The Uses and Users of PHA/HAZOP Results

William Bridges, Jeff Thomas, Paul Casarez
Process Improvement Institute, Inc. (PII)
1321 Waterside Lane
Knoxville, TN 37922
Phone: (865) 675-3458
Fax: (865) 622-6800
e-mail: wbridges@piii.com
e-mail: jthomas@piii.com

©Copyright 2018, all rights reserved, Process Improvement Institute, Inc.

Prepared for Presentation at
American Institute of Chemical Engineers
2018 Spring Meeting and 14th Global Congress on Process Safety
Orlando, Florida
April 22 – 25, 2018

AIChE shall not be responsible for statements or opinions contained
in papers or printed in its publications

The Uses and Users of PHA/HAZOP Results

William Bridges, Jeff Thomas, Paul Casarez
Process Improvement Institute, Inc. (PII)
1321 Waterside Lane
Knoxville, TN 37922
Phone: (865) 675-3458
Fax: (865) 622-6800
e-mail: wbridges@piii.com
e-mail: jthomas@piii.com

Keywords: PHA, HAZOP, LOPA, SIS, Mechanical Integrity, Fire risk scenarios, safety critical equipment, operating procedures, safeguards, independent protection layers, IPLs, trouble shooting guides

Abstract

Process Hazard Analyses (PHAs) performed using methods such as HAZOP and What-if that are augmented by checklists, have become well establish as a core for understanding risk in a hazardous chemical process and other processes. Some see the PHA results as an end to them itself. But, the real benefit of performing a PHA lies in its usefulness within all aspects of controlling risk day-to-day.

This paper explains the different uses of the PHA results and who uses the PHA results. It charts the path for extracts of the PHA results (including the formal PHA report) to the rest of process safety implementation and process safety control. The many uses, intended from the start of hazard evaluations in the 1960s or discovered years later, will surprise many in the industry. Knowing the uses will help you implement process safety thoroughly and more efficiently, and this knowledge of the uses will change the amount of effort you put into the documentation of the PHA results.

.

Background

The increasingly complex and technical demands of process safety management (PSM) have placed a large demand on existing resources across the process industries. Success requires recognition of the synergies between process safety activities. Process hazard analyses (PHAs) are the "heart" of process safety because it identifies all process safety accident scenarios for the process and documents these scenarios. If the documentation in the PHA is clear enough and thorough enough, then it can provide critical input to the rest of the process safety elements.

1. The PHA report

Many consider the PHA report to be “The PHA”. Actually, the brainstorming meeting with the team is much more important (100 times more important) to the company than the report itself because the brainstorming meeting is where the team uncovers accident scenarios and determines if the risk is tolerable. If the scenarios are not found, then organization will not know if it has sufficient safeguards against these scenarios.

The report is a record of the meeting and the resulting recommendations for lowering the risk. It is a short summary of the team discussions (10,000 words per scenario discussion that are condensed to 100-200 words per scenario).

Purpose and benefits of a thorough report

The report serves several key functions listed below:

- Provides a record of the meeting discussion, including a list of summarized accident scenarios discussed during the meeting
- Lists the recommendations for lowering the risk to tolerable levels (each of these recommendations must be resolved)
- Is one of the basis of judging the quality of the PHA meetings for internal and external compliance evaluations
- Is a valuable input to the other process safety activities and systems 🡐 **Most of the paper will focus on this as the main purpose of the PHA report**

Figure 1 illustrates the relationship of PHAs to the rest of process safety

Writing Effective Recommendations

One key component of every PHA report, including executive summary reports, is the recommendation section. Recommendations help management decide how to lower the risk to tolerable levels. Recommendations many times feed directly into the engineering of the process, such as by specifying the limit scenario for sizing a relief valve or by judging when additional independent protection layers (IPLs) are needed.

