



## **You've Received Your PHA Report: What Now?**

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Prepared for Presentation at  
American Institute of Chemical Engineers  
2019 Spring Meeting and 15th Global Congress on Process Safety  
New Orleans, LA  
March 31 – April 3, 2019

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**Keywords:** PHA, Draft Report Review, Quality Assurance

### **Abstract**

This paper provides guidance for the review of a Process Hazard Analysis (PHA) draft report. The draft phase of a PHA is the final chance for site personnel to make updates and corrections before the PHA becomes a permanent part of a facility's Process Safety Management (PSM) records. There are several things that can and should be checked before the final report is issued.

Guidelines are provided that can be used by those reviewing a PHA draft. Key quality control points are defined to ensure that minimum requirements are met in various areas including meeting auditable requirements, appropriate documentation depth, consistency for risk ranking, and robust PHA recommendations. With this quality assurance in place, the resulting integration of the PHA into a site's PSM program has positive ripple effects, improving the quality and effectiveness of other PSM elements such as Procedure Development, Process Safety Information, Training and Management of Change.

### **Introduction – Importance of PHA Report Review**

Following the conclusion of a PHA, the results are documented in a PHA report. The first submitted draft of the PHA report is not final and should be reviewed before it is updated to a final version. Even though this draft is not final, it should be as complete and correct as possible. A quality assurance process, such as peer review should be used to identify and correct as many errors or deviations from best practice and procedure requirements as possible before delivering it to the reviewer.

The final stage of verifying a PHA is conducted at the site level, where site management is responsible for ensuring the report is reviewed. If the responsible manager is not familiar with the unit, they may assign this review to qualified personnel. During this final review several aspects of a PHA can and should be checked before the final report is issued. Because the PHA report serves a key function in feeding information to multiple areas, including the recommendation tracking system, this is an important opportunity to ensure information is accurate and clearly documented to provide a complete summary of the hazards and resulting actions necessary by site staff to prevent a future incident.

This review has the potential to be a daunting task since a multi-week PHA can stretch across hundreds of pages. Experienced process safety professionals at a site are generally the preferred personnel to conduct this review, since they are aware of the site's technology, corporate requirements, involved personnel, and are aware of known pitfalls and key areas to check before a PHA report is accepted.

### Industry Perspective

Cargill has been developing a PHA Draft Review process and shared what they found important and what they found challenging in putting a process in place. From their perspective, skipping the review step or not doing it well can result in:

- More time and effort to make corrections later
- Scenarios coming up again in revalidations, and
- Risk of an incident where the intended safeguard was not implemented because it was not clear.

They found it important to define who will perform the review, recognizing that it could be more than one person. Specific recommendations and responsibilities for each reviewer need to be defined. Also key is communicating and gaining acceptance of updates with the PHA team for improved wording or substantive changes.

A Manufacturing Technology Lead or similar technology representative is a key reviewer, specifically to confirm:

- Consistent risk assessment with similar sister plants
- Scenario development and documentation are complete such that it will make sense a few months later
- Consequence probability assignment is appropriate
- Safeguards are credited correctly
- Rules of independence are followed, and
- Solutions are right sized to solve the risk gap

The biggest challenges have been time to do a thorough review and getting key team members back together to review specific scenarios if needed. When there is a new facilitator, a new Manufacturing Technology Lead or a new process, the review is taken to a business unit or central PSM management level for added scrutiny. Deep reviews by business unit or central management

review also contributes to identification of leading practices and opportunities for improvement in the PHA process.

