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The bridge link between university and industry: A key factor for achieving high performance in process safety

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ABSTRACT

Process safety has undergone a tremendous growth over the last decades, both in terms of required competencies and in terms of market demand. Although its cultural background mainly consists of the traditional subjects of chemical and process engineering, a multi-faceted range of expertise has made it autonomous and different from the general chemical engineering frame: the interdisciplinary degree is much wider, the relevant regulations and standards have become so stringent and specific to become a key driver for the scientific and technical development of the discipline, its current growth trend is probably incomparable to others, role and functions of process safety engineers have acquired more significances and implications in the industrial scenario. This article considers the learning lessons of a long tutoring and teaching activity that the author has carried out in process safety between university and industry in Europe and in Asia. The findings have been analysed and converted into specific indicators and trend data, with the aim to contribute to reduce the significant gap which still exists in a branch of chemical engineering that is expected to increase its complexity and importance in the near future.

1. Introduction

Although many incidents had already left their mark on the industrial scenario, process safety revealed its full importance in chemical and process engineering in the seventies, when Flixborough (1974) and Seveso (1976) incidents showed the world the catastrophic potential of process industry (Mannan, 2005). Levels of complexity, depth of analysis, multidisciplinary approach, legal and ethical implications have so grown that this part of chemical engineering presents an opposite behaviour with respect to other disciplines, including its cultural mother, process engineering. In fact, the main peculiarity of process safety engineering is its great difficulty in being organised and structured according to relatively simple and well defined models which, instead, work much better within traditional chemical and process engineering. For the latter, combinations of transport phenomena theory and unit operations models are very effective in dealing with very complex momentum, heat and mass transfer process scenarios. Equilibrium thermodynamics and physical chemistry are generally adequate. Process industry has tailored its operations to minimise unsteady states and to properly manage transient behaviours.

Process safety is very far from this. A high level of unpredictability exists due to the probabilistic nature of risk. Time scales are generally much shorter than those

Abbreviations: ATEX, atmosphere explosive; BLEVE, boiling liquid expansion vapour explosion; CCPS, center for chemical process safety; CCS, carbon capture and storage; CEI, chemical exposure index; CLP, classification labelling packaging; FEI, fire exposure index; HAZID, hazard identification; HAZOP, hazard and operability study; J–T, Joule Thomson; IEC, International Electrotechnical Commission; IChemE, Institution of Chemical Engineers; KPI, key performance indicator; OSHA, Occupational Safety and Health Association; PRV, pressure relief valve; RHA, reactive hazard assessment.

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related to process engineering; and this tremendously affects the validity of equilibrium assumption (Johnson et al., 2000; Benintendi, 2014). Safety regulations and standards, for example OSHA (1992), ATEX (Official Journal of the European Communities, 1994), functional safety (International Electrotechnical Commission, 2004), chemical safety (CLP, Official Journal of the European Union, 2008), have increased their level of complexity, because process industry is at the same time the final user and the originator of safety issues; and the scientific world is engaged in providing the required solutions to current challenges. Specifically:

- risk tolerability is undergoing a progressive reduction
- reliability and requirements of models and techniques are more and more stringent
- the prescriptive approaches is being replaced the by risk based approaches
- inherent safety is a fundamental principle of the design phase.

On the basis of these considerations, this paper analyses the status of process safety engineering in terms of its real effectiveness in reducing major incidents. In the light of this analysis, the relationship between university and industry has been investigated and the reciprocal roles and functions have been discussed with the aim to increase the competencies of chemical engineers in the process safety scenario.

2. Objectives and methodology

Catastrophic incidents are the outcome of the combination of several factors which always include, as root causes, management and organisational failures and procedural and technical failures as immediate causes. The Dow Chemical incident assessment frame (Englund, 1990) includes these two different cause categories along with a *contributing causes* step. The importance of failure of organisational memory has been pointed out by several authors (Kletz, 1993; Jefferson et al., 1997). Actually, a fundamental key driver in loss prevention is the scientific and technical background of process safety engineers and the top management should take any necessary actions to ensure that the required expertise is achieved. For this purpose, a strong relationship with university and research world is essential.

This article has the following objectives:

(1) Identification of the key drivers of process safety engineers technical background
(2) Review of the relationship and cooperation between university and industry in the light of the engineers' performance and capabilities
(3) Definition of general criteria to assess the effectiveness of the educational system in achieving process safety targets
(4) Identification of a more specific bridge-link between the academic and the professional world.

The following methodology has been adopted:

(1) Analysis of the competencies gap has been carried out with the major incident case-history
(2) The chemical engineering educational frame has been assessed against the process safety requirements
(3) The general status of the university background has been analysed with the aim to identify any possible improvements.

In particular, the study has been conducted analysing and developing:

- the characteristics and the evolution of many incidents, including some major catastrophic scenarios
- data on the status of chemical engineers education and professional level, with specific reference to process safety
- the significant recommendations provided by teachers and institutional entities
- the writer's experience in tutoring junior engineers in process safety master courses

The findings have been compared with the real professional scenarios with the aim to identify the gaps and propose a specific partnership between university and industry. Finally, some indications have been provided in order to ensure that non-technical organisational and management levels take the required actions to strengthen this partnership.

3. Definition of a general lesson learned in cultural gap

In addition to organisational, procedural and management causes, the three major on-shore incidents, Flixborough (1974), Seveso (1976) and Bhopal (1984) can be related to a significant lack of technical competencies (Venart, 2004; Mannan, 2005). Substantial changes were made to the statics, the dynamics, and the flow in the assembly of Nypro plant, Flixborough. Even if senior technical staff was not on-site on Saturday, an embarrassing and unacceptable lack of technical competence of junior staff was identified. The final outcome of the incident of Seveso, Italy, several kilograms of dioxins being released to the atmosphere, was also due to a complete neglect of the potential effects of chlorinated compounds released to the atmosphere (Mannan, 2005). A similar lack of holistic and technical approach sometimes still affects HAZOP and other safety studies, when, for some reasons, arbitrary and unjustified limits and border lines are often assumed in the technical analysis, moving from causes to consequences, depending on the individual's expertise, on the facilitator's background and attitude, and on the accuracy of the analysis. Most of the root causes of these omissions are related to lack of competencies. The Dow Chemical Company is a highly reputable organisation also noted for its contribution to process safety and risk assessment. The CEI and FEI Dow indices are the most widely used indices since 1964 (Khan and Abbasi, 1998) and the first versions of the periodically upgraded Dow Chemical Hazard Engineering Guidelines (for example Englund, 1990) have probably been the first company literature source dealing with hazard identification and consequence assessment. However, the American company had two serious incidents in the fifties, which showed a significant gap in its technical background. On the 16th Feb 1950, an explosion occurred at the Latex Plant (Michigan Division), the root causes of which were an inadequate process technology and the presence of flammable material processed in an enclosed building. On the 3rd April 1955, the acrylamide reactor blew up at the Dow Acrylamide Plant (Michigan Division). By mistake, it was loaded with acrylonitrile and sulphuric acid but the agitator off.