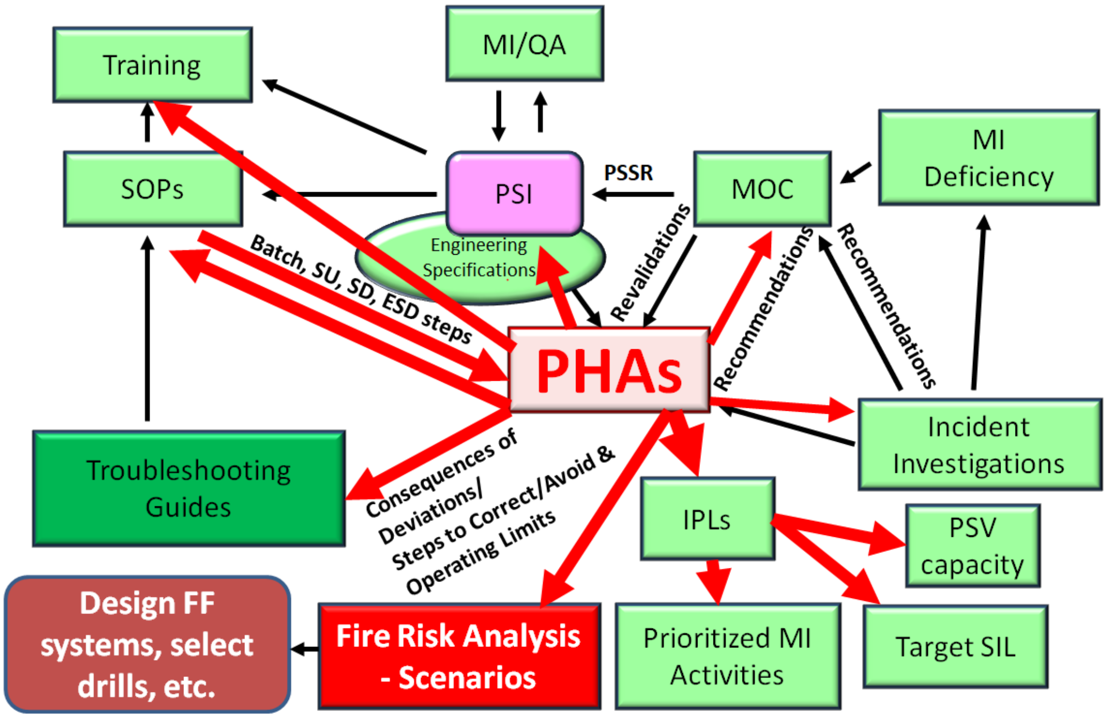

Figure 1: The Relationship of PHAs to the Rest of Process Safety Activities and Systems
© Process Improvement Institute, Inc. (2013-2018)

PII team leaders and scribes ONLY develop recommendations to bring the risk of a scenario to a tolerable level, so our PHA teams believe that all of their recommendations are necessary to achieve tolerable risk. However, not all recommendations will be accepted by management; they have the right and responsibility to reject recommendations that will not lower risk effectively, or to reject recommendations if the risk is already low enough without the recommended improvement. Therefore, it is best to write the recommendation in a style that allows management flexibility in deciding what will be implemented.

The best style for writing a recommendation is shown below. Always begin with a general statement of the concern so that management can address it in the best way possible. Then, provide management with a listing of specific suggestions (if possible)

Recommendation Nº: Consider… (state general concern). Otherwise… (state the consequence that could occur). The team considered… (list the existing safeguards). Specific suggestions by the PHA team include ….

The *Otherwise* sentence is optional. If the existing safeguards are not listed, then management may think the team missed these safeguards and may judge that the exiting risk is tolerable. Specific suggestions from the team are listed without rating. (Example: *"Provide an independent high level switch to shut down the feed pump.")*

Report Content

In order to decide how to structure the report you must first decide what purpose the report will serve. If the report is strictly for compliance then a very thin report will typically suffice. If the report will be used to aid in the development of trouble-shooting guides or to support other process safety activities and management systems, then the clarity and quality of the report are very critical.

