producing and managing the information obtained during a PHA including specialized software platforms, databases or spreadsheets. Familiarity with the software platform to be used is essential, so that the software becomes a benefit for the team instead of something that slows the process down.

Whatever the mode used, it is helpful to display the information documented in the analysis to the team as the elements of the analysis are discussed. By displaying the information in real time, the facilitator can get immediate feedback on the information documented. The PHA team can review the summarized response and provide comment. This also helps minimize surprises and solicits discussion among the team. Before moving on to the next element, the facilitator should confirm with the team that the documented response (as displayed) accurately represents the team's intentions.

By displaying the results of the analysis in real time, the facilitator can verify with the team that the control selected is appropriate for the consequence modeled. Also, that the control recommended can be implemented based on the necessary resourced needed to accomplish the recommended task. In most cases, each control selected is predominantly focused on a specific role (engineering, operations, maintenance, etc.). The member of the team that represents this role should be given ample time to review and consider the recommendation before moving on.

Remember that recommendations are meant to be conceptual ideas related to a specific outcome and not "design on the fly". For example, a recommendation to install a control to prevent overfilling a tank should indicate: "install high level controller interlocked with tank feed pump" as opposed to detailed specifications on the control points and type of controller units.

Scenarios to Model

The "what-if" PHA method is a process that requires a high degree of inquiry with most of the initial questions coming from the facilitator. This type of analysis typically branches off into increasing numbers of questions as multiple scenarios are investigated.

As previously discussed, the PHA documentation should already be pre-populated with questions taken from employee interviews, operating limits, and review of applicable codes and standards. Even for simple processes, the number of scenarios that could be modeled would likely outnumber the time available to conduct the PHA.

However, it is not the objective of the PHA team to model every single unintended event (or combinations of events) to document the results of these outcomes. The true objective is to prevent catastrophic events by identifying the scenarios that could cause these events first and reviewing the controls designed to prevent these events from occurring.

As such, the first steps in the process are to identify the scenarios that have catastrophic consequences, out of hundreds of likely scenarios, and then analyze an appropriate number of these scenarios to prevent these consequences from occurring.

Scenario Brainstorming

The first step in the PHA process is to identify the list of scenarios to model. Although there is an initial list of scenarios for the team to consider, each member of the team will probably have their own ideas. These ideas come from each team member's individual roles and experiences. These experiences can include near hit events, their own practices, education, or even similar processes at prior companies. The brainstorming event is where these scenarios get documented for further consideration and modeling by the team.

Members of the PHA Team are encouraged to provide their own potential scenarios, which are recorded by the PHA facilitator. At this point, the process is meant to be free flowing with no judgment regarding the likelihood or consequences of a particular scenario. The brainstorming should continue until the exercise ceases, or it is obvious to the team that redundant scenarios are being presented.

Throughout the brainstorming phase, the facilitator should ensure that a free flow of ideas is occurring from all team members. The facilitator should monitor the process to ensure that all team members are encouraged to provide their own ideas and that none of the team members are being shut out of the process.

At this point, the team should have a healthy list of scenarios to consider, significantly more than can be realistically modeled in the time allotted. Many of these scenarios may have similar traits or characteristics based on the team member that presented the scenario. It is up to the facilitator to help quickly parse through this information, prioritize and start modeling the scenarios that make the most difference.

Organize/Mind Mapping and Managing the Information Stream

While brainstorming is a process that encourages creative thought and a free flow of ideas, the downside of brainstorming is that it typically results in informational chaos; lots of ideas, and little clarity. The facilitator is challenged with taking the information gathered from a creative process (brainstorming) and importing that information into a highly analytical and rigorous process (the hazard analysis), in short order.

One method to bridge the gap from brainstorming to the hazard analysis is through a mind map. A mind map is a graphical representation of the information gathered from the brainstorming process. A mind map starts with a central idea (the process) and radiates out from this central process. The idea of the mind map is that it graphically shows the interrelationships of these ideas and how they are all connected to the central idea.

Mind maps are easy to produce quickly since they are meant to convey only the specific snippets of information associated with the scenario (e.g., “tank overfill”, “cooling tower failure”). With assistance from the PHA team, the facilitator can quickly develop a mind map from the scenarios.

A mind map for a typical scenario brainstorming exercise would show the process as the central idea with the major components of the process radiating from the center. The radial concept implies that there is no hierarchy to the ideas presented. Following these main branches are sub-branches that represent components of the system with the nodes representing the specific scenarios to be modeled. Where specific components of the system are inter-related then their relationships should be documented by connecting the components graphically in the mind map. The mind map helps to visualize the process and the relationships that the components have with each other in an obvious way.

