PROCESS HAZARD ANALYSIS STRATEGIES FOR THE LIFE CYCLE OF A GRASSROOTS PROJECT

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Abstract

During the past three years Stone & Webster has performed a variety of process hazard analyses (PHAs) on projects for a variety of major clients, each with a different corporate PHA performance requirement. This paper discusses Stone &Webster's experience with preliminary hazard reviews, safety integrity level (SIL) analyses, facility siting reviews, health safety & environmental reviews, HAZOPs and vendor equipment HAZOPs during the life of a project. The paper then evaluates the successes and failures during the application of each of these methods and the respective advantages and disadvantages for both owners and engineering contractors. Finally, the paper presents Stone & Webster's current strategy for identifying health and safety concerns based upon these experiences.

Introduction

Process hazard analyses (PHAs) have a bad reputation from project management's perspective because they have the potential to create more changes in the design, and they consume project resources both in their performance and in the resolution of their recommendations. Many people realize the value of PHAs for systematically reviewing a design for potential problems and the need to meet regulatory requirements, but if not properly managed a project's PHA program can significantly impact a project's budget and schedule. These problems are further magnified with large projects that take several years to implement and require several different PHA methodologies during their life. In a large project, thousands of manhours can easily be consumed between performing the reviews and resolving their recommendations in addition to the costs associated with design rework and any schedule delays. To ensure the success of a PHA program for a large project, the major obstacles that one should consider when developing the basis and resources for the program are:

- Connecting the PHAs through the life of a project and thus increasing their efficiency, so that design intentions and hazards do not have to be re-learned and re-documented.

- Performing the correct type of review at the proper time in the project schedule.

- Assimilating changes in the process design into the PHA program.

- Communicating the large volume of recommendations to the project team in a timely manner, and having a mitigation system to ensure that the resolutions are addressed in a timely manner, and

- Presenting the PHA documentation in a format that makes it useful beyond the life of the project.

To overcome these obstacles the recommended tasks that the PHA program leader should implement are:

- Develop a process safety project specification that identifies all of the client PHA requirements and then describes a PHA program for the life of the project to meet these requirements. Specifically describe the contents of each deliverable to be produced to ensure that the customer's intentions for using the deliverables after the project has ended are considered.

- Develop a strategic use for consequence and risk analysis studies for the life of the project and incorporate this into the process safety specification for the project.

- Use several PHA and consequence analysis review techniques, each appropriate to the stage of the project. Establish the required inputs for each type of review and then integrate the timing of these tasks into the project schedule based upon the availability of these inputs.

- Capture as many facts about the design as possible in each PHA so that later PHAs can build upon this information.

- Determine what software will be utilized for PHAs, consequence analyses and the administration of recommendations. Consider how data can be exchanged between each piece of software and ensure that the software system (and storage media) can handle PHA meetings that could last for months and produce thousands of recommendations.

- For consistency and accountability, assign a specific project position, full or part-time as required, for the oversight of this effort through the life of the project.

Process Safety Specification

The process safety project specification is the foundation for a successful PHA program on a project. This specification establishes the types of PHAs to be performed, the type of consequence analyses to be performed, the timing of their performance, their required inputs and the deliverables to be produced. The first issue of this specification needs to address these aspects, and once there is agreement on this strategy, then the specifics to each PHA review can then be elaborated.

This specification also needs to describe how the overall process facility will be divided into specific process units that will then be subdivided into more specific systems. This can take the form of a report outline in which each process unit is assigned a certain number and all of the systems in that unit are then assigned a sub-number. This system of plant/unit division will most likely follow a standard drawing numbering system established for the project. An organized system of organizing each area in the plant is of utmost importance if PHAs are to build on one another as the project progresses.

The process safety project specification should also establish the recommendation procedure and the work flow process that eventually leads to a recommendation being resolved and implemented into the design. The computer application that is going to administer these recommendations should be structured so that it can serve as a cumulative source for the outputs from all PHAs. Since a fairly rigorous system needs to be in place to administer the hundreds or even thousands of recommendations, the project team might also want to use this system to track all other project action items. For instance, the program could also be utilized for action items produced from meeting minutes or drawing review comments.

The process safety project specification needs to specify when and how consequence analyses will be performed. The use of consequence analyses need to be precisely defined at the onset of a project because they can be resource intensive and their output often significantly impacts the process design. For instance, their results may require equipment plot plan modifications, occupied building relocation or significant upgrades in instrumentation, design conditions or metallurgy changes. Consequence analyses need to be anticipated within the project schedule, and also considered how to be used as tools to analyze issues identified in the PHAs.

Preliminary Hazard Analysis

A preliminary hazard analysis (Pre-HA) should be performed in the early stages of the project and focus on the process and utility flow diagrams. The Pre-HA provides an opportunity to discuss and resolve safety and design issues as soon as possible in the project life so that they do not become significant and irreversible issues when identified in later PHAs. The Pre-HA functions as an abbreviated version of a detailed PHA (i.e., HAZOP) because design details have not been developed, but the review can still discuss design issues in general terms. Discussions in the Pre-HA force project management to begin making decisions regarding how certain hazards will be mitigated early in the design stage of the project. For instance, the Pre-HA might discuss special metallurgy considerations, inherently safe options, and sparing philosophies for both pressure relief valves and equipment. The Pre-HA is also the starting point for identifying where safety instrumented systems (SIS) will be utilized in the design, and thus begin the consequence analysis process of defining safety integrity levels (SILs) (ref. 1).

The Pre-HA is also a wonderful tool for capturing and communicating the design intentions of process systems to all members of the project team. During the early stages of a project, there is usually no single project document that discusses why certain systems are designed a certain way, the inherent hazards they possess or how they are intended to be operated. In the Pre-HA this information can be collected so that others who are working on the design will have an organized knowledge base for reference. Before they delete or modify a system during their design work, they will have a better understanding of the system's purpose and if their work will be affecting that purpose. The Pre-HA is also used as a reference tool during more detailed PHAs (i.e., HAZOP) to expedite the review by providing the review team with the basic design intentions and information on the system rather than having it regenerated.

Health, Safety & Environmental Review

A health, safety and environmental (HS&E) review is used by some organizations as an extremely thorough PHA that is used in place of other detailed PHAs such as HAZOPs. The HS&E review consists of an audit of all aspects of the design to corporate or industry standards using experienced personnel. Since the review method is so thorough, it requires more design information than other types of PHAs. Unfortunately, because the information produced on a project is so dynamic, the HS&E review methodology is inefficient unless the project can be placed on hold so that the all design information can be fixed at the same level of design detail.

The HS&E review method is useful on fast paced projects if its scope can be clearly defined and if the review is contained within this scope. This method has also been found to be more effective if performed in a team environment with specialists from different disciplines providing their own unique perspective and if performed in stages as the design of each process area becomes available. As with all PHAs, the HS&E can only be properly performed when all of the required inputs are available, because if the review is performed too early, then a significant number of questions concerning the design requiring responses will be generated. As with any PHA, there is always a trade-off between identifying issues as soon as possible and generating more questions about the design or waiting until the design is more developed and risk identifying issues later in the project schedule with the potential for greater impact to the project.

The best strategic use of an HS&E review is when a specific process or design aspect requires a level of review beyond that provided by most other PHA techniques. In addition, the HS&E review may be a useful design check during a fast paced project that identifies and mitigates targeted issues prior to the final PHA, so that the final PHA is more expedient.

HAZOP

The HAZOP methodology is the most popular PHA technique for process industry projects. However, because the HAZOP is so systematic and thorough as a P&ID review tool (ref. 2), it can only be performed when almost all design aspects of the P&IDs have been developed. This is usually about the stage of the project when the P&IDs are issued for detail design. On a large project the HAZOP meetings can be several months in duration, so it is wise to treat the HAZOP almost as its own separate project with its own schedule and staffing plan.