Introduction/Scope

This section should provide:

- The purpose of the PHA (e..g, to satisfy requirements of OSHA PSM, company standard XXX,)
- Whether the PHA is an initial PHA, a revalidation, or a re-do of a previous PHA
- What phase of the life cycle of the process (e.g., detailed design, pre-commission, post-commission, ongoing operations)
- The scope of the process(es) covered (including any procedures reviewed as part of PHA of non-routine modes of operation)
- Date(s) the PHA was conducted
- Name and position/title of team members present during the meeting(s)
- Any special circumstances affecting the scope, etc.

Method Used

This section should describe the method (e.g., HAZOP, What-if, FMEA) that was used to complete the PHA and a brief description of the method itself.

Executive Summary

This section should provide:

- Summary of recommendations perhaps with a table breaking down the type and number of recommendations if safety, environmental, and operability issues were considered.

PHA Tables

This section should include final copies of each of the completed PHA analysis tables (in the best format for each chosen method, HAZOP, What-if, 2 Guideword HAZOP of steps, etc.)

Appendices

Any documents that were used to support the PHA should be referenced. These may include:

- Previous incidents
- Checklist tables
- MOCs
- Drawings, P&IDs, etc. (ensure the same revisions used during the meeting are attached/referenced in the appendix)
- List of procedures (with revision number) used

To produce a report of good quality and excellent level of detail takes about the same amount of time after the PHA meeting as the meeting itself takes. But typically, only the leader and scribe write the report. The rest of the team members dedicate their time to providing input during the meetings and gathering data to close open items. The following table shows the typical responsibilities of the leader and scribe in preparing a high quality PHA report.

Table 1. Leader/Scribe report responsibilities

Scribe	Leader

Finish tables
• convert rough notes to words
• move info to the correct location in tables
• try to ensure consistency of words, links, etc.
	Finish recommendations
	• convert notes to words
	• add phrases to explain "why"
	• embellish if necessary
	• issue Preliminary Report of Recommendations
	
	Draft the rest of the report
	• introduction/scope
	• method used
	• executive summary
	• appendices
	  ○ previous incidents
	  ○ checklist tables
	  ○ list of documents
	  ○ etc.

Review leader's work	Review scribe's work
	Compile/issue Full PHA Report

© Process Improvement Institute, Inc. (2013-2018)

Steps for completing the report

- Prepare summary of recommendations and have the team and management review
- Management can already assign responsibility and estimate completion schedule, or assign completion date for each recommendation (optional at this point)
- Draft report
    - Formalize logistical notes (i.e., attendance records, list of drawings, list of documents)
    - Develop detailed recommendations
    - Develop detailed hazard review notes/data (HAZOP or FMEA tables)
- Have draft report reviewed (distribute for employee review – optional at this time)
- Make corrections as necessary
- Finalize PHA report and obtain signoffs, distribute, and/or file official copies
- Distribute PHA report to affected employees for comment/review (if not done at draft stage). Obtain written proof of employee review.

2. Uses and Users of PHA Results (*with EXAMPLES*)

As stated earlier and as illustrated in Figure 1, there are many users of the results of the PHA. Table 2 is a partial listing of the users and uses, in relatively order of importance (the ordering is based on the combined experience of PII, who have helped more than 50 organizations implement process safety and who have led and documented thousands of PHAs of entire units or plants.