### PHA Draft Review Process

A draft review process can identify issues within a specific PHA. It can also identify systematic problems that occurred during a specific PHA so that they can be corrected in future PHAs at that site. A review of OSHA citations shows that the PHA element is cited routinely during audits and post incident investigations. Industry examples of inadequate hazard analysis range from subtle deficiencies that lead to cost inefficiency to major incidents that grab headlines. Some of the key deficiencies commonly cited include<sup>1-7</sup>:

- Prior incidents not identified during the PHA
- Not considering all modes of operation
- Failure to consider early warning/detection systems
- Failure to ensure that the process hazard analysis addressed possible safety and health effects from failure of engineering and administrative controls.
- Failure to address the all hazards of the process and operating procedures
- PHA did not address the hazards appropriate to the complexity of the process
- Failure to address process hazard analysis deficiencies
- Failure to address the hazards associated with inadvertent manual valve operation.
- Inadequate or missing documentation
- Failing to address the findings and recommendations of the process hazard analysis team
- Failing to ensure that the process hazard analysis is accurate

The following sections provide key areas to review in your draft report to improve the robustness of PHAs.

## **Guidelines for PHA Draft Report Review**

### **1. First Steps**

#### Administrative Details

Upon receiving the PHA draft report the reviewer should ensure that it contains all the required elements. This is comprised of the name of the unit studied, the dates that the study was conducted, as well as team members names, expertise and attendance. The report must include a list of all Process Safety Information (PSI) that was referenced during the PHA including, but not limited to, PFDs, P&IDs, MSDS and procedures. The reviewer should spot check to verify that the most up to date and accurate version of the PSI information was used.

Next, the reviewer should evaluate the Node descriptions. Are they clearly identified both in the description and on the P&IDs? They should also analyze the node descriptions to ascertain if there is a clear process description for the node, one that includes the design conditions and safe

operating limits. This is important to later determine if the appropriate scenarios were reviewed within the node. For example; if temperature is a concern, then the safe operating limit should be identified. This helps the team understand and identify what the actual hazard is, or can be, when the temperature goes beyond the safe operating limits, such as exceeding metallurgical limits of equipment leading to failure of the equipment.

In addition to the node description, the reviewer should evaluate if it is clear what P&ID/PDF drawings were used within the node (normally with the nodes of study delineated by color), as well as the equipment covered within each node.

### Missing PSM Data

The PHA worksheets should be spot checked to reveal inadequacies in documentation. In a situation where such documentation is unavailable, a recommendation that deficient PSM information will be complied and brought up to date should be made and the analysis should be continued as well as can be managed with the available data.

All referenced documents must be up to date and accurate. P&IDs should have a specific name or reference number and a date when was last revised. Equipment and instruments referenced should be called out by their unique ID numbers. PSVs used as safeguards should reference the relief device's set point, the MAWP of the vessel protected, and if the PSV has been sized for the scenario it is being used for.

## **2. Auditable Requirements**

In addition to the above items; reviewing administrative information, appropriateness of depth, consistent scenario development, severity and likelihood ranking, as well as recommendations, there are several other auditable requirements that one must consider.

### Causes

The reviewer should spot check to verify that Causes (or what-if questions) address initiating causes/events rather than consequences. Additionally, they should verify that the causes address equipment failure, failure of administrative controls, and human error.

### Safeguards

One must review safeguards used to determine if they are appropriate for the scenario as written. Again, this can be done, initially, by spot checking. For example, if the scenario includes a valve malfunctioning closed ultimately leading to overpressure of a vessel, but the safeguard is a high-level alarm, is it clear how a high-level alarm will help prevent the scenario? If not, then the safeguard should not be considered as a valid safeguard and should be flagged for review. The reviewer should also do a spot check of safety instrumented functions, if appropriate.

Additional concerns around safeguards would include whether there is enough information to appropriately identify it for inclusion in maintenance programs or procedures (i.e., is there a tag

number or other way to clearly identify it). Also, if there are corporate (or site) requirements about how a safeguard is written for inclusion in a maintenance or ‘IPL management like’ program afterward, have the safeguards been written to meet those requirements?

### Industry and Corporate Standards

Other areas for evaluation would include compliance with the company’s written policy on conducting a PHA. There are often differences in what items may be considered safeguards (i.e., preventative vs. mitigative), specific language preferred in a scenario, (i.e. personnel injury vs. fatality), and guidance on how to risk rank particular types of scenarios (i.e. overpressure). This is particularly important when the facilitator is a 3<sup>rd</sup> party facilitator that works with multiple clients. The reviewer should verify that the report contains a description of the risk matrix that was utilized during the PHA.

