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HAZOP – Local approach in the Mexican oil & gas industry

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ABSTRACT

HAZOP (Hazard and Operability) studies began about 40 years ago, when the Process Industry and complexity of its operations start to massively grow in different parts of the world. HAZOP has been successfully applied in Process Systems hazard identification by operators, design engineers and consulting firms. Nevertheless, after a few decades since its first applications, HAZOP studies are not truly standard in worldwide industrial practice. It is common to find differences in its execution and results format. The aim of this paper is to show that in the Mexican case at National level in the oil and gas industry, there exist an explicit acceptance risk criteria, thus impacting the risk scenarios prioritizing process. Although HAZOP studies in the Mexican oil & gas industry, based on PEMEX corporate standard has precise acceptance criteria, it is not a significant difference in HAZOP applied elsewhere, but has the advantage of being fully transparent in terms of what a local industry is willing to accept as the level of risk acceptance criteria, also helps to gain an understanding of the degree of HAZOP applications in the Mexican oil & gas sector. Contrary to this in HAZOP ISO standard, risk acceptance criteria is not specified and it only mentions that HAZOP can consider scenarios ranking. The paper concludes indicating major implications of risk ranking in HAZOP, whether before or after safeguards identification.

1. Introduction

HAZOP (Hazard and Operability) studies appeared in systematic way about 40 years ago (Lawley, 1974) where a multidisciplinary group uses keywords on Process variables to find potential hazards and operability troubles (Mannan, 2012, pp. 8-31). The basic principle is to have a full process description and to ask in each node what deviations to the design purpose can occur, what causes produce them, and what consequences can be presented. This is done systematically by applying the guide words: *Not*, *More than*, *Less than*, etc. as to generate a list of potential failures in equipment and process components.

The objective of this paper is to show that in the Mexican case at National level in the oil and gas industry, there is an explicit acceptance risk criteria, thus impacting the risk scenarios prioritizing process. Although HAZOP methodology in the Mexican oil & gas industry, based on PEMEX corporate standard has precise acceptance criteria, it is not a significant difference in HAZOP studies applied elsewhere, but has the advantage of being fully transparent in terms of what a local industry is willing to accept as the level of risk acceptance criteria, also helps to gain an understanding of the degree of HAZOP applications in the Mexican oil & gas sector. Contrary to this in HAZOP ISO standard (ISO, 2000), risk acceptance criteria is not specified and it only mentions that HAZOP can consider scenarios ranking. The paper concludes indicating major implications of risk prioritizing in HAZOP, whether before or after safeguards identification.

2. Previous work

HAZOP studies include from original ICI method with required actions only, to current applications based on computerized documentation, registering design intentions at nodes, guide words, causes, deviations, consequences, safeguards, cause frequencies, loss contention impact, risk reduction factors, scenarios analysis, finding analysis and many combinations among them.

In the open literature there have been reported interesting and significant studies about HAZOP, like HAZOP and HAZAN differences (Gujar, 1996) where HAZOP was identified as qualitative hazard identification technique, while HAZAN was considered for the quantitative risk determination. This difference is not strictly valid today, since there are now companies using HAZOP with risk analysis

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and its acceptance criteria (Goyal & Kugan, 2012). Other approaches include HAZOP execution optimization (Khan, 1997); the use of intelligent systems to automate HAZOP (Venkatasubramanian, Zhao, & Viswanathan, 2000); the integration of HAZOP with Fault Tree Analysis (FTA) and with Event Tree Analysis (ETA) (Kuo, Hsu, & Chang, 1997).

According to CCPS (2001) any qualitative method for hazard evaluation applied to identify scenarios in terms of their initial causes, events sequence, consequences and safeguards, can be extended to register Layer of Protection Analysis (LOPA).

Since HAZOP scenarios report are presented typically in tabular form there can be added columns considering the frequency in terms of order of magnitude and the probability of occurrence identified in LOPA. There should be identified the Independent and the non-Independent Protection Layers, IPL and non-IPL respectively. Then the Probability of Failure on Demand (PFDs) for IPL and for non-IPL can be included as well as IPL integrity.

Another approach consists of a combination of HAZOP/LOPA analysis including risk magnitude to rank risk reduction actions (Johnson, 2010), a general method is shown, without emphasizing in any particular application. An extended HAZOP/LOPA analysis for Safety Integrity Level (SIL) is presented there, showing the quantitative benefit of applying risk reduction measures. In this way one scenario can be compared with tolerable risk criteria besides of being able to compare each scenario according to its risk value.

A recent review paper has reported variations of HAZOP methodology for several applications including batch processes, laboratory operations, mechanical operations and programmable electronic systems (PES) among others (Dunjó, Fthenakis, Vílchez, & Arnaldos, 2010).

Wide and important contributions to HAZOP knowledge have been reported in the open literature that have promoted usage and knowledge of HAZOP studies. However, even though there is available the IEC standard on HAZOP studies, IEC-61882:2001 there is not a worldwide agreement on HAZOP methodology and therefore there exist a great variety of approaches for HAZOP studies.

At international level there exist an ample number of approaches in HAZOP studies; even though the best advanced practices have been taken by several expert groups around the world, there is not uniformity among different consulting companies or industry internal expert groups (Goyal & Kugan, 2012). The Mexican case is not the exception about this, but in the local oil and gas industry there exist a national PEMEX corporate standard that is specific in HAZOP application, it includes ranking risk scenarios (PEMEX, 2008), qualitative hazard ranking, as well as the two approaches recognized in HAZOP, *Cause by Cause* ($C \times C$) and *Deviation by Deviation* ($D \times D$).

Published work including risk criteria include approaches in countries from the Americas, Europe and Asia (CCPS, 2009), but nothing about Mexico has been reported.

3. HAZOP variations

In the technical literature there is no consensus in the HAZOP studies procedure, from the several differences it is consider that the more important are the variations according to: ($D \times D$) or ($C \times C$). Table 1 shows HAZOP variations, where ($CQ \times CQ$) means *Consequence by Consequence* analysis.

Table 1
Main approaches in HAZOP studies.

Source	HAZOP approach
(Crowl & Louvar, 2011)	($D \times D$)
(ABS, 2004)	($C \times C$) & ($D \times D$)
(Hyatt, 2003)	($C \times C$), ($D \times D$) & ($CQ \times CQ$)
(IEC, 2001)	($D \times D$)
(CCPS, 2008); (Crawley, Preston, & Tyler, 2008)	($D \times D$), ($C \times C$)

Table 2
HAZOP recommendations without risk ranking.

Description
Recommendation 1
Recommendation 2
Recommendation 3
Recommendation 4
Recommendation 5

The implications of choosing ($C \times C$) are that in this approach there are obtained unique relationships of *Consequences*, *Safeguards* and *Recommendations*, for each specific *Cause* of a given *Deviation*. For ($D \times D$), all *Causes*, *Consequences*, *Safeguards* and *Recommendations* are related only to one particular *Deviation*, thus producing that not all *Causes* appear to produce all the *Consequences*. In practice HAZOP approach ($D \times D$) can optimize analysis time development. However, its drawback comes when HAZOP includes risk ranking since it cannot be determined easily which *Cause* to consider in probability assignment. In choosing ($C \times C$) HAZOP there is no such a problem, although it may take more time on the analysis. The HAZOP team leader should agree HAZOP approach with customer and communicate this to the HAZOP team. In our experience factors to consider when choosing HAZOP approach are:

1. If HAZOP will be followed by Layers of Protection Analysis (LOPA) for Safety Integrity Level (SIL) selection, then choose ($C \times C$).
2. If HAZOP is going to be the only hazard identification study, it is worth to make it with major detail using ($C \times C$).
3. If HAZOP is part of an environmental risk study that requires a *Consequence* analysis, then use ($D \times D$).
4. If HAZOP is going to be done with limited time or because HAZOP team cannot spend too much time in the analysis, then use ($D \times D$). Although this is not desirable since may compromise process safety.

Regarding risk ranking in HAZOP, looking at IEC standard (IEC, 2001) it is found that HAZOP studies there are ($D \times D$) it refers to (IEC, 1995) in considering deviation ranking in accordance to their severity or on their relative risk. One advantage of risk ranking is that presentation of HAZOP results is very convenient, in particular when informing the management on the recommendations to be followed first or with higher priority as a function of risk evaluated by the HAZOP team regarding associated *Cause* with a given recommendation. Tables 2 and 3 are shown as illustrative example of the convenience of event risk ranking under HAZOP, showing no risk ranking in Table 2 and risk ranking in Table 3.

When HAZOP presents a list of recommendations without ranking, the management can focus to recommendations with perhaps the lower resource needs and not necessarily the ones with higher risk.

Table 3
HAZOP recommendations with risk ranking.

Scenario risk	Description
High	Recommendation 2
High	Recommendation 5
Medium	Recommendation 3
Low	Recommendation 1
Low	Recommendation 4