Table 2. The Primary Users and Uses of PHA/HAZOP Results

Rank	User	Use
1	Process engineering, Project Engineering, Designers, Instrumentation, EPC, etc.	▫ Identifying the Independent Protection Layers (IPLs) needed (including SIFs) ▫ Identifying the target SIL (PHA = SIL Study) ▫ Finding the limiting case for PSV sizing ▫ Vent, duct, flare, and dike sizing
2	Mechanical integrity - inspection, test, PM plans & schedules & procedures	▫ List of Initiating Events (IEs) and IPLs (all safety critical equipment) ▫ Information on component reliability or availability needed to reach the target risk reduction factor
3	Operations department, including operating procedures and focusing of training and drills	▫ List of Human IEs and procedure and human factors aspects to focus on ▫ List of Human IPLs that will need trouble-shooting guides and annual drills per operator ▫ Beginning portions of Trouble-shooting Guides (the procedures for responding to critical deviations)
4	Fire protection design and fire-fighting plans	Identifying fire scenarios for ▫ Fire-fighting system design; fire water capacity ▫ Fire-fighting scenarios for active drills ▫ Gas/fire detection requirements
5	Management of Change	▫ PHA describes current risk control envelope ▫ PHA is one basis to identify and document changes
6	PHA Revalidation	▫ Each PHA Revalidation builds upon the prior PHA
7	Incident Investigations	▫ PHAs identify possible accident scenarios to check (Did the initiating predicted occur? Did one or more IPLs fail?)
8	Auditors and quality assurance checks	▫ Did the PHA address the requirements ▫ Did the organization user results per listing above

© ***Process Improvement Institute, Inc. (2013-2018)***

A small fraction of PHA/HAZOP studies and related PHA/HAZOP reports meet the needs of all of the users listed above. Some people may say that is it possible for the PHA and report to meet all of the needs. But the authors and other experienced PHA

Leaders have been providing PHAs and reports that meet these needs for decades.

An organization that ensures their PHAs meet the needs of these users is one that understands how to control process safety. PII tests for this linkage during PSM audits. One way we do this is to extract about a dozen causes and a dozen safeguards (those that either are or appear to be IPLs) and then we check to see if these are in the list of Safety Critical Elements (SCE) and check to make sure that site is inspecting, testing, and maintaining each of these components. If not, then the site has a gap or perhaps the site fails to understand the relationship between the PHA and the rest of process safety.

The next few sections are examples of how to use the PHA to provide the information stated in Table 2 or how this information may be extracted from the PHA results and used in controlling risk at the site.

EXAMPLE 2-A: Determination of IPLs and SIFs during PHA/HAZOP as feed into Engineering/Design and into Mechanical Integrity[1]

One of most valuable outcomes of starting LOPA in the mid-1990s was the crystallization of the qualitative definition of an IPL. If the PHA/HAZOP leader was competent in the definition of an IPL, we found that IPLs could be just as easily identified in a PHA/HAZOP as in a LOPA. This was a significant outcome, since IPLs (along with the Initiating Events, IEs) are what we need to focus on to maintain tolerable risk for each scenario. In other words, we can focus our reliability/maintenance and operational efforts on IPLs to conserve resources while maximizing control of risk. SIFs are just one type of IPL and we found the same was true for identifying SIFs and setting their SILs. Also, as mentioned earlier, ANSI/ISA 84.00.01-2004 allows SIL to be set qualitatively.[2] *COMPETENCY*, as always, is Critical; the path to competency includes learning the rules for using this approach, so the rules are explained first in this paper.

Intentionally Achieving COMPETENCY in the Qualitative Definition of an IPL and SIF

First, the PHA Leader must become fully competent in the rules and descriptions of SIFs (of various SILs) and other IPLs. This is discussed in details in other papers by PII. Many PHA leaders are not competent in even how to conduct a PHA; in fact, about 90% of the PHAs reports that we have reviewed around the world are woefully deficient, especially with respect to finding scenarios during startup, shutdown, and online maintenance. Per the authors' experience, the path to the necessary competency is typically:

- Already be an experienced PHA leader, trained in all PHA methods, and capable of applying these methods to all modes of operation and capable to make sound qualitative judgments, along with the PHA team members, on when the number and type of IPLs is sufficent to control the risk. Achieving full competency as a PHA leader may require some remedial training on how to lead PHAs of startup, shutdown, and online modes of operation; or remedial training on how to uncover and discuss all plausible damage mechanisms.
- Attend a LOPA course to learn the basics of IPLs (including SIFs) as described in the previous sections. The key on qualitative risk judgment is to know when there are enough IPLs for the accident scenario under review.
- Get coaching (by someone already competent) during actual PHAs to learn how to help a team make judgments if safeguards meet the definition of an IPL (or SIF) or not and also on if there are enough IPls for the accident scenario (risk judgment). We know from thousands of PHAs over the past decades that a PHA team can make excellent risk judgments > 95% of the time, which also means that the IPLs and SIFs can be clearly identified > 95% of the time.
- Achieve competency, in the opinion of the competent coach on the skills above.
- In addition to the PHA team leader competency, the PHA team has enough understanding of either qualitatively risk judgment or LOPA risk judgment– just in time training by the PHA leader (we tend to accomplish this training across the first 5-10 accident scenarios we discuss)