The reviewer should also consider if there are industry standards for the reviewed process. They can verify that those standards referenced and utilized during the PHA along with appropriate (or recommended) safeguards (i.e. Chlorine).

### Additional Study Information

Reviews of the Human Factors and Facility Siting Checklists, Hazardous Incidents/Near Misses and MOCs since last PHA must be reviewed as part of the PHA.

Once the reviewer has confirmed that these checklists and reviews have been performed, those sections may also be spot checked for appropriate depth. Do the checklist responses include sufficient detail such that the full impact is understood or is the entire checklist a string of “yes” answers? If there has been a serious incident, near miss or MOC, is it referenced in a specific PHA scenario? Software “search/find” functions can help with this type of checking.

## **3. Appropriate Scenario Development**

There are several things the reviewer(s) should consider when reviewing the scenarios throughout the PHA. As previously discussed, this can be done initially through spot-checking, then, if determined to be necessary, a more thorough review can be conducted.

The reviewer must consider if the consequences clearly illustrate the hazard and how it impacts employees and the public.

The reviewer(s) should consider if the consequences are appropriate for the process being reviewed and if the worst credible case is considered. For example, if the process is light hydrocarbons, highly flammable, but the consequences do not include fire, then a deeper dive into the PHA may be necessary.

Additionally, the reviewer should look to see if safeguards were considered in the development of the consequence. In other words, did the scenario stop at a PSV lifting? Or did the team take it all the way to vessel failure then call out the PSV as a safeguard.

Next thing to review is whether or not upstream and downstream consequences were both considered. Too often, a team will be concerned about a scenario in one direction and miss potential hazards in the other.

#### **4. Consistency for PHA Scenario Development**

PHA consistency challenges and techniques is an on-going challenge for sites and inconsistency between PHA's can occur for a variety of reasons. In some instances, as PHA sessions progress, the understanding of the PHA process improves leading to changes in how scenarios are identified and developed. This then can lead to inconsistencies between the beginning and the end of the PHA. Occasionally, changes in PHA team personnel can lead to different conclusions. In instances such as these, different conclusions can lead to inconsistent risk ranking if not managed and corrected for consistency. A reviewer of a draft PHA should look for the following key areas.

##### Consistency for Overall Scenario Development

Achieving overall PHA scenario consistency within a company and even between PHAs conducted at a single site is an ongoing challenge. There exists various methods to achieve consistency and the PHA team and the draft PHA reviewer are key players in this process. Consistency should be applied in all aspects of a PHA, including scenario selection, consequence development, risk ranking, safeguard selection, and even gap closure/recommendation development. Various techniques used to assure consistency include:

- Application of generic/template PHA scenarios
- Alignment with industry codes/standards for applied safeguards
- Inclusion of corporate subject matter experts to assure alignment.
- Use of existing site PHAs to cross-check appropriate scenario development

The use of templates is a popular option for companies that have similar technology installations at multiple sites. Alignment with industry codes is useful for well-understood hazards in industries that have applicable institutions (i.e. The Chlorine Institute).

A PHA draft review may also have access to previous PHAs performed on similar units at other sites, corporate subject matter experts and other PHAs performed on the same site which include similar scenarios. While it is possible for potential hazardous scenarios may deviate from each other in consequence and frequency, even for similar units, these resources may be used to drive general consistency between PHAs.

##### Consistent Ranking for Severity

Scenarios with a similar outcome should have consistent results. For example, a PHA consequence that ends with "...loss of containment of hexane leading to possible fire and personnel injury" should be treated consistently throughout a PHA. If a subsequent scenario includes a consequence with "...loss of containment of hexane leading to possible fire, explosion and fatality" and different severity ranking without sufficient context, the PHA study may be seen as inconsistent. Variations

may exist due to potential release quantities and locations. In these cases, the PHA should provide sufficient details so that differences in severity ranking are clear.

#### Consistent Ranking for Likelihood

In a HAZOP, as opposed to a LOPA, where likelihood is qualitative in nature, the likelihood of a scenario is subjective and dependent on the experiences of the PHA team. Due to this, likelihood rankings in a HAZOP are inherently prone to inconsistency if care is not applied. This risk is especially relevant in cases where safeguards and surrounding conditions are situationally dependent. Valid discrepancy may occur when items such as occupancy, release orientation, or complexity associated with safeguard variable. For this reason, PHA Draft reviewers should spot check the likelihood of similar scenarios to ensure that the likelihood is either reasonably constant or there is sufficient explanation to justify the difference.

### **5. Appropriate Level of Depth**

It is important to determine that an appropriate level of detail was used is to ensure that the PHA can be understood by someone who was not a member of the PHA. Without an appropriate level of depth, scenarios that were completely understood when the PHA was being performed can be baffling to those who helped develop them only a few years later.

Some errors may be readily apparent and other will be subtle errors. Spot checking is the most practical method to find subtle errors that may be systemic to how the study was facilitated. It is normally impractical to completely review an entire multi-week PHA line-by-line but if a more rigorous method is required to reveal systematic subtle errors, a single node or section of a node made be reviewed line-by-line.

#### Risk Gaps Not Addressed

One of the most glaring depth of documentation errors which may be discovered when reviewing a PHA is a risk gap not addressed by a recommendation. Spot checking is sufficient for most other level of depth concerns but not unclosed risk gaps. Most PHA software offers functions to quickly check for unclosed gaps but even if the PHA was performed using a spreadsheet program, it is necessary to completely review that all gaps have been adequately addressed. In this case the reviewer must scroll through all PHA worksheets looking for unclosed gaps. A similar error is a cause/consequence pair where the risk ranking has not been completed (i.e., a scenario where either the likelihood, severity or both is not recorded).

It is also possible to have “orphan recommendations” not associated with any cause/consequence pair or checklist item. While there may be cases where the team wanted to make a general recommendation, orphan recommendations are normally artifacts of adding a recommendation to a scenario and later removing it without deleting it from the “master” recommendation list. A reviewer should confirm with the report author whether any orphan recommendations found are intentional or should be deleted.



### Missing Hazards

The reviewer of a PHA draft report should check that all obvious major hazardous scenarios which exist in the unit have been caught by the PHA team. This can be more difficult than catching other errors in documentation because there is no existing scenario to check for deficiencies. The reviewer should be familiar with all the known major hazards of the unit and check that each has been covered by the PHA. Ideally, the reviewer for this part is an “expert” in the process. However, a list of these scenarios, either compiled by subject matter experts or from industry experience of previous incidents in similar units, could be compiled and checked off as they are located in the PHA worksheets. This is more critical if the PHA team was composed of less qualified personnel. Example: A unit has a batch reactor with a potential to run away resulting in overpressure and loss of containment – the reviewer should check the node containing the reactor to make sure that this scenario has been covered.

## **6. Robust PHA Recommendations**

Upon completion of a PHA, recommendations are vetted for acceptance by the site, assigned to responsible parties, and tracked to completion. Most sites now use electronic tracking systems which means they no longer have the context of the full PHA worksheet and by necessity must provide complete information to communicate the full nature of the hazard and the action(s) to be completed.

A robust PHA recommendation is SMART:

- **S**pecific
  - Recommendations should be clear and complete. It simplifies the review and closure of recommendations immensely if their wording is such that each recommendation can stand alone. A Recommendation that “stands alone” allows for anyone reading it to have the complete story on why there is a concern, where the concern is and what the intention of the team was. The recommendation should include equipment numbers, lines numbers and/or drawings where relevant.
- **M**asurable, therefore able to close
  - Recommendations must be written so that they are accomplishable and have a clear point of closure.
- **A**ccountable
  - During the closeout meeting all recommendations must be assigned to a responsible party. This may occur after the PHA meeting and so, not present in the draft report.
- **R**elevant
  - Recommendations should have a direct impact on the risk ranking of the scenario for which they are made.
- **T**ime Limited

- Recommendations are expected to be completed in a timely manner. The language used in the recommendation should reflect this expectation. Individual companies often have specific rules around when recommendations should be closed based on ease of closure and risk ranking. If a recommendation requires a shutdown to be implemented or a significant engineering study to be performed, a recommendation may be split into multiple recommendations – some of which may be performed more immediately.

The following recommendations were cited in an OSHA report<sup>7</sup> and provide and provide a good example of weak recommendations which are not explicit in how they are meant to close a specific risk gap. If the reviewer were to encounter similar recommendations, they should consider how those recommendations could be revised to be **SMART**.

*“Consider installing a level gauge on the pentane tank (vessel E1) to monitor tank level”*

*“Consider locking valves in pentane piping system in desired positions”*

*“Consider providing a safeguard to alert operators when the ventilation system above the laminator fails”*

*“Consider implementing a site mechanical integrity program to include tanks, piping, valves, and components”*

Context for why these recommendations were not completed in time is not available, initial inspection reveals the following:

- They don't provide context or basis for why a recommendation is required. Rather, the reader is left to assume the surrounding PHA context
- The actions required are ambiguous as it relates to closing an identified risk gap

To avoid weak recommendations, the PHA draft reviewer should inspect that a recommendation contains sufficient information to stand alone and is clear as to how its closure will address an identified risk. Recommendations associated with cause/consequence pairs should effectively prevent or mitigate the consequence of every scenario they are referenced in. Just because a recommendation addresses the consequence of a cause doesn't mean it is effective at preventing the same consequence from a different cause.

#### Is the Recommendation stand-alone?

PHA Draft reviewers should ensure that PHA recommendations are written with sufficient detail such that they can be completed accurately and confidently with the information provided in the recommendation.

Generally, a PHA recommendation is ultimately exported into an action tracking database that contains three key pieces of information: The PHA Recommendation, the person responsible for closing it, and a due date. The full PHA report for surrounding scenario context is generally not attached, so it's critical that a recommendation include sufficient detail for its audience: the personnel assigned to close the recommendation. Critical information to include is:

- The action that needs to be achieved (such as “provide effective overpressure protection on Vessel XXX for the liquid overfill scenario...”)
- The risk that exists, and how the desired recommendation would mitigate the risk
- Any flexibility that may exist to the recommendation closure task.

Would completion of the recommendation close the identified risk gap?

PHA Draft reviewers should ensure that closure of a given PHA recommendation would unambiguously lead to closure of an identified risk tolerance deficiency. Earlier, it was discussed how every unclosed risk gap should be addressed by a PHA recommendation. All recommendations must also be reviewed to ensure that they unambiguously close the risk gap of all scenarios they are utilized in.

Example: A recommendation for upsizing a PRV currently in service is used in multiple blocked vessel outlet scenarios. Some of these scenarios result in vapor overpressure and some result in liquid overpressure. The reviewer must check that the recommendation specifies a PRV appropriate for both liquid and vapor scenarios and that a liquid valve is feasible for this application in order to take credit for the recommendation.

Recommendations that do not address a gap between an identified risk exposure compared to a risk tolerance threshold represent pitfalls to a PHA program and erode confidence in the PHA process. This can occur in instances where well-intentioned operability improvement opportunities are not separated from risk-driven requirements. In other cases, use of the word “consider” as a prefix to a recommendation sometimes can be interpreted as if the recommendation merely needs to be subjectively considered as a useful improvement for sufficient closure. This is rarely the desired intention of the PHA evaluation conclusion.