Once the map is completed, the team should review the impact of the scenarios radially from the center of the mind map. Since each of the primary branches represents the major system components, the primary branches should be reviewed to determine if there are catastrophic outcomes based on the scenarios (nodes) from these branches. If the answer is “no” then that branch is essentially “dead” and the scenarios from this branch are not analyzed.

Conversely if the component that represents the primary branch could cause a catastrophic incident (e.g., fire, explosion, toxic gas release, serious injury), then the nodes on that branch would be given high priority for analysis. Typically, the branches are color coded based on priority so that the results and the identified nodes are clearly displayed.

The mind map also helps to show the level of complexity of the process and their individual components. Once the “dead” branches are identified, then the map is reviewed to see the number of inter-related scenarios based on the branches represented. Scenarios with a high degree of inter-relatedness should be given higher priority than isolated scenarios, since these scenarios would likely have a higher chance of occurring.

Conducting the Analysis

Following identification of the target scenarios, the PHA team is now in a position to do the heavy lifting, focusing on the scenarios that have the most significant outcomes and on process components (equipment or operational) that have the greatest impact on the safety of the process. Each scenario is documented to identify the consequences of the event and the controls used to prevent the occurrence of each scenario.

At this phase, it is the facilitator’s job to challenge the PHA team’s understanding of the appropriateness of the controls. The facilitator should constantly be asking the question “what happens if?” Multi-point failures should be considered for each scenario modeled since the scenarios selected each have catastrophic consequences. Multi-point failures look at the initial scenario, PLUS the effect on the system if the identified control ALSO fails. By identifying the catastrophic scenarios first, the PHA team has more time to concentrate on these high priority items, where the implementation of additional controls will have the greatest benefit.

In the event that the PHA team determines that the current controls are not sufficient to adequately protect the facility from the catastrophic consequences of a given scenario. Then the team will make recommendations for additional controls. Control recommendations will consider the direct effects of the process change, cost, implementation, resources and the potential to create new or additional hazards. Where possible, the recommended controls should first consider engineering solutions to incorporate “prevention by design” principals. Operational controls should be considered where structural controls are infeasible or for redundancy.

Finally, each recommendation is given an action priority score based on the severity of the consequence and the probability or frequency of occurrence. The priority score will correlate to the amount of resources and timing for each particular activity. Higher priority scores will be considered for initial action first before moving on to the next recommended measure.

Feedback

Throughout the process of documenting the PHA, the facilitator should constantly monitor the PHA team to ensure that he is accurately reflecting the intention of the team. When feedback is not provided, the facilitator must actively engage the team. Constructive criticism is a welcome counterpoint to the opinions and impressions of the team and the identified "critics" on the team should be checked at every available opportunity. By displaying the results of the analysis in real time, there is a constant signal to the team looking for review and endorsement before moving on. Nothing is hidden in the process.

The Results

At the conclusion of the process, the "what-if" PHA method will produce a report which documents the scenarios modeled, the consequences of the scenario playing out, the existing controls in-place to prevent the scenario from occurring, and any recommended improvements to system controls, where appropriate. Each of these recommendations is prioritized based on a scoring process so that the more significant scenarios are given greater attention.

If the PHA is performed correctly, there should be little work for the facilitator following the process. The information and decisions provided by the PHA team are keyed during the analysis and displayed in real time for the team members. The safety professional should review the report for readability and make changes where necessary, but the essential content of the analysis should not change.

Conclusion

The safety professional needs to gain input from many different stakeholders in an organization to maximize the effectiveness of the "what-if" PHA methodology. This input is important since it is the variety of knowledge, experience and perspectives collaborating all at once that helps to identify the hidden hazards of a process and ensures that recommendations to fix one problem do not create additional problems in a different area.

However, the variety of personnel and perspectives has its own problems. The conduct of a PHA can initially appear to look like organized chaos, with various disparate members of an organization providing input in their own realm of specialty. The inherent flexibility of the "what-if" method means that the process does not take a strict path. It is up to the facilitator to create organization out of chaos.

Organization of the process comes from doing the hard work before the date of the hazard analysis and by being as familiar as possible with the process and its operation beforehand. Setting clear goals and expectations for the PHA team ensures that there are no surprises on the date of the analysis.

Providing visual representation of the PHA in real time through mind mapping and outlining the what-if scenarios helps the team visualize the results of their efforts, increases interest and involvement by the whole team. It also helps eliminate confusion and ensures that the process captures the best efforts of the entire hazard analysis team.

Many processes have the potential to produce catastrophic results under the right combination of circumstances. It is up to the PHA team, facilitated by the safety professional, to find these hidden traps and eliminate them, before the process does.