In addition, the HAZOP procedure specification should be highly detailed and undergo a through review to ensure a consistent HAZOP process, because there will be many different team members during the duration of the review and each will have their own perspectives on how HAZOPs are to be performed. (ref. 3).

Consequence Analysis

Consequence analyses can be used for determining the safe distance between equipment, the location of critical buildings, the location of occupied buildings, the design basis (i.e., blast resistance) of occupied buildings, and a better understanding of the consequences associated with specific hazard scenarios. Consequence analyses need to be performed rapidly because of their potentially significant impact to major aspects of the process design.

The use of consequence analyses is defined in the process safety specification described above. Primarily, the use of consequence analyses should be anticipated, and the techniques used along with the allocated resources should ensure that they quickly produce the required results.

SIL Studies

The use of instrumented systems as safeguards to mitigate hazardous or financially undesirable events is first determined in the Pre-HA. A separate safety integrity level (SIL) study for each instrumented system is then required to be performed. In order to ensure consistency and expediency, a SIL study method must be developed. This method often uses a risk matrix (severity versus frequency) to quickly assign a SIL value. The Pre-HA provides a description of each scenario that requires a safety instrumented system. The SIL study can then extrapolate the Pre-HA information to determine severity and frequency values that can then be applied to the SIL matrix. Each safety instrumented system will then have a specific SIL value assigned to it. (In addition, the design of the safety instrumented system should consider reliability to ensure that the system does not frequently fail to its safe mode and cause nuisance trips).

After the safety instrumented system has been designed, the required performance requirement of the system must be verified mathematically. In large plants where there may be many safety instrumented systems, it is often, it is advantageous to engineer generic designs that can be applied repeatedly in order to simplify engineering, minimize different maintenance routines and the number of performance verification calculations.

Management of Change

As the process design develops there are always additions or changes to the design due to new information or design development, or changes in preferences. Consideration of potential changes should be anticipated when performing each of the PHA methodologies, consequence analyses and SIL analyses. Each study may have to be amended and revised, and as the change is assimilated into the design, decisions will be required whether to analyze the change using all or just the more thorough PHA review techniques. For large changes the Pre-HA method followed later by the HAZOP method may the correct approach. However, just as with the management of change program for an operating facility, a single simple approach or a series of reviews may be required based upon the complexity and degree of hazards presented by the process. In summary, the PHA program should anticipate how it would handle changes through the life of the project.

Mitigation

On a large project, the Pre-HA, the PHA and the HS&E review (if performed) can produce hundreds of recommendations that require resolution. The quantity of recommendations depends upon the objective of the review and the stage of the project in which the review is performed. It has been our experience that reviews can potentially produce about twenty recommendations per day. For a large chemical complex in which the PHA lasts for several weeks, this can result in several thousand recommendations being produced.

<u>Types of Recommendations</u>

If a PHA's single objective was to satisfy the OSHA PSM standard, then discussions and the resulting recommendations would be limited to only health and safety issues. However, a PHA can provide more value to the customer if it also identifies potential operability and

maintenance problems. A PHA can also be used to identify areas requiring further study (i.e., SIL analysis, consequence analysis, etc.) or to provide guidance in establishing alarm criticality.

Recommendation Administration

Recommendations produced by any review need to be addressed as soon as possible in order to minimize their impact to the project schedule, scope or budget. Recommendations need to be provided to the project team at the end of each day instead of waiting until the complete PHA has been completed. The risk of providing duplicate or mis-numbered recommendations and confusing the project team is insignificant when compared to the potential financial impact in delaying critical changes or design corrections to the project.