Using the Qualitative Definition of an IPL and SIF

The competent PHA/HAZOP leader can now guide the PHA/HAZOP team through the following thought processes:

- IF (1) the safeguard meets the definition of an IPL and (2) if the team believes (qualitatively) this safeguard is critical to control risk to tolerable level (qualitatively),then add the designator " – IPL" to the right of the safeguard text. If the safeguard is not going to be labeled an IPL, then it can be run to failure; unless the safeguard supports an IPL, such as when a sight glass supports an LAH used in an Human Response IPL, in which case the sight glass will have some PM (such a periodic cleaning of the sight glass).

- IF an instrument is already in the ESD system or SIS and qualitatively meets the archetecture of an SIL 1, or SIL 2, or SIL 3, and also meets the definitions/rules for an IPL, then add the "- SIL-1" (or SIL-2, or SIL-3) to the right of the text.

Table 3: Excerpts from Petrochemical Process PHA at SS-TPC[3]

No.: 2 XXXX storage spheres xxx-T-XX A/B/C/D/E/F/G/H/I/J/K/L (1 of 12)					
#	**Dev**	**Causes**	**Consequences**	**Safeguards**	**Recommendations**
2.1	High level	Too much flow to one sphere from XX Plant (through their pump; about 40 bar MDH)	High pressure (see 2.5)	High level SIF with level sensors voted 2oo2, to close inlet valve **- SIL 1** Overflow thru pressure equalization line to other spheres (through normally open [NO] valve) **- IPL**	
		Misdirected flow - Liquid from xxx Plant(s) to spheres (see 1.4)	Overpressure of sphere not credible from high level, for normal operating pressure of the column (which is 1.75 MPa), unless all spheres are liquid filled and then thermal expansion of the liquid could overpressure the spheres	High level SIF with level sensors voted 2oo2, to close inlet valve **- SIL 1** Overflow thru pressure equalization line to other spheres (through normally open [NO] valve) **- IPL** Spheres rated for 1.95MPa (19.5 Bar, approx) and the highest pressure possible from the column feeding the spheres is 1.75 MPa Level indication and high level alarm in DCS, used by operators to manually select which tank to fill - **Human Response IPL**	
			Overflow into the equalization line will interfere with withdrawal from the column, but this is an operational upset only		
			Excessive pressure on inlet of high pressure liquid pumps, leading to excess load on pumps and trip of pumps on high pumps, causing trips of xxx, xxx, etc. - significant operability issue		
2.2	Low level	Failing to switch from the sphere with low level in time (based on level indication)	Low/no flow - Liquid from spheres through high pressure product pumps to the vaporizer (see 4.2)	Level indication and low level alarm, inspected each year, per government regulation **(not IPL; part of the cause)** Feeding from two spheres at all times, so unlikely for BOTH spheres to have low level at the same time **- IPL** Two level indication from SIS level transmitter, with low level alarm, with more than 60 min available to switch tanks (SIF driven alarm and response) - **possible IPL, if action of the operator is quick enough**	Rec 4. Make sure the Human IPL of response to low level in all spheres and tanks is described in a trouble-shooting guide (like an SOP) and practiced once per year per unit operator. This will make this response a valid IPL.
			Low/no flow - Unqualified liquid from spheres back to Plant (see 6.2)		

Table 3 is an excerpt from a PHA report that illustrates the identification of a safeguard as IPLs or SIFs; and this also defines the target SIL needed.

For the PHA illustrated in Table 3, in some cases the SIF that was installed for protection against scenarios during continuous mode of operation did not protect against even more catastrophic and much more likely consequences during startup or online maintenance. For such situations, additional IPLs, including SIFs specific to startup or online maintenance, were recommended by the PHA team.

At this site in China, the non-human IPLs identified were entered into the computerized maintenance management system (CMMS) and maintained as critical features in reliability/maintenance systems. The human IPLs put on a schedule to test (using live drills) once a year. All of these activities are to ensure the IPLs/SIFs deliver the PFD anticipated, while still ensuring reliable operation/control by not causing too many spurious trips.

EXAMPLE 2-B: Developing Trouble-Shooting Guides from PHA/HAZOP Results [4]

Trouble-shooting guides are a special form of operating procedure; they are written for the actions that we want the operators to take to recover from a process deviation, *before an emergency situation occurs.* They are called guides (rather than procedures) since rarely can we predict the process conditions at the time the action is required (so a rigid procedure with exact ordering of steps is not possible to write). Trouble-shooting guides (and training and drills of the action) are required for any action that is considered a Human Response IPL. The Action Limit is what we show as the Min or Max in a Trouble-Shooting Guide. The action limit triggers the demand to use the trouble-shooting guide.

- The response is typically still possible, but it is time dependent. The time available is called the process safety time (PST). The operator must complete the diagnosis, make the necessary change(s), and make sure they are out of harm's way by the end of the Maximum Allowable Response Time (MART).
- We usually set an alarm or a pre-alarm to trigger this action.
- This is usually before the shutdown triggers (ESD occur automatically) or release points (PSV set points) are reached
- The Min and Max shown in the Trouble-shooting Guide table is not the absolute safety limit for a system, but is instead some value that leaves us some time to take action to prevent from reaching the absolute limits.

- There is still time to prevent or avoid the final consequence that could occur if we reach the ultimate limits of the process. Usually, we want the MART to be ½ or less of the PST, and we want MART > 10 minutes for trouble shooting in the field/plant and MART > 5 min for trouble-shooting only from the control room.

If the unit has a good PHA/HAZOP, then it is best to extract information from the HAZOP (or What-If) analysis tables to start the development of each troubleshooting guide. The guide is then finished with input from the process experts.

Table 4. Examples of Creating a Trouble-Shooting Guide from a HAZOP Table

HAZOP Table Entry	Trouble-Shooting Guide Entry
Cause: *Bypass valve is open or passing*	Make sure the bypass is tightly closed
Safeguard: *Isolation valves for the vessel*	Isolate the vessel, if necessary
Safeguard: *Relief valve*	Make sure the relief valve block valves/relief path are open

The key categories of information needed in a trouble-shooting guide are:

- IMMEDIATE ACTION (by system or by operator)
- DECIDE IF ALARM is REAL
- FINDING and FIXING the CAUSE
- FIX or BYPASS PROBLEM

The example below is of a trouble shooting guide for one critical alarm/action.

Figure 2

Trouble-Shooting Guide

Alarm or Indicator:	**PAL 4446 – Low Pressure Alarm for Suction of Organic Feed Pump 40-PM-18.445**

Action Limit:	5 kPa		
Consequence:	Possible pump seal failure, releasing or spraying organic waste into the berm.		
Process Area:	FB&D Incinerator; Liquid Organic Liquid Feed	**Oper. Mode:**	Normal
Drawing #s:	D-400-PI-013		

IMMEDIATE ACTION (by system or by operator)

- DCS should shut down the organic feed pump (40-PM-18.445).
- From the DCS display, MAKE SURE the organic feed pump is shutdown.
- HAVE the field operator check for leaks near the organic feed pump.
- IF there is a large leak/release, THEN use the ESD switch to shutdown the unit and then follow/complete the shutdown and isolation procedure, OPS-ESD-117.
- IF there is a minor leak or no leak, THEN:
    - COMPLETE the rest of the trouble-shooting,
    - and DECIDE how to contain the leak for now,

DECIDE IF ALARM is REAL

- From the DCS, CHECK the pressure and feed tank level trends. IF the trends indicate the alarm if valid, THEN continue with finding the cause or fixing or bypassing the problem.

FINDING and FIXING the CAUSE

- CHECK valves upstream of the organic feed pump to see if any are closed too far, including checking ESD valves.
- CHECK, by feel with hand, if the heat tracing is on; IF Not, then TURN ON or open heat trace valves
- MAKE SURE nitrogen to the pump seal is at the normal operating pressure.
- CHECK if the line if plugged or frozen (skill)

Trouble-Shooting Guide

Alarm or Indicator:	**PAL 4446 – Low Pressure Alarm for Suction of Organic Feed Pump 40-PM-18.445**

- CHECK if the line if plugged or frozen (skill)
- CHECK if the level is actually low, use the Organic Feed Tank.
- IF the cause is low level in the feed tank, THEN resolve the problem if necessary based on cause that is found (skill)

FIX or BYPASS PROBLEM

- IF necessary, SHUT DOWN the Unit to allow fixing of the problem.
- FOLLOW the proper procedure to resolve problems (repair procedure, line clearing procedure, etc.)
- IF the decision is made to continuing operation without all equipment in normal condition, THEN:
  - FOLLOW Temporary Operating mode, if there is a temporary procedure already written for this possible problem/condition
  - FOLLOW MOC procedures to obtain approval for any non-standard temporary operating procedure or mode

END

Image and layout copyrighted by PII, 2008-2018

Optimal presentation of trouble-shooting information.

Ideally (or ultimately) such trouble-shooting information should be imbedded in the basic process control system (DCS) so that the operators can access the information on the DCS screen “on demand,” with the click of mouse or key.

EXAMPLE 2-C: Documenting Changes in Baseline PHA/HAZOP to streamline Next PHA Revalidation (Evergreen PHA)[5]

An evergreen PHA is the result of using the baseline PHA report to the fullest for documenting MOC risk review results and for updating for learnings from incidents, as they occur (not waiting for the 5 year cycle to complete). See the table on the next page.

(A.3) (Reviewed 2005) Measuring Level on Bulk Storage Tanks

Drawing: SP 03.201.02

Item	Deviation	Causes	Consequences	Safeguards	Action Items
33.7	Step 2 (old Step 4) to remove measuring stick and record level performed incorrectly		(1998) No consequences of interest (2005) Operator could fall resulting in serious bodily injury (2005) Resin spill could damage valve	(2005) Railing around work area on tanks	
33.9	Skip step 4 (old step 6) to replace cap on quick connect	Typical causes of procedural errors (see Table A.1)	Release of process material if preparing to unload a tank wagon into the tank; fire and explosion hazard affecting a large area	Continuous ventilation The tanks are located in a containment area Checklist Generic and inherent safeguards protecting against or mitigating process material releases (see Table A.2) (2005) Air Monitors in Bulk room	'98Rec 26. See recommendation 19, item 29.12 (1998)
33.10	Step 4 (old Step 6) to replace cap on quick connect and pull ears up and secure Velcro straps performed incorrectly (poor seal when cap is replaced)		(2005) Quick connect cap can pop off during the filling stage and flammable material can spill out of tank; fire hazard affecting a medium area Incident Report 2/12/03 - Bulk Room - 878 Resin leak from valve on bulk resin tank during resin tanker unloading - (A.9) (Added Reval 2005) Incident Investigation Reports and Spill Reports 1998-2005 (linked to 82.11) MOC 92-2005-04 - 4/1/05 Replace portable tank valve lever stainless actuator to oval actuator brass construction - (A.8) (Added Reval 2005) Management of Changes 1998-2005 (linked to 81.23)	(2005) Velcro straps on valves	

This approach requires a high quality and thorough baseline PHA. It uses codes, in brackets, to note which MOC or incident the new information came from.

So, if the organization intends to keep their baseline PHA evergreen, then the PHA Leaders and Scribes of MOC risk reviews need to learn how to find and edit the baseline PHAs. This approach results in the baseline PHA being up-to-date with each single or grouping of revisions. The approach also saves considerable time as each 5 year revalidation cycle as the bulk of the updating is already complete well in advance, while the information is still fresh in the minds of the PHA leader and scribe.

3. IMPLEMENTATION PATH FOR USING PHA RESULTS

The path forward is not complicated, but it is hard work and requires organization discipline, primarily meaning that management acts upon a long term vision and not short-term vision. The basic steps to achieve the goals using PHAs are:

- Develop the organizational requirements for the linkages from the PHA/HAZOP results as listed in Table 2. Develop the standard to document these requirements and establish the roles and responsivities and accountabilities in this standard.
- Develop the guidelines and rules for documentation of PHA/HAZOP results, as illustrated in this paper and related papers, so that the basic data required in Table 2 is available in the PHA/HAZOP results.
- Have PHA/HAZOP Leaders attain the competencies necessary to deliver the quality and thoroughness of results needed, especially for identifying the IEs and IPLs (including SIFs and SILs) as illustrated in this paper and as described in detail in other papers by the authors.
- Develop one or more guidelines for extracting the data from the PHA/HAZOP reports to use the rest of process safety activities and management systems
    - Guideline for Creating Trouble-Shooting Guides from PHA/HAZOP results
    - Guideline for Extract critical IPLs and IEs from PHA/HAZOP Results to Identify Critical Engineered Features (or Safety Critical Equipment)
- Have staff develop the competencies needed for the extractions and use mentioned above.
- Develop the capabilities to keep the baseline PHA/HAZOP evergreen for each Change, one the MOC is actually implemented.
- Periodically audit and improve these systems

4. CONCLUSIONS

For many organizations, PHA/HAZOP results are an untapped gold mine of information. If the right protocols for performing and documenting PHA/HAZOPs are put in place and if the rules and guidelines for using the vast data in the PHA/HAZOP results are established, then HUGE gains in synergy from the PHA/HAZOP results are possible. These are gains that were intended from the beginning of process safety to help prevent incidents

5. ACRONYMS USED

AIChE – American Institute of Chemical Engineers
CCPS – Center for Chemical Process Safety (of AIChE)
GCPS -- Global Congress of Process safety
HAZOP – Hazard and Operability; as in HAZOP Analysis or HAZOP Study
IE – Initiating Event
IPL – Independent Protection Layer
LAH – High level alarm
LOPA – Layer of Protection Analysis
MOC – Management of Change
PHA – Process Hazard Analysis
PSM – Process Safety Management
OSHA – US Occupational and Health Administration
SIF – Safety Instrumented Function
SIL – Safety Integrity Level
SIS – Safety Instrumented System

6. REFERENCES

1. "Identify SIF and Specify Necessary SIL, and other IPLs, as part of PHA/HAZOP – or - Why it is not necessary to 'Boldly Go Beyond HAZOP and LOPA'**",** W. Bridges and A. Dowell III, *12th Global Congress on Process Safety*, Houston, TX, AIChE, April 2016.

2. *Functional Safety: Safety Instrumented Systems for the Process Industry Sector - Part 3: Guidance for the Determination of the Required Safety Integrity Levels*; ANSI/ISA 84.00.01 Part 3, 2004.

3. "Implementation of Process Hazard Analysis at SINOPEC-SABIC Tianjin Petrochemical Company Ltd, China**",** Homoud Al-Maymouni, Yunzhong Gao (both from SS-TPC), and W. Bridges, *11th Global Congress on Process Safety*, Austin, TX, AIChE, April 2015.

4. "Best Practices for Writing Operating Procedures and Trouble-Shooting Guides*"* W. Bridges and R. Tew, *13th Global Congress on Process Safety,* San Antonio, TX, AIChE, March 2017.

5. "Best practices for PHA Revalidations," W. Bridges, R. Tew, M Massello, *14th Global Congress on Process Safety.* Orlando, FL, AIChE, April 2018.