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Journal of Loss Prevention in the Process Industries 19 (2006) 70–77
Journal of Loss Prevention in the process industries
www.elsevier.com/locate/jlp

How the management aspects can affect the results of the QRA

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Received 29 March 2005; received in revised form 1 June 2005; accepted 6 June 2005

Abstract

This paper describes a procedure to include into the quantitative risk assessment (and namely in the construction and solution of the Fault Trees) the Safety Management System (SMS) aspects.

The parameters used for probabilistic assessment of the Expected Number of Failures (ENF) of a Top Event are parameterised depending on:

1. a weight assigned to each SMS section with reference to the parameter;
2. a judgment about the correct application of the same SMS section.

Each probabilistic parameter (e.g. failure rates, mean time to repair, and so on) is thus modified using a mathematical algorithm, where an overall parameter including all the SMS sections influencing each single parameter is defined.

The application of the procedure to a formaldehyde plant allowed the validation of the method and is here entirely reported.

Keywords: Safety management system; Quantitative risk assessment; SMS and QRA integration

1. Introduction

The analysis of accidents in major hazard plants, as well as research findings, have indicated that management and organizational factors play a very important role in the safety of these installations, often more than hardware failures (van Vuuren, 2000). In recent years, great efforts have been made in analysing the relationships between the management system and the safety level of the installation (Demichela, Piccinini & Romano, 2004).

In the works of Papazoglou and Aneziris (1999), Papazoglou et al. (2002), and Papazoglou, Bellamy, Hale, Aneziris, Ale, and Post (2003) the Safety Management System (SMS) was explicitly linked to the Quantitative Risk Assessment (QRA), in order to provide the necessary quantitative basis for making risk management decisions particular to each plant. Their integrated methodology consists of four parts:

1. Initiating event identification;
2. Event Tree/Fault Tree Analysis of the plant;
3. Modelling of the Safety Management System;
4. Modification of the frequency of Loss of Containment (LOC) according to the SMS.

In the present work, the whole procedure is not different from the literature one, but some modifications have been introduced at the 3rd and 4th step; they will be discussed in the related sections of the paper. An application to a formaldehyde plant is shown to illustrate the methodology.

In general terms, the expected number of occurrence of a Top Event (TE) can be expressed as a function of the following parameters:

– failure rates of the on-line or stand-by components (λ);
– human error probability (HE);
– test time (TT);

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0950-4230/$ - see front matter
doi:10.1016/j.jlp.2005.06.004

Nomenclature

ENF	Expected Number of Failures	m	weighted value of the SMS assessment, with reference to each reliability parameter
HE	Human Error	p	probabilistic parameter
LOC	Loss of containment	p_0	probabilistic parameter, literature value
MTTR	Mean Time to Repair	p_{max}	probabilistic parameter, maximum value
QRA	Quantitative Risk Assessment	p_{min}	probabilistic parameter, minimum value
ROA	Recursive Operability Analysis	w_i	weight of the ith SMS sub-section insisting over the probabilistic parameter
SMS	Safety Management System	y_i	judgment of the ith SMS sub-section insisting over the probabilistic parameter
TE	Top Event		
TT	Test Time		
λ	failure rate		
k	maximum allowed variation of the probabilistic parameter		

– mean time to repair the repairable components (MTTR).

In order to include in the risk assessment also organisational parameters, a relation within the SMS sections and the reliability parameters was investigated. It appears immediately clear that more than one organisational factor could have an influence over each probabilistic parameter.

Thus, a correction factor was defined for probabilistic parameters, taking into account the contribution of each organisational factor affecting them: it obviously should be a function of the 'judgment' on the correct management of the organisational factor and also of a parameter expressing its importance, namely a weight.

With the corrected probabilistic parameters it should be possible to compute an up-dated expected frequency of occurrence for the TE.

2. The QRA of the formaldehyde plant

The application of the procedure to a plant for the production of formaldehyde allowed the validation of the method.

The formaldehyde production is a consolidated process (see, as an example Faliks et al., 2001) made of two steps:

- catalytic (Mb oxides) oxidation of methanol with air, with the subsequent formation of gaseous formaldehyde;
- gaseous formaldehyde adsorbing in water (or water + urea) in order to obtain a 36% solution.

In Fig. 1 a sketch of the plant under analysis, located in the northern Italy, is reported.

Through the application of a Recursive Operability Analysis, ROA (Demichela, Marmo, & Piccinini, 2002; Piccinini & Ciarambino, 1997; Piccinini, Scarrone, & Ciarambino, 1994) the most significant TE was found to be the possible formation of an explosive mixture within methanol and air, due to the feed of liquid methanol to the reactor (in Table 1 an extract of the ROA).

The quantitative solution of the Fault Trees directly drawn from the ROA tables (Fig. 2) was then performed through the software ASTRA (Contini & de Cola, 1996; Contini, de Cola, Wilikens, & Cojazzi, 1998) and the failure rates taken from literature (AIChE, 1989; Lees, 1996; Procaccia, Arsenis, & Aufort, 1998) (Table 2).

With this classical approach the expected number of occurrence for the TE was found to be ENF $= 3.37 \times 10^{-03}$ occurrence/year.

3. The links between SMS and reliability parameters

A model of the SMS was then used to define the links between SMS and reliability parameters: this model is different from the one proposed in Papazoglou et al. (2002), as developed by Hale, Heming, Carthey, and Kirwan (1997), since it use as reference the SMS structure for 'Seveso II' installations, as defined in Mitchison and Papadakis (1999).

Each SMS section was subdivided in the relevant sub-sections and a weight was assigned to each of them, with reference to their influence on the probabilistic parameters.

The weights range from 0 to 3, the last representing the maximum influence. The weights assignment was made on the basis of general criteria, in order to obtain a table of broad validity. During the application some modifications were made to the table in order to better reflect the real situation; e.g. the control of the oxidation reactor requires a number of manual operations, thus to the 'Operational procedures and instructions' section a higher weight must be assigned with reference to the probability of human error.