To re-iterate a point made above, any flexibility that may exist to the recommendation closure task should be clearly delineated. For example, the example recommendation above of “Consider installing a level gauge on the pentane tank (vessel E1) to monitor tank level” could possibly be improved to the following:

*“Provide a preventative safeguard to protect against overfill of the E1 pentane tank. Possible measures to consider:*

- *Install a level gauge, independent of the existing E1 level control loop, with a high alarm*
- *Install a high level trip on E1 to close inlet flow in the event of a high high level*

*Basis: In the event that the existing level control gauge in E1 malfunctions, there is the potential to overfill E1 pentane tank, leading to a spill of pentane to the E1 diked area with possible flammable vapor cloud formation, fire/explosion, and personnel injury/fatality.”*

The above recommendation example is sufficiently detailed so as to not require reference to the original PHA documentation, and gives the personnel assigned an action a clear closure plan. Conversely, this recommendation is not excessively rigid and is not overly prescriptive on a specific design solution.

## **Conclusions**

Upon completion of the review(s), there may be cause to update the PHA with corrections and/or changes. Depending on the level of change required, there may a number of ways that this can be completed. If the changes are minor in nature, in other words, they do not effect a change in how the scenario is described, this may be done without team involvement. However, if there are questions about the legitimacy of a scenario, the effectiveness of a safeguard or the validity of a ranking, the team, or its equivalent, must be convened to revisit the PHA.

The appendix of this paper includes a simple Quality Assurance checklist to assist reviewers in completing site reviews of PHAs. It could be augmented with specific corporate standards to personalize it to your company.

Having an effective Quality Assurance process in place to review a PHA draft report is particularly beneficial to a site. There are ripple effects to the PHA process and to other aspects of PSM. It is one way to improve overall PHA robustness which in turn strengthens the site personnel's understanding of hazards and communication of the hazards to better manage them. Better management of hazards leads to fewer incidents which thereby reduces risk for both site personnel and the surrounding community.

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**Appendix A:**  
**PHA Draft Review Checklist**

# Quality Assurance

PHA Questions	
Question	Comment/Finding
1. Are the PHA team members identified?	
2. PHA Facilitator name and company	
3. Is complete team member information provided (title, department, experience, expertise)?	
4. Are sessions listed?	
5. Is attendance tracked?	
6. Is the study scope, purpose and methodology described?	
7. Are drawings listed, including rev number and rev date?	
8. Are study nodes clearly defined, both in tabular form and on the P&IDs?	
9. Is the design intent of each node clearly defined and understandable? [Note: Are design & operating limits defined (i.e. MAWP at xF)]	
10. Do Causes (or what-if questions) generally address initiating causes/events rather than consequences?	
11. Do the what-if questions or HAZOP causes generally address both equipment failure and human error?	
12. Spot check P&IDs to ensure that obvious what-if questions or HAZOP causes are being identified and documented. (For example, check to make sure that all control valves fail open and close, pumps stop or do not start, etc.).	
13. Spot check to ensure that consequences are being developed without safeguards.	
14. Spot check to ensure that consequences are being developed in what appears to be chronological order.	
15. Have upstream and downstream consequences been considered and documented?	
16. Are the Consequences fully and comprehensively developed to "worst plausible" consequence?	
17. Are consequences documented consistently and appropriately for the process under study?	
18. Do the consequences described in the worksheets illustrate the hazard(s) and how employees and the public may be affected by the scenario?	
19. Do the recommendations appear to address the identified cause/consequence scenarios?	
20. Are Recommendations fully developed, clear and concise such that they remain comprehensible when extracted from the worksheets?	
21. Is there a description of the risk-ranking matrix, and how it is used as a tool to qualitatively evaluate a range of safety and health effects on employees and the public?	
22. Compare Risk Priority Ratings of similar scenarios to determine if risk factors are applied consistently.	
23. Are Severity and Likelihood assignments consistent with the Consequence and process under study?	
24. Spot check safeguards versus initiating cause to ensure that common-mode failure is considered.	
25. Are recommendations SMART (specific, measurable, accountable, relevant, time limited)?	