A good recommendation administration program includes:

- Timely communication of the recommendations to the project team and responsible individuals.
- Resolution action assignment for each recommendation.
- Developing a resolution in a timely manner.
- Project team approval of the resolution.
- Implementation of the recommendation.
- Periodic reporting on the resolution status of each recommendation.
- Determination that the recommendation has been completely addressed and that the issue is closed.

The recommendations produced from small PHAs can usually be administered using an Microsoft® Word table or a Microsoft® Excel spreadsheet. Separate columns can be added to the data to match management's workflow process and to indicate the status or answer to each administrative step. Most PHA documentation programs have an export feature that outputs the data (e.g., comma delimited ASCII file) which can then be imported into Microsoft® Excel. However, when recommendations begin to number in the hundreds, then a database program such as Microsoft® Access should be used to manage the information. Most PHA documentation software packages provide additional columns for the resolution of recommendations, but unfortunately the information cannot be accessed without wide distribution of the specialized and costly PHA software.

Regardless of which type of software is used, the PHA documentation that led up to the recommendation will have to be accessible in order for the recommendation to be completely understood. To expedite this process additional columns of information may have to be exported to the recommendation administration software. Rather than having this information carried

along and be an additional burden to the recommendation administration software, one option is to generate an individual summary page for recommendation and place all of this support information on this page. This summary page can then be distributed to the individual responsible for mitigating the recommendation.

Finally, the greatest problem in resolving PHA recommendations is not producing or managing the records, but getting actions from others to resolve the issues or approve their resolution. During a fast-track project every project team member, both client and engineering contractor, is busy responding to their own defined responsibilities and scope of work. The project team often has the misconception that once the PHA meetings have ended that the entire task is complete, or that the PHA leader on his own will provide a response to each of the many recommendations. Unfortunately, the success of resolving all recommendations often requires involvement from many individuals, and most importantly the expedient approval by project management and the client.

Commitment

For the PHA program to succeed to its completion, the project needs to establish a role of responsibility for this task for the duration of the project. With several PHAs, consequence analyses and SIL studies being performed on a project, at least one individual is occupied full-time with additional support provided periodically. However, on some projects if there is less PHA work then a full-time individual may not be needed. In these cases, the individual should perform other tasks for the project (i.e., project engineering, calculations, etc.) on a part-time basis while still being able to monitor the progress of the project. An individual dedicated to the life of the project provides consistency for the PHA program, enables the PHAs to be more easily connected and provides insights into the design basis from a historical perspective.

Future Trends

Many organizations are undergoing initiatives to improve project execution through the utilization of electronic documents instead of hard copies. Electronic versions of documents are now being sent as e-mail attachments or can be viewed on a centralized file server, and comments can be made electronically. There is a huge cost savings through reduced copying, the ability to instantly distribute documents and comments worldwide, and the increased ease in managing this information.

This technology is certainly applicable to the volume of documents produced by PHAs. Documents can be provided in their native format or in a rendition format such as PDF for greater security and control. The utilization of this technology should be even more advantageous when monitoring the status of responses to recommendations and their review and approval during the entire workflow process.

Summary

The success to a large PHA program is the same as for any initiative of importance; the greater the effort in planning and organization, then the lesser the chance for unexpected surprises and an out of control program. When applied to a large project this means that resources are allocated in an efficient manner, and that weeks of PHA meetings, unexpected

findings from consequence analyses or thousands of recommendations requiring resolution are handled in a composed manner with minimal impact to the final estimated cost of the project.

References

1. Eidson, Mark A. and Moderski, Mark M. “Safety Integrity Level in Process Designs”, Process Safety Conference, Mary O’Conner Conference Center, Texas A&M University, March 1998, College Station, Texas

2. Eidson, Mark A. and Moderski, Mark M., "Establishing the Requirements of a HAZOP", American Institute of Chemical Engineers, South Texas Chapter, Process Safety Symposium - February 1993, Houston, Texas

3. Eidson, Mark A., "Strategies in Performing a HAZOP", American Institute of Chemical Engineers, Annual Meeting - 1991, Los Angeles