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Eddy De Rademaeker, Georg Suter, Hans J. Pasma, Bruno Fabiano. *A review of the past, present and future of the European loss prevention and safety promotion in the process industries.*

In 2013, the European Federation of Chemical Engineering (EFCE) celebrates its 60th anniversary. EFCE has continually promoted scientific collaboration and supported the work of engineers and scientists in thirty European countries. As for its mission statement, EFCE helps European Society to meet its needs through highlighting the role of Chemical Engineering in delivering sustainable processes and products. Within this organizational framework the Loss Prevention Symposium series, organized throughout Europe on behalf of the Loss Prevention Working Party of the EFCE, represents a fruitful tradition covering a time span of forty years. The tri-annual symposium gathers experts and scientists to seek technical improvements and scientific support for a growingly safer industry and quality of life. Following the loss prevention history in this paper, a time perspective on loss prevention and its future is presented.

- **Keywords:** Loss prevention; Resilience; Process safety research; Inherent safety; Blended Hazid

Paul R. Amyotte. *Some myths and realities about dust explosions.*

The necessary conditions for a dust explosion to occur are well-expressed by the explosion pentagon: (i) fuel, (ii) oxidant, (iii) ignition source, (iv) mixing of the fuel and oxidant, and (v) confinement of the resulting mixture. While it might seem relatively straightforward to prevent or mitigate a dust explosion by simply removing one of the pentagon elements, the field of dust explosion risk reduction is more complex. Building upon previous work by the author and other dust explosion researchers, the theme of the current paper is that this complexity is partially rooted in several erroneous beliefs. These beliefs ignore the realities found with full consideration of appropriate scientific and engineering principles. Several such myths and their factual counterparts are presented with an illustrative example.

- **Keywords:** Dust explosions; Prevention; Mitigation; Explosion pentagon; Myths; Realities

Martin Glor, Carsten Blum, Wolfgang Fath, Claus-Diether Walther. *Electrostatic ignition hazards in insulating or dissipative tubes and hoses*

for pneumatic transfer of powders : measurements and model calculations.

When transferring powder through pipes or hoses made from insulating material, propagating brush discharges cannot be excluded. To calculate the limit value of the resistivity of the insulating material, below which no propagating brush discharges will occur, the charging current due to the powder transfer must be known. This charging current has been determined experimentally. Based on analytical calculations and computer models limit values for the resistivity of the hose material are derived from these experiments.

- **Keywords:** Electrostatics; Dust explosion; Pneumatic transfer; Tubes and hoses; Propagating brush discharges

Abdelkarim Habib, Bernd Schalaus, Dirk Schmidt. Comparing tools of varying complexity for calculating the gas dispersion.

When handling flammable and/or toxic liquids or gases, the gas dispersion following a release of substance is a scenario to be considered in the risk assessment to determine the lower flammability distance (LFD) and toxicity thresholds. In this work a comparison of different gas dispersion tools of varying complexity ranging from a simple Gaussian model over a boundary layer model (BLM) and a Lagrangian model to CFD (in this case ANSYS CFX v14) is presented. The BLM covers the special case of liquid releases with formation of a pool. It does not only solve the gas dispersion but also calculates the evaporating mass flow out of the pool. The simulation values are compared to each other and to experimental data resulting mainly from our own open air experiments covering the near field and carried out on the Test Site Technical Safety of BAM (BAM-TTS) for different release types (pool evaporation, gas release) and topologies. Other validation data were taken from literature and cover large scale experiments in the range of several 100 m.

- **Keywords:** Gas dispersion; Modeling; CFD; Hazard assessment; Gauss; Lagrange

Agnès Janès, Alexis Vignes, Olivier Dufaud, Douglas Carson. Experimental investigation of the influence of inert solids on ignition sensitivity of organic powders.

This work presents the results of the experimental characterization of the ignition sensitivity of solid inertant/combustible powders mixtures. Three inert solids (alumina, Kieselguhr, aerosil) and eleven organic powders have been considered and the following parameters have been determined: (1) the minimum ignition energy, (2) the minimum ignition temperature in cloud and (3) the minimum ignition temperature in 5 mm layer. The effects of the addition of inert solids are described and a simple model is proposed to represent the experimental results. Generally, increasing inert solid content in a powder leads to a higher minimum ignition energy as well as a higher minimum ignition temperatures in cloud and in layer. In some cases, the flammability is influenced above a threshold concentration value, which can be quite high (up to 85 wt.%). Indeed, the proposed model shows a zone below the minimum ignition concentration (MIC), which does not enable an efficient or safe inerting: either the admixed inert solid does not provide a sufficient effect, or it can even facilitate the ignition of the dust by notably improving its dispersability. The influence of key parameters such as the thermal conductivity or optical properties on the efficiency of the inerting by admixed solid need to be further assessed in a future work in view to better understand the mechanisms involved and to extend the scope to other types of oxidizable materials.

- **Keywords:** Dust explosion; Ignition; Solid inertant; Organic powder; Experimental investigation

Alan G. King. *SIL determination : recognising and handling high demand mode scenarios.*

The International Standards for Functional Safety (IEC 61508 and IEC 61511) are well recognised and have been adopted globally in many of the industrialised countries during the past 10 years or so. Conformance with these standards involves determination of the requirements for instrumented risk reduction measures, described in terms of a safety integrity level (SIL). During this period within the process sector, layer of protection analysis (LOPA) has become the most widely used approach for SIL determination. Experience has identified that there is a type of hazardous event scenario that occurs within the process sector that is not well recognised by practitioners, and is therefore not adequately handled by the standard LOPA approach. This is when the particular scenario places a high demand rate on the required safety instrumented function. This paper will describe how to recognise a high demand rate scenario. It will discuss what the standards have to say about high demand rates. It will then demonstrate how to assess this type of situation and provide a case study example to illustrate how to determine the necessary integrity level. It will conclude by explaining why it is important to treat high demand rate situations in this way and the resulting benefit of a lower but sufficient required integrity level.

- **Keywords:** SIL determination; IEC 61508; IEC 61511; Layer of protection analysis; LOPA; High demand rate

Konstantinos Kirytopoulos, Myrto Konstandinidou, Zoe Nivolianitou, Konstantinos Kazaras. *Embedding the human factor in road tunnel risk analysis.*

The paper is focusing on road tunnel safety and builds upon the Directive 2004/54/EC launched by the European Commission; the latter sets basic requirements and suggests the implementation of risk assessment in several tunnel cases apart from technical measures imposed on the basis of tunnel structural and operational characteristics. Since the EU Directive does not indicate the method for performing risk assessment, a wide range of methods have been proposed, most of them based on quantitative risk assessment (QRA). Although the majority of current road tunnel QRAs assess physical aspects of the tunnel system and consider several hazards concerning the transportation of dangerous goods through a tunnel, they do not take into account, sufficiently, several organizational and human-related factors that can greatly affect the overall safety level of these critical infrastructures. To cope with this limitation this paper proposes a fuzzy logic system based on CREAM method for human reliability analysis (Hollnagel, 1998) in order to provide more sophisticated estimations of the tunnel operator's performance in safety critical situations. It is deduced that a human reliability analysis component to analyze operator performance, like the fuzzy system proposed here, is important for risk analysts. Consideration of organizational and human factors will enhance risk analysts' studies and highlight the uncertainty related to human performance variability.

- **Keywords:** Road tunnels; Directive 2004/54/EC; Fuzzy systems; CREAM; Risk analysis; Uncertainty representations; HRA

Adam Stanisław Markowski, Dorota Siuta. *Fuzzy logic approach to calculation of thermal hazard distances in process industries.*

In this paper, a general procedure to deal with uncertainties in each stage of consequence modeling is presented. In the first part of the procedure, the sources of uncertainty are identified and confirmed by sensitivity analysis for the source term, dispersion, physical effects and consequence analysis. While the second part comprises an application of the fuzzy logic system to each step of the consequence modeling. The proposed procedure is verified by the case study for a pool fire liquefied natural gas

(LNG) on water. The results in terms of thermal radiation distances are compared with calculations obtained using the Monte Carlo method and with experimental data. The consequence model based on fuzzy logic approach provides less uncertain and more precise results in comparison to the deterministic consequence model.

- **Keywords:** Hazard distances; LNG; Fuzzy logic system; Monte Carlo simulation; pool fire; uncertainty

Peter Okoh, Stein Haugen. *A study of maintenance-related major accident cases in the 21st century.*

This paper is based on a review of 183 detailed, major accident investigation and analysis reports related to the handling, processing and storage of hydrocarbons and hazardous chemicals over a decade from 2000 to 2011. The reports cover technical, human and organizational factors. In this paper, the Work and Accident Process (WAP) classification scheme is applied to the accident reports with the intention of investigating to what extent maintenance has been a cause of major accidents and what maintenance-related causes have been the most frequent. The main objectives are: (1) to present more current overall statistics of maintenance-related major accidents, (2) to investigate the trend of maintenance-related major accidents over time, and (3) to investigate which maintenance-related major accident causes are the most frequent, requiring the most attention in the drive for improvement. The paper presents statistical analysis and interpretation of maintenance-related major accidents' moving averages as well as data related to the types of facility, hazardous substances, major accidents and causes. This is based on a thorough review of accident investigation reports. It is found that out of 183 major accidents in the US and Europe, maintenance was linked to 80 (44%) and that the accident trend is decreasing. The results also show that "lack of barrier maintenance" (50%), "deficient design, organization and resource management" (85%) and "deficient planning/scheduling/fault diagnosis" (69%) are the most frequent causes in terms of the active accident process, the latent accident process and the work process respectively.

- **Keywords:** Maintenance; Major accident; Statistics; Hydrocarbon; Chemical; Process

Emilio Palazzi, Fabio Currò, Andrea Reverberi, Bruno Fabiano. *Development of a theoretical framework for the evaluation of risk connected to accidental oxygen releases.*

A short-cut methodology for a fast estimation of hazards from oxygen releases and the evaluation of safety distances is presented. Starting from a historical survey on accidents involving oxygen releases and consequent scenarios, the approach includes analytical models for the quantification of incremental hazards due to oxygen releases, in non-obstructed areas, both for continuous and nearly instantaneous scenarios, adopting a simple Gaussian dispersion model. An example of the application of the model in a real case-study and relevant quantitative results are presented.

- **Keywords:** Accident statistics; Carbon capture sequestration; Gas pipeline; Hazardous release; Oxycombustion; Flammable limits

Nico H.W. van Xanten, Chris M. Pietersen, Hans J. Pasma, Pieter van der Torn, Han K. Vrijling, Ariën J. van der Wal, Jan G.M. Kerstens. *Risk evaluation in Dutch land-use planning.*

In Dutch external safety policy, the acceptance of risk for the population in areas surrounding hazardous substances establishments is based on a limit value for individual risk (IR). Additionally, changes to societal risk (SR) must be justified. A specific software

program (SAFETI-NL) with the associated Reference Manual Bevi Risk Assessments (RIVM, 2009) is legally required for the calculation of IR and SR. This prescribed "Bevi calculation method" forms the basis for decisions with important consequences for industry, land use planning and the protection of citizens. It is important that the outcome of calculations made with the prescribed method can be relied upon when making decisions about land use planning that affects both industry and population. This is the subject of this paper. The prescribed calculation method has been evaluated by performing a case study. The evaluation focussed on risk modelling of a Boiling Liquid Expanding Vapour Explosion (BLEVE) at an LPG filling station, an incident type that plays a significant role in Dutch external safety. The risk modelling of the BLEVE with the prescribed calculation method was found to have a number of serious deficiencies. It is concluded that the prescribed calculation method yields no reliable perspective on the safety of production, use and storage of hazardous substances, nor of possibilities to increase safety. Decision making should not only depend on quantification of IR and SR. Improving the safety-relevance of the prescribed calculation method requires an increase of the number of dