Identification of Common PHA Shortcomings

Undergraduate Research – Fall 2019

Zachary Piontek

Executive Summary

Process Hazard Analysis is a major part of the American process industry. Any process that is covered by OSHA PSM must have a PHA completed or revalidated every five years. The goal of PHAs are to identify potential hazards based on the design and operating conditions of a plant and then determine if there are adequate safeguards to prevent an incident from occurring. If the proper safeguards are not in place then the PHA will make recommendations to improve the process. PHAs are only effective if they are done properly and identify the potential hazards. The United States Chemical Safety Board investigates major incidents in the process industry, reports on their findings of those incidents, and makes recommendations so similar incidents will not occur. In 80 incidents that the CSB investigated from 1998-2018 they identified PHAs as a root cause in 35 of them. PHAs did not cause the incidents, however they should have identified the conditions and hazards which led to them. Of the 35 incidents only 18 had PHAs that were completed. Further investigation of the 18 incidents showed there were eight common shortcomings within all of the PHAs. Guidelines were developed for each of the shortcomings that can be given to PHA teams to make sure they do not have the same deficiencies in their future PHAs.

Issue

One of the 14 elements of Process Safety Management (PSM) is the Process Hazard Analysis (PHA). A PHA is an organized way to assess all of the hazards around a particular process or piece of equipment. By May of 1997 all plants and process areas that fell under the scope of PSM were required to have a PHA completed. Even though these requirements have been in place for over 22 years there are still incidents where PHAs were completed for the process, but they did not properly identify or address the hazards. This report breaks down the eight most common PHA shortcomings, how they were identified, and guidelines for PHA teams to follow to avoid the shortcomings.

Identification of PHA Shortcomings

This work focused on US incidents that were investigated by the Chemical Safety Board (CSB). In total 80 incidents were included, ranging from 1998-2018[1]. After the CSB completed their investigations they write and publish a final report of the findings from the incident which includes the process description, timeline of events, root causes, and final recommendations. The first step was to develop a data base of the root causes for each incident. These root causes were broken down into nine categories, many corresponded to one of the PSM elements. Earlier work done by Baybutt and Kaszniak broke down the root causes of many of the older incidents, newer data was pulled directly from the CSB [2][3] as part of this study.

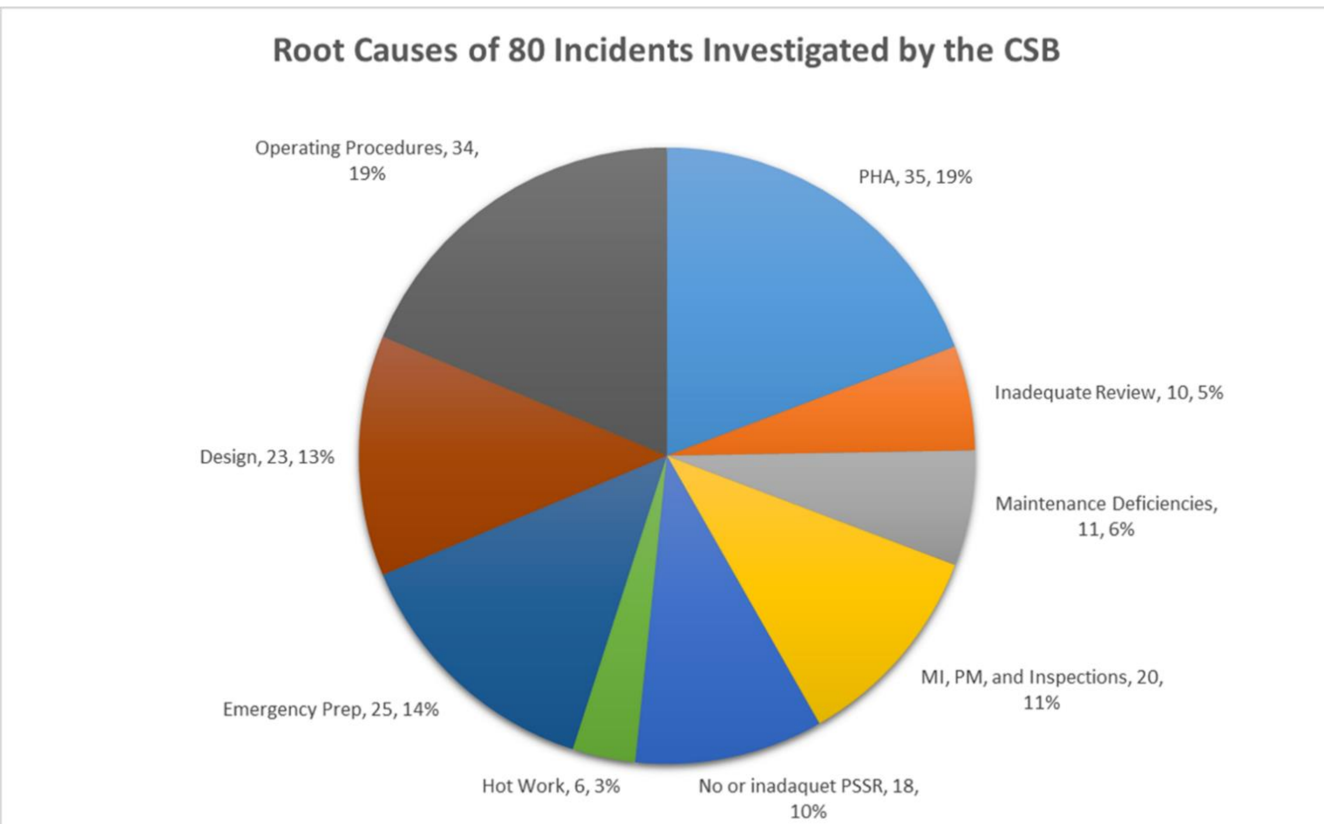

Figure 1. A breakdown of the root causes of 80 incidents investigated by the CSB.

Most incidents had multiple root causes. From Figure 1, 35 incidents that were investigated by the CSB had PHA as at least one of the root causes. However, this also includes all of the incidents where a PHA was never completed. If one had been done it likely would have identified the hazard and made recommendations to prevent the incident. Not conducting a PHA is an issue in its own right, however this report only focuses on PHAs that were completed and how to make them more robust.

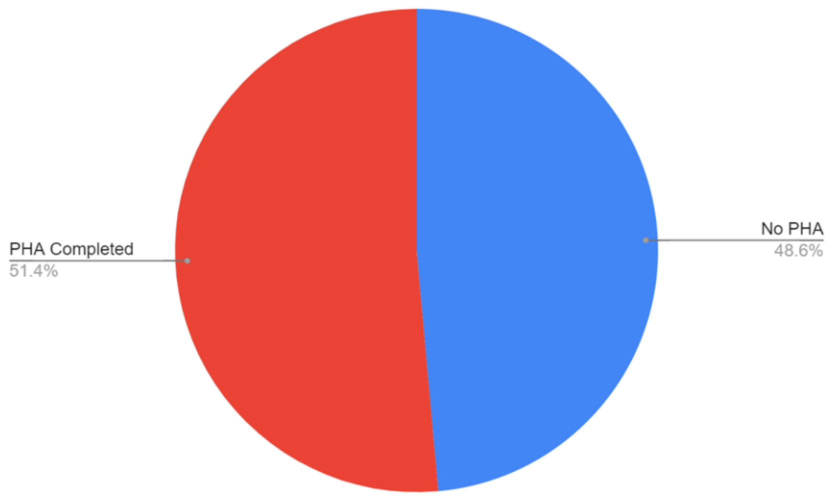

Figure 2. A breakdown of incidents investigated by CSB where PHAs were a root cause.

Of the 35 incidents where a PHA was identified as a root cause only 18 had conducted a PHA. From those 18 incidents the root causes were grouped together into eight different shortcomings.

The Figure 3 Pareto chart below is used to show the breakdown of each shortcoming. The axis on the left shows the frequency, while on the right is the percentage of the total number of recorded instances of the shortcomings. The following paragraphs describe each of the shortcomings and give an example from one of the 18 incidents.

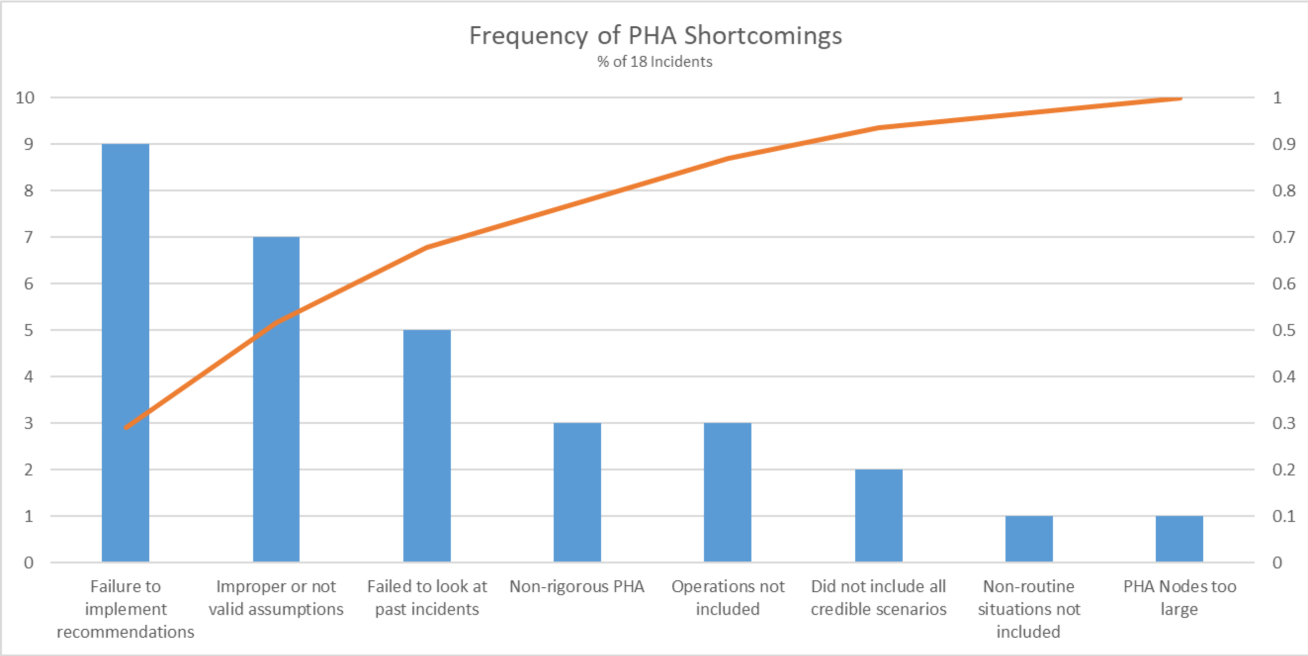

Figure 3. A Pareto chart showing the frequency of the 8 PHA shortcomings.

The most common shortcoming is failure to implement recommendations. This shortcoming is not due to the PHA team as they identified the hazard and made a recommendation to add an additional safeguard to prevent the incident from occurring. This is a failure on the management team to allocate resources to properly implement the recommendation in a timely manner. Prior to the Valero McKee Propane fire a PHA had recommended the plant install remote shut off valves. A line which had been valved off had been mistakenly filled with water and burst during the winter in 2007. The shut off valves had never been installed and all hand operated valves were too close to the fire and could not be shut. Additional lines broke and caused the fire to grow out of control.

Improper or not valid assumptions falls under the PHA team. In this case the team made an assumption about either procedural or technical aspects of the process and did not validate them. Due to the incorrect assumptions the team believed the process could not cause hazardous conditions or there were additional safeguards to prevent the hazards from occurring. Members of the PHA team at the ExxonMobil Torrance Refinery believed that CO would always accompany hydrocarbons in the vapor stream to the ESP so only CO monitors were installed. In February of 2015 hydrocarbons reached the ESP without CO present and caused an explosion.

Failed to include past incidents also falls under the PHA team. All near misses and recordable incidents that occurred in the process area since the last PHA should be reviewed to determine if there are any possible outcomes and how they may effect process hazards. If any major incidents occurred in the same industry they should be included as well. There have been many incidents involving oxidizers in the sterilization industry, however Sterigenics did not review any of those incidents to determine if they could occur in their process. During a maintenance operation EO was left in a sterilization chamber and it ignited in the oxidizer which caused an explosion.

Non-rigorous PHA's are the PHA team leader's responsibility. A HAZOP is often considered one of the most rigorous PHA techniques. HAZOPs are not infallible and consume significant time and resources. However, if done well, they are often very effective at identifying process hazards. During the construction and start-up of the Concept Sciences process in 1999 only a one page what-if analysis was completed. A more rigorous PHA, like a HAZOP, may have identified the operating conditions which lead to the explosion.

A PHA team leader most likely choses their team or has a major voice in the selection, so the failure to include a representative from operations falls on the team leader. Because operators are working with the process every day they have the most hands on knowledge of what will occur in different scenarios. An experienced operator needs to be involved in every meeting during a PHA. The PHA at Sierra Chemical was done by corporate engineers without on site operators. They did not know about specific everyday tasks that some operators performed which added additional hazards to the process. Operators left a partially filled tank of base mix for high explosives overnight, when they restarted the mixer in the morning the mix detonated.

Did not include all credible scenarios falls under the PHA team. Credible scenarios involve specific pieces of equipment. Scenarios include level, temperature, pressure, and flow rate variations that could possibly occur. In the case of BP Amoco Polymers, the PHA team did not evaluate what could occur if the polymer tanks were over-filled. This is what happened in 2001, polymer then blocked emergency vents and thermally detonated due to an uncontrolled reaction.

Non-routine situations fall under the PHA team. These scenarios are often non-standard operating conditions that can be expected to occur, like shutdowns and start-ups, which often present many different hazards than normal operations. A PHA team should always include these non-standard conditions in the analysis. The third incident at Honeywell in 2003 occurred because the PHA team never assessed what could happen after an emergency shutdown. And as a result two operators were exposed to HF when trying to drain a vaporizer.

The PHA team leader is tasked with developing the size of each node for a PHA. If PHA nodes are too large then they will take too long to complete. PHA teams often lose focus if they are taking too long to complete a node and hazards can be missed. The majority of the process where the Valero McKee Fire occurred was done in one PHA node. It was very large and its size is likely why the team missed the dead leg which failed and released propane which ignited.

The following chart combines the frequency of each shortcoming by the responsible group as described above. Roughly half of the deficiencies were due to the PHA Team. A quarter were due to the PHA leader and the remainder due to management's failure to implement the PHA recommendations.

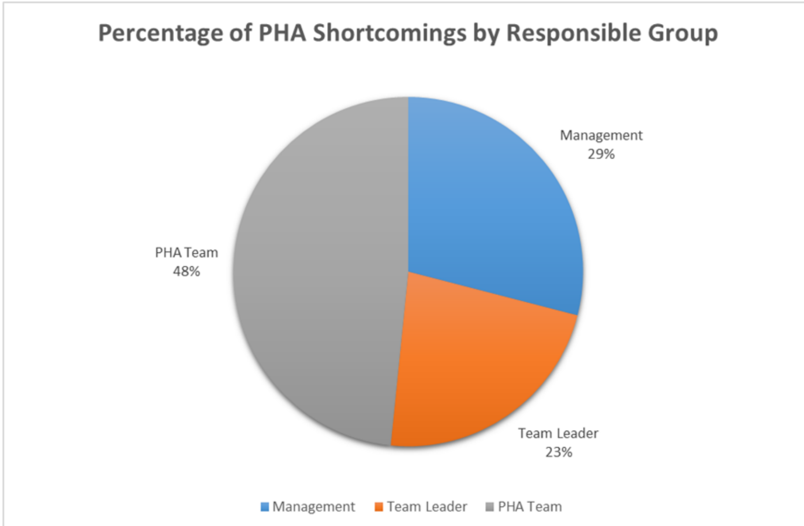

Figure 4. A percentage of 31 shortcomings by each responsible group.

Guidelines to Eliminate PHA Deficiencies

The following points describe techniques that PHA teams should follow to reduce the eight shortcomings that have been identified.

Failure to Implement PHA Recommendations:

- All PHA recommendations must be tracked. This verifies that the recommendation has been made and seen by the area management team. Tracking should continue through implementation and closing of the recommendation [4].
- Recommendations must be completed promptly. This is a general term and will be different for each recommendation. The installation of a new piece of equipment will take much longer than a simple procedural change.
- Once the Final PHA report has been completed all recommendations should be assigned to the appropriate parties. All work that is completed should be documented in the tracking system for auditing purposes.
- It is the management team's responsibility to allocate resources to resolve all recommendations.
- Further guidelines can be found in the CCPS: 'Guidelines for auditing Process Safety Management Systems', 2nd ed.

Improper or not Valid Assumptions:

- Assumptions can be procedural or technical.
- Procedural assumptions- Non-valid procedural assumptions occur when a PHA team assumes a specific operating procedure is followed but operations does the task differently. If a task or procedure is used as a safeguard, meaning it must be followed to prevent a hazard, the PHA team needs to verify with the operations group that they follow the proper written procedures. If operations does not follow the procedure then recommendations need to be made to develop a new procedure, train the operators on the current procedure, or install new safeguards in the process.
- Technical assumptions- Non-valid technical assumptions occur when the PHA team makes assumptions about operating conditions and determines if any hazards are present due to those conditions. These assumptions are often based on process temperature, pressure, flow rates, concentrations, and many other conditions. If any assumptions are made by the PHA team they must be validated. Validation should occur by comparing assumed conditions to design specifications, standard operating procedures, and historic operating conditions.
- It is the PHA team's responsibility to validate any assumptions that they make during the analysis. The team should document how they validated the assumptions for auditing purposes.
- Further guidelines can be found in the CCPS: 'Guidelines for auditing Process Safety Management Systems', 2nd ed.

Failed to look at past incidents:

- All incidents and near misses that occurred since the last PHA must be reviewed to determine any possible outcomes and how they may effect process hazards. If any major incidents occurred elsewhere in the same industry they should be investigated as well.
- The PHA team is responsible for finding all relevant incidents that occurred in the process area and include them in the analysis.
- Further guidelines can be found in the CCPS: 'Guidelines for auditing Process Safety Management Systems', 2nd ed.

Non-Rigorous PHA:

- Simple PHAs often are not very effective for more complex processes as they do not identify all of the possible hazards. If the resources are available a HAZOP should be conducted by a properly trained leader along with the appropriate team members.
- If the resources are not available or the process is simple then a what-if/checklist analysis can be completed.
- The PHA team leader and management are responsible for determining which PHA type will be used. They should be properly trained on how to conduct the chosen method and how to determine which method is needed for the given process.
- Further guidelines can be found in the CCPS: 'Guidelines for auditing Process Safety Management Systems', 2nd ed.

Operations Not Included:

- PHAs are conducted with multidisciplinary teams. An experienced operator needs to be part of every PHA team. Because operators work with the process every day they understand the process better than others. Operators may also have knowledge of different issues in the process or near misses that have not been reported, all of which could present additional hazards.
- The PHA team leader has a major influence on who is a part of the PHA team, it is their responsibility to choose the proper people to participate.
- Further guidelines can be found in the CCPS: 'Guidelines for Auditing Process Safety Management Systems', 2nd ed. and CCPS: 'Guidelines for hazard evaluation procedures', 3rd ed.

Did not include all credible scenarios:

- Credible scenarios are easily covered in a HAZOP by pairing each of the guide words with the process parameters that are present in the study node.
- Each guide word should be covered for each process parameter, if the guide word does not apply then nothing has to be done. By following this methodology credible scenarios will not be missed.
- The PHA team is responsible for discussing all credible scenarios.
- Examples of guide words and further guidelines can be found in the CCPS: 'Guidelines for hazard evaluation procedures', 3rd ed.

Non-routine situations not included:

- Non-routine situations are ones that do not occur during normal operation but can be expected to occur during the lifetime of the plant. Start-ups and shutdowns are examples of non-routine situations.
- These situations must all be considered during a PHA. Since these are outside of normal operating conditions there may be different hazards present and they need to be evaluated to determine if the safeguards that are in place will be effective.
- The PHA team is responsible for discussing all credible scenarios.
- Further guidelines can be found in the CCPS: 'Guidelines for hazard evaluation procedures', 3rd ed.

PHA Nodes too large:

- Each node should take the team an average of 20-30 minutes to complete. This amount of time is not set in stone but is a guideline for PHA team leaders to understand how large a node should be [5].
- As an example, if a vessel has two inlets, two outlets, and a vent there would be six nodes.
- Nodes should be kept to this smaller size so they can be studied more thoroughly.
- The PHA team leader develops all of the nodes that will be studied and should be trained on how to properly choose process nodes.
- Further guidelines can be found in the CCPS: 'Guidelines for hazard evaluation procedures', 3rd ed.

Conclusions and Recommendations

Through this research eight common PHA shortcomings were identified by analyzing the root causes of 80 different incidents that have been investigated by the CSB. Recommendations were developed for each of the shortcomings, if the recommendations are followed the shortcomings will not occur in future PHAs.

Future work in this field will involve including any additional incidents that occur which have PHAs as a root cause. Long term trends in the number of incidents which have PHAs as a root cause can also be tracked. This will show if PHAs have improved overtime.

Work can also be done to develop easier to use training documents based on the previous recommendations. These documents could come in the form of a training pamphlet or PowerPoint presentation. This is a much easier form to distribute to companies so it could be utilized during the PHA itself.

References

[1] “Chemical Safety Board.” *CSB*, https://www.csb.gov/.

[2] Paul Baybutt, Insights into process safety incidents from an analysis of CSB investigations, Journal of Loss Prevention in the Process Industries, Volume 43, 016, Pages 537-548, ISSN 0950-4230, https://doi.org/10.1016/j.jlp.2016.07.002

[3] Kaszniak, M. (2010), Oversights and omissions in process hazard analyses: Lessons learned from CSB investigations. Proc. Safety Prog., 29: 264-269. doi:10.1002/prs.10373

[4] American Institute of Chemical Engineers. Center for Chemical Process Safety. Guidelines for Auditing Process Safety Management Systems (2011). Web.

[5] American Institute of Chemical Engineers. Center for Chemical Process Safety. Guidelines for Hazard Evaluation Procedures (2008). Web.