The Benefits of Comparing Similar Hazards across ‘Sister’ Plants

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ABSTRACT

Companies often have multiple ‘sister’ plants in different locations, sometimes scattered around the globe. Generally, these companies are striving for similarly low risk among all these sister plants, even though they may have been built at different times, using evolving technology, and often have different capacities. In the pursuit of achieving acceptably low risk at all the chemical plants within a company, Process Safety specialists tend to put each under the PHA ‘microscope’ separately. FMC has several businesses that operate multiple “sister” plants, and has found that there are substantial benefits to be gained by also <u>*comparing*</u> *the hazards at similar plants.*

We first applied the comparison technique that is the subject of this paper to one of our world-wide chemical operations that had several sister plants. Our assumption was that any given high consequence scenario should appear as a common element at all the plants unless there was a fundamental difference between plants. Comparing each of these common scenarios one by one across all similar plants allowed us to ensure each scenario had been recognized, evaluated and safeguarded in a consistent manner. Some surprising inconsistencies were discovered.

This paper briefly describes the general organization of FMC’s Process Safety Risk Profile program, including some recent improvements, then focuses on our scenario comparison methods in sufficient depth for others to apply them.

1. INTRODUCTION

About ten years ago FMC developed and implemented a chemical process hazard analysis application called Process Safety Risk Profile (PSRP), and presented it as a topic to this forum. We will now share our experiences gleaned from the implementation and growth of this tool. This paper will provide a little refresher on what a PSRP is, how it can enable comparisons between similar plants, and the experiences and lessons learned, complete with some examples[1] and anecdotes to reinforce key points. Lastly, we will identify the critical success factors of this endeavor, should you be interested in applying this tool and concept to your business.

2. Identifying the High Consequence scenarios (Scenarios vs Deviations)

FMC developed Process Safety Risk Profiles (PSRPs) at all its chemical manufacturing locations world-wide using the PSRP methodology presented by FMC to the CCPS, several years ago. However, even for sites that aren't required by regulations to perform Process Hazards Analyses (PHAs), the PSRP is a useful tool for performing an economical hazard review. The PSRP is simple yet comprehensive. It takes less time to conduct, and allows for a compact report to be generated. The PSRP at a plant can be developed using one of two different methods.

2.1 Team-based PSRP Development (Method 1)

FMC typically develops the scenarios, at sites not governed by PSM, using PSRP methodology, by using a team that functions much like a "What-if" PHA. This group is facilitated by a corporate Process Safety specialist familiar with the process and, in particular, with estimating risk.

PSRP's use techniques similar to Process Hazards Analyses (PHA's), but do not focus so closely on the details of the process as PHA's have to. PSRP's are 'coarser', tend to be done at the Flowsheet level, and are looking only for scenarios that have the potential for very significant consequences. Similar techniques have been used for years, and have been referred to using several different terms, including "Coarse Scale HazOps"[2]. The significant differences between these 'predecessors' and our PSRP's is that we have estimated the magnitude of the potential consequence (both on- and off-site) and the likelihood of the scenario, before and after considering active safeguards. See Table 1 for highlights of the differences between HAZOP and PSRP approaches to a hazard analysis

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[1] Examples used in this paper are real but are not drawn from FMC operations.

[2] Kletz, "Hazop & Hazan"

Scenarios vs Deviations

• **HAZOP** 1. Causes/Events 2. Deviations 3. Scenarios 4. Consequences 5. Recommendations	• **PSRP** 1. Hazard Matrix 2. Consequences 3. Scenarios 4. Recommendations
Node level	Flowsheet or unit level

Table 1

Before we can compare scenarios at various sites, we have to bring them to some sort of common basis. It's difficult to compare HazOp or What-If results directly, because issues can surface at different points in the discussion. For example, the hazard of over-pressuring receiver vessel V-2 in Fig 1 may show up under several different Hazop Deviations. However, every high-pressure polyethylene plant in the world has plenty of safeguards against the hazard of rupturing its low pressure separator in case they blow through from the high pressure separator.

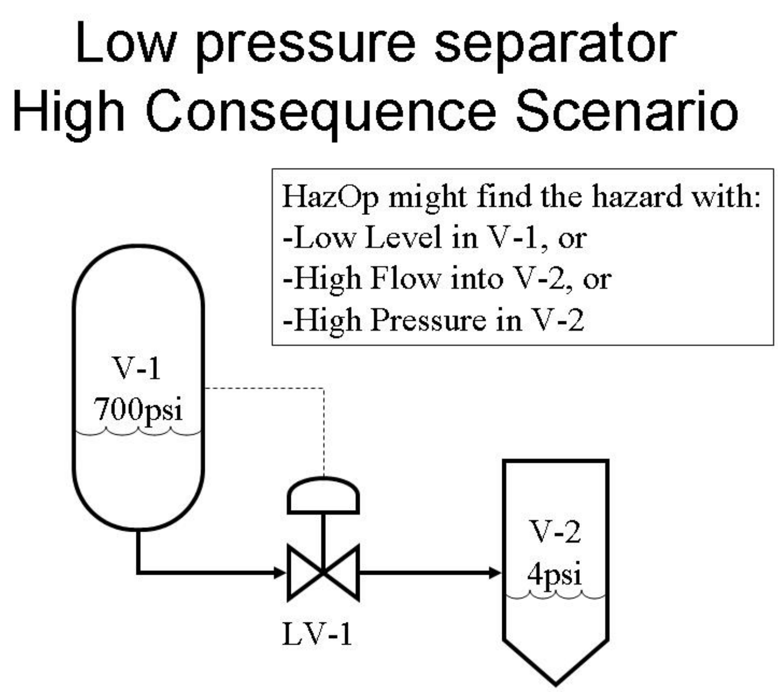

Figure 1

2.2 Extracting High Consequence Scenarios from existing PHA's (Method 2)

At PSM/RMP sites in the US, or in any other jurisdiction where required, site staff (sometimes with the help of a consultant) conduct the mandatory PHA's. When this is the case, we extract the PSRP scenarios from the PHA using a small team composed of a corporate Process Safety specialist, a senior process engineer and/or the site's process safety coordinator. This is not an onerous task, requiring only 2-4% of the time needed for the PHA itself.

Most PHAs document all the deviations they consider, regardless of the consequence/risk level. They may choose to flag any recommendations against lower consequence deviations as optional "Operations only" recommendations and manage these outside the PHA's "safety recommendations" system. This dramatically increases the effort required by the corporate safety staff to manage the corporation's High Consequence Scenarios (Fig 2). We needed a way to "separate the wheat from the chaff".

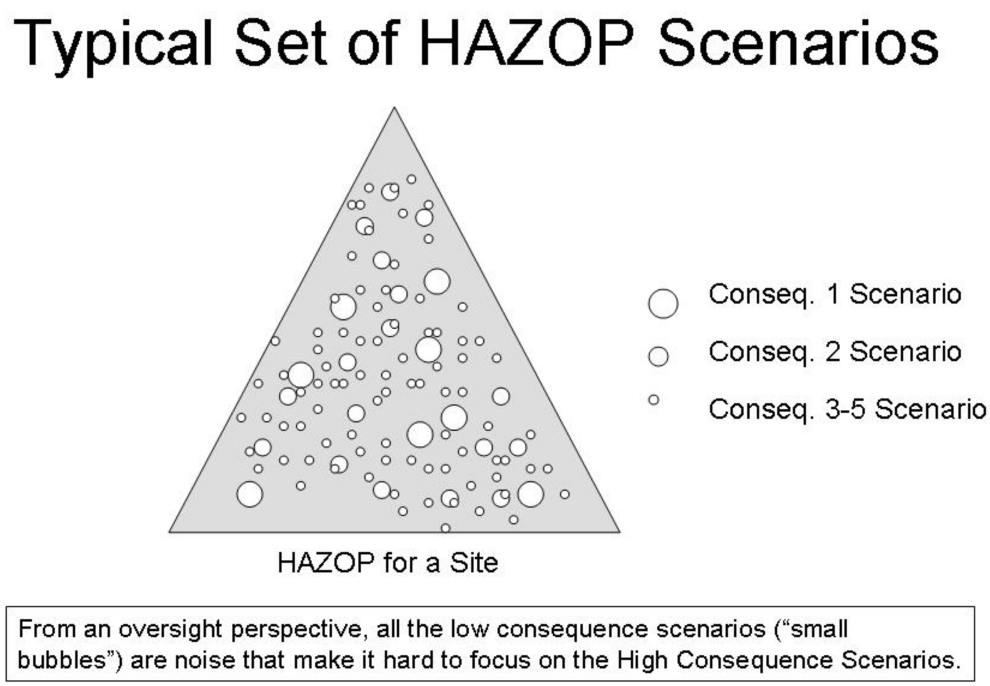

Figure 2

Providing your company estimates the risk levels (at least for deviations, or What-if cases, with potentially high consequences), you can easily skim through hours of PHA teamwork to identify those "important" scenarios that you may wish to compare from site to site (procedure depicted in Figure 3). Some software packages for recording PHAs allow you to apply filters so only the high consequence deviations are displayed.

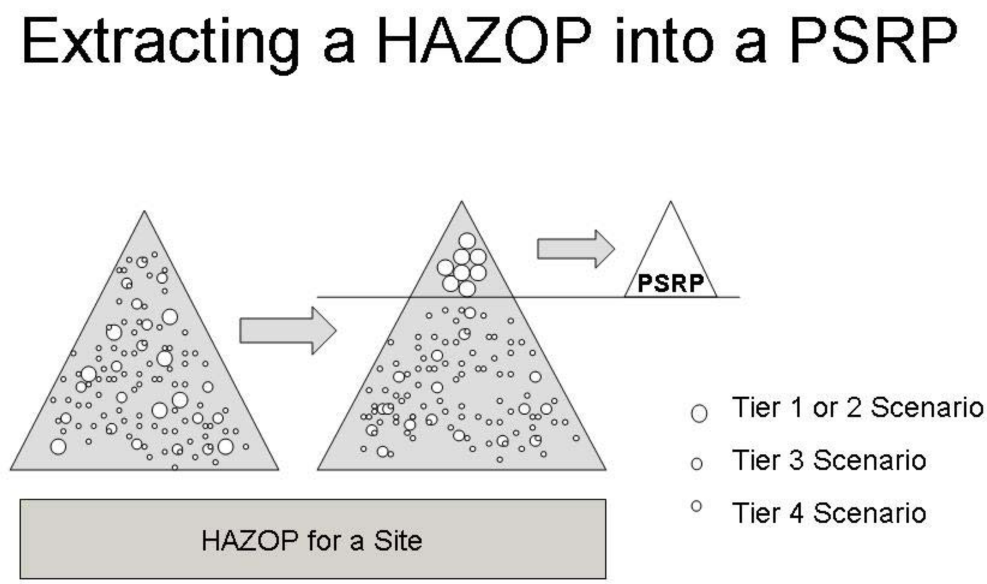

Figure 3

2.3 FMC Verified the Validity of PHA → PSRP Conversion

To make sure the process to extract important scenarios worked, we put it to a test. Several FMC employees, with varying experience in Process Safety (from 5 to 20 years), each independently performed the procedure. It only took about 2 hours to identify the high consequence scenarios from a week-long HazOp and extract the Description, Cause, Safeguard & Risk information, as well as the important Recommendations to reduce that Risk. Everyone identified the same High Consequence Scenarios.

3 CONDUCTING THE COMPARISON OF SISTER PLANTS

Once the information about each plant's High Consequence Scenarios has been analyzed, we can compare similar scenarios at similar plants. This should be done by a group of experienced process engineers, each representing their own plant. In our comparison we used a mix of technical department managers, senior process engineers, and site process safety specialists, all coordinated by a corporate process safety specialist. To provide focus for their discussions, we compiled all the High Consequence Scenarios at each of the plants into a spreadsheet table.

3.1 Making the comparison table

Prior to the comparison meeting, we developed a spreadsheet (as shown in Figure 4) to collect and display the information. The first four columns (A-D) were:

A) The Row Number - For easy reference when using paper copies of the comparison. We left this blank until we had added all the scenarios.
B) The System name - e.g. Feed Prep, Catalyst Injection, Reaction, etc.
C) The Sub-system name - depending on the complexity of the Plants, this may or may not be necessary
D) The Brief Description - We filled this in as we were populating the comparison spreadsheet with the scenarios from the plants.

We placed the scenarios from the Plant A into the table using 5 columns (E-I):

E) The Scenario number - used to refer back to each plant's PSRP information if/when further details were needed.
F) The Scenarios column - containing the text of the Scenario Description as copied from each plant's PSRP.
G) The Consequence category - From 1-5 where 1 is the highest Consequence
H) The Likelihood category - from A – E where A is the highest Likelihood
I) The Risk tier - where 1 is the highest Risk (Fig 6)

A	B	C	D	E	F	G	H	I
				Plant A PSRP Results				
#	System	Sub-system	Brief Description (by Corporate Safety)	Scen#	Scenarios	C	L	R
14	Separation	Low Pressure Separator	Rupture LPS due to blow-throughof gas from HPS	PlantA-LDP-04.06	Lose liquid level in HiPress Separator. Safeguards are LSLL to LV and RD to atmosphere.	1	D	2
15	Separation	Recycle compr'r	Draw air into the low pressure compressor leading to Decomp in the reactor if [O2] exceeds ~10ppm	PlantA-LDP-06.02	Draw air into suction of 1st stage Recycle compressor for any reason, leading to Decomp in Reactor. Safeguards are lab sampling, RD's on reactor and reactor blast walls	3	B	2

Figure 4

Next, we looked for similar scenarios at Plant B and placed them into the table on the corresponding rows so that the same scenario was on each row for all plants. If Plant B had identified a scenario that wasn't identified by Plant A, then we inserted a blank row in the appropriate System/Subsystem (Fig 5) and placed the new scenario in the blank row, in the Plant B columns. We repeated this process with each of the other sister plants. We added two additional columns to the right edge of the spreadsheet to record Comments and Recommendations for use during the comparison meeting.

			Plant A PSRP Results					Plant B PSRP Results				
System	Sub-system	Brief Description (by Corporate Safety)	Scen#	Scenarios	C	L	R	Scen#	Scenarios	C	L	R
Separation	Recycle compr'r	Draw air into the low pressure compressor leading to Decomp in the reactor if [O2] exceeds ~10ppm	PlantA-LDP-06.02	Draw air into suction of 1st stage Recycle compressor for any reason, leading to Decomp in Reactor. Safeguards are lab sampling, RD's on reactor and reactor blast walls	3	B	2	PlantB-LDP-02.04	Oxygen level in reactor exceeds 10ppm due to air ingress at Recycle compressor suction eg. Draw vacuum & leak into system from extruder	3	C	3
Separation	Recycle compr'r	Draw air into the low pressure compressor due to Unloader air leak -> Decomp (Plt B experience)		*No equivalent scenario identified*				PlantB-LDP-02.04	Oxygen level in reactor exceeds 10ppm due to air ingress (eg. Due to air leak through recycle complessor 1st or second stage unloaders)	3	C	3

Figure 5

3.3 The Comparison Meeting

The division involved has periodic technical exchange meetings. We added a day and a half to one of the participants to do the comparison using a team as described in section 2. There were 47 high consequence scenarios in the table, so we averaged about 15 minutes per scenario. As you might expect, some scenarios were essentially identical, uncontroversial, and only required a minute of discussion. The most controversial scenario took about 45 minutes and we eventually agreed to launch a study to resolve some thorny questions outside of the meeting.

The general flow of the discussion for each row was to:

A) Describe the scenario and ensure everyone understood what we were talking about,
B) Look for any differences in risk rating (C, L or R) and ask the relevant site representative to describe their situation to the group.
C) Discuss how the scenario was handled at each of the sites and look for common patterns and/or best practices.
D) Record any notes in the Comments column and any required actions in the Recommendations column.

Recommendations to an individual plant might be to consider revising their PSRP and/or add a Safeguard that they didn't have, or to look for a better technical solution for a problem that was common to all the plants, or even to begin a test program to develop reactivity data.

4. FINDINGS

The following are examples of issues that surfaced during the comparison meeting.

4.1. Missed scenarios

The first problem we noticed was that a number of significant scenarios had been identified at some plants, but not at others. Some teams had just missed them - not just once, but in several revalidations.

Example: Potential for a pool fire in the Purification Unit

Each of the plants in our comparison operates a Purification Unit. One hazard common to all of the units is that they contain substantial volumes of organic solution above the flash point. In cases like this, FMC always assumes that a pool fire is possible. Since there is little containment or confinement for vapors, and the vapor generation rate is small anyway, we do not consider a vapor-cloud explosion to be a realistic scenario in this area.

Using industry data, we've estimated the likelihood of a pool fire to be about 1 per 100 unit-years (0.01 per year at each unit). In FMC's risk profile system, this is in the "C" region. At most of the sister plants, we estimated that A) there would not be off-site consequences, B) a fatal injury to an employee was unlikely and C) that the combined Property Damage and Business Interruption from such a fire might be in the region of $500,000. This combination of consequence and likelihood (risk) is considered by FMC to be generally acceptable. Note that the risk analyst is estimating a point along a continuum of likelihood-consequence pairs for this unit. In this case, the area is properly classified electrically, there are no unusual hazards and there is an automatic deluge system. We assume the deluge will limit the damage in most fires. A deluge failure might result in approximately 10 times more damage, but is considered to be at least 10 times less likely. For our purposes this estimate is close enough.

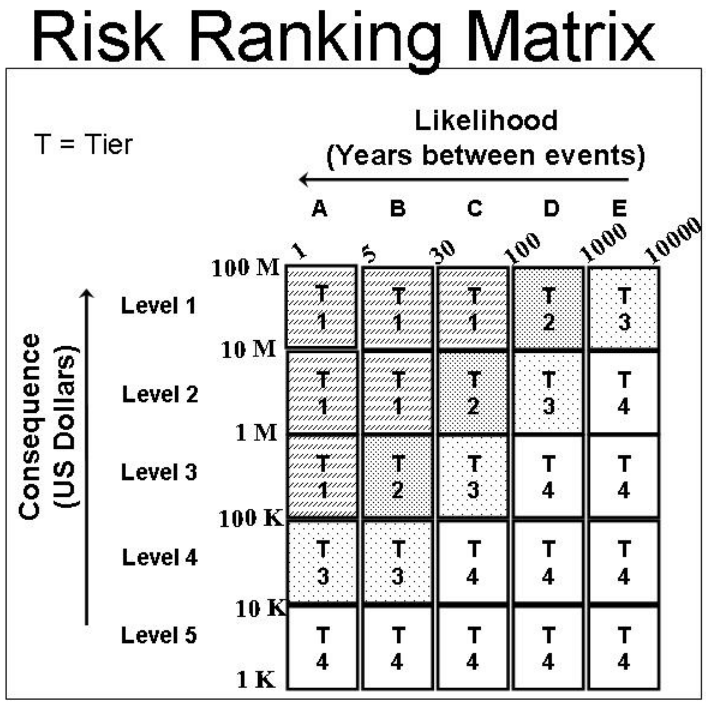

Figure 6

The PHA team at one of the facilities had not considered a pool fire at all. They just missed this Loss of Containment scenario. The worst scenario they identified in the Purification Unit was a small flash fire inside one of the purifier vessels. They rated the consequences as well as the likelihood of such a flash fire to be low. Therefore their PSRP did not contain this scenario. This oversight was not identified until we did the comparison of all the facilities. They added the scenario to their analysis. At this point, you may be asking yourself, “So what? The risk of this scenario was acceptable anyway.” As a general principle, emergency response plans should be based on broad versions of the scenarios identified in the hazard analysis, so this difference is significant to Emergency Response planning, even though it is considered an “acceptable risk”.

At another of the plants, the physical arrangement of the Purification Unit is different, it’s significantly closer to the rest of the process areas, and there is not good drainage to prevent the possible spread of a pool fire to adjacent units. In this case, the likelihood was left at “C”, but the consequences of a pool fire were estimated to be significantly higher. The risk ratings at the two facilities were different, but that difference was documented and was explainable. It may be necessary to explain such differences to division-level management who wonder why they need to spend money to address a risk at Plant A but Plant B doesn’t appear to have a problem. A table showing that the hazard exists at both places but is less at B can be very helpful.

4.2 Taking credit for Active Safeguards before estimating Consequences

A typical error that inexperienced PHA teams make is to estimate the consequences of a scenario after considering the safeguards that are in place. For example, in most multi-stage gas compression systems, there is a possibility of liquids accumulating between each stage. For this reason, there is usually a suction drum ahead of the next stage, complete with a liquids drain and a high level interlock to shutdown the compressor. If the liquid is not all drained out, then it may carry over to the next stage and can cause a catastrophic failure of the compressor. One PHA team missed this and rated the worst consequences of high level as a shutdown of the compressor due to the active safeguard, which they rated as a low consequence. Unfortunately, the consequence level was also used to determine (at a first pass) those devices that must be scheduled for periodic inspection in the Mechanical Integrity program. Since the high level interlock wasn't deemed to be protecting against a high consequence safety event, it wasn't initially included.

5. LEARNINGS

It's obviously a good idea for sister plants to cooperate on process safety issues. Beyond "two-heads-are-better-than-one", there are the opportunities for multiple plants to learn lessons from unusual incidents that happen at one of them.

The following are some generalized learnings about the comparison process, its requirements and benefits.

5.1 Critical Success Factors

If you've read this far you are probably interested in applying the PSRP concepts in some form at your company. Keep these critical success factors in mind:

- FOCUS - Use a compact, efficient hazard scenario identification process that focuses attention on high consequence scenarios. Consider using a coarse-scale what-if method or an extraction process from existing PHA work.
- UNIFORMITY - A uniform process facilitates cross-site comparisons
- EXPERIENCE – The person driving this process must have technical and operational experience combined with strong process safety knowledge. The team members must be very knowledgeable about their own processes and plant systems including key safeguards.
- TEAMWORK – The corporate oversight person needs to work effectively with site process safety resources to conduct the PSRP process and the cross-site comparisons depicted in this paper.

5.2 One-time-only (probably).

Once we've completed the comparison study and established the standard safeguard requirements for the process, there seems to be no need to revisit it. The ongoing maintenance of the study results should be done via each plant's process safety programs. When a new plant is built, we may choose to add its list of scenarios to the comparison table, though in practice, we have used the scenario list from one of the existing plants as an input to the design and hazard assessment process for the new plant.

6. CONCLUSION

It's possible to compare high consequence process safety scenarios across sister plants to ensure they have treated these situations uniformly. Using the methods described in this paper, the required effort is small in comparison with the benefits. If your company does PHAs using completely independent teams, this comparison may identify high consequence scenarios that have been missed, or mis-rated, through several revalidations.

7. REFERENCES

1. Fryman & Roopchand "Process Safety Scenario Evaluations", CCPS Conference, 1999 NB. PSSE has since been renamed PSRP within FMC, but the methodology is largely unchanged.
2. Kletz, T.A. "Hazop & Hazan"(4th ed) IChemE 1999,