Journal of Loss Prevention in the Process Industries 32 (2014) 182–191

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

journal homepage: www.elsevier.com/locate/jlp

Requirements for improved process hazard analysis (PHA) methods

Paul Baybutt

Primatech Inc., Columbus, OH, USA

ARTICLE INFO

Article history:
Received 13 May 2014
Received in revised form
23 July 2014
Accepted 15 August 2014
Available online 2 September 2014

Keywords:
Process hazard analysis
Hazard and Operability (HAZOP) study
Process safety

ABSTRACT

In order to develop better process hazard analysis (PHA) approaches, weaknesses in current approaches first must be identified and understood. Criteria can then be developed that new and improved approaches must meet. Current PHA methods share common weaknesses such as their inability specifically to address multiple failures, their identification of worst-consequence rather than worst-risk scenarios, and their focus on individual parts of a process. There has been no comprehensive analysis of these systemic weaknesses in the literature. Weaknesses are identified and described in this paper to assist in the development of improved approaches. Knowledge of the weaknesses also allows PHA teams to compensate for them to the extent possible when performing studies.

Key criteria to guide the development of improved methods are proposed and discussed. These criteria include a structure that facilitates meaningful brainstorming of scenarios, ease of understanding and application of the method by participants, ability to identify scenarios efficiently, completeness of scenario identification, exclusion of extraneous scenarios, ease of updating and revalidating studies, and ease of meeting regulatory requirements. Some proposals are made for moving forward with the development of improved methods including the semi-automation of studies and improvements in the training of team members.

1. Introduction

Over the years, hazard studies for processes have evolved from a simple identification of hazards and control measures to the detailed evaluation of hazard scenarios and the determination of the need for risk reduction. Hazard studies now involve both the identification of hazards in a process and the determination of hazard scenarios through which they may be realized. Initial hazard identification is often addressed using checklist methods (CCPS, 2008). Hazard scenarios are identified using process hazard analysis (PHA) methods, such as the Hazard and Operability (HAZOP) study. Although not intended specifically for the identification of all the hazards present in a process, PHA methods do provide information indirectly about hazards that are present. However, the focus in this paper is on the identification of hazard scenarios. Current PHA methods address the questions shown in Table 1. Traditional methods are reaching their practical limits for scenario identification in their current form.

There are both inherent weaknesses in current PHA methods as well as weaknesses in how PHA is practiced, such as inadequate team composition. Investigations of accidents show that scenarios are sometimes missed in PHA (CSB, 2014). For example, the Chemical Safety Board (CSB) investigation of an accident at Valero's McKee refinery found fault with the refinery's PHA which did not identify the scenario that occurred (CSB, 2008).

This paper focuses on inherent weaknesses in PHA. Individual PHA methods offer different advantages and disadvantages (CCPS, 2008; Baybutt, 2013a). However, current PHA methods share a number of weaknesses. There has been no comprehensive analysis of these systemic weaknesses in the literature. In order to develop improved PHA approaches, these weaknesses must be addressed. Also, knowledge of weaknesses allows PHA teams to compensate for them to the extent possible. This paper identifies and describes key weaknesses in PHA methods. Using the assessment of current methods, criteria are proposed that should be met by new and improved approaches. The paper concludes by offering some suggestions on possible PHA improvements.

2. Weaknesses in current PHA methods

This section identifies and describes numerous weaknesses in current PHA methods.

E-mail address: paulb@primatech.com.

http://dx.doi.org/10.1016/j.jlp.2014.08.004
0950-4230/

Table 1
Questions addressed by PHA.

Question	Item
What can go wrong?	Initiating event
What happens?	Scenario events including consequence
How bad could it be?	Scenario severity
How often could it happen?	Scenario likelihood
What is the risk?	Combination of severity and likelihood
Is the risk tolerable?	Comparison of estimated risk with a risk tolerance criterion, considering existing safeguards
If not, what actions are needed to reduce the risk? (If included within the scope of the study)	Recommendations for corrective action

2.1. Role of subjective judgment

PHA studies depend on people to use their imagination and creativity to identify hazard scenarios. Study teams also use judgment in evaluating hazard scenarios. Consequently, PHA studies are inherently subjective. Notably, a US Occupational Safety and Health Administration (OSHA) publication stated (OSHA, 1994a), "PHA is dependent on good judgment". Subjectivity influences various aspects of studies including:

- Identification of initiating events
  Credible initiating events are included in a PHA study while incredible ones are not. However, "credible" may mean different things to different people and subjective judgment is involved in its interpretation. Team judgment must be used to decide whether events are sufficiently probable to be considered credible. It is prudent to include events with a low probability of occurring because catastrophic events will be in a probability domain that is naturally low and such events are of most concern in PHA. They do not occur with a frequency that would cause them to be observed within the typical lifetime of a process but that does not mean that a facility will not experience one. While some data may be available to assist in decision making on credibility, data are often sparse or may not apply to the particular circumstances.
  Human perception influences estimates of likelihood. A person's experience is reflected in their estimates. Usually, people underestimate the probability of an event they have not experienced and overestimate the probability of an event they have experienced. For example, some external events, such as a 500-year flood, likely will be outside the experience of facility personnel. Perception plays an important role in estimating the likelihood of events and team leaders should address the issue with team members (Baybutt, 2013b).
- Completeness of scenario identification
  Typically, PHA teams brainstorm the identification of hazard scenarios until they can think of no more. Thus, scenario identification is subject to the vagaries of human judgment and the stamina of PHA teams and these issues must be managed (Baybutt, 2013b; Baybutt, 2003a).
- Scenario risk ranking
  Risk ranking is performed by qualitatively estimating the severity and likelihood of hazard scenarios based on the collective knowledge and experience of the team. Estimates may not be consistent from team to team within a company or even within the same study owing to the subjective judgment involved. The estimation of scenario severities is easier than for scenario likelihoods. Most team members will have some appreciation of the possible spectrum of consequence severities, from the benign to the catastrophic, that derives from their personal experience or awareness of industry events. Estimating likelihoods for events with frequencies less once every 100 years, the nominal human lifetime, is more difficult for PHA team members. In order to eliminate some subjectivity, some companies provide specific guidelines for the assignment of scenario severities and consequences according to the type of scenario.
- Credit for safeguards
  The assessment of scenario likelihoods includes the likelihood of failure of safeguards. Usually, such estimates are made using engineering judgment rather than actual data. PHA teams optimistically may assume the best possible performance rather than the worst-case. This is particularly true when teams credit the actions of people as safeguards. Usually, people think they will not themselves make mistakes and they may project this view onto actions by other people. Usually, human failures rates are higher than many people realize. PHA team leaders should ensure that team members are aware of typical human failure rates under various conditions in a process facility.

In those parts of PHA where subjective judgment is critical, team members should practice using scenarios that have already been assessed by experts so that they can make a comparison with their own assessments and calibrate their judgment against that of experts. The process provides the benefit of sensitizing team members to the difficulty of making objective judgments in PHA.

2.2. Only departures from design intent are addressed

Many practitioners use PHA during the design of a process to improve the design. However, PHA focuses on looking for ways the process may deviate from the design intent and does not evaluate the adequacy of the design intent itself. Verification of the design intent is part of a formal design review and is outside the scope of PHA studies. Notably, the Center for Chemical Process Safety (CCPS) states (CCPS, 2008), "PHA should never be considered a substitute for an organization's customary design review activities. PHA is best used to supplement project design reviews."

Certainly, PHA cannot replace design reviews but it can augment them. Thus, a design review must address matters such as the operability of the process, application of inherently safer design principles, value engineering, and compliance with codes, standards and regulations. Of course, new designs may be hazardous even within the envelope of the design intent and design reviews must address such hazards.

This issue is of greater concern during the design of a process than for an existing process for which the design effectively has been proven in use. However, the issue does arise again when changes are made to an existing process.

2.3. Ability to address all aspects of design intent

Usually, hazard scenarios occur when there is a deviation from the design intent for a process. Unfortunately, there are many aspects of design intent (see Table 2) and it is a significant challenge to identify those aspects for which deviations will result in scenarios of concern. Various design representations are needed to portray design intent in order to address the different aspects. They may be drawings, procedures, etc. For example, traditional HAZOP studies use piping and instrumentation diagrams as the central reference document making such studies equipment-oriented. However, operating and maintenance procedures are important design representations when addressing human failures. Similarly, cause and effect diagrams must be consulted when addressing control system failures. The more aspects of design intent that are included in a study, the more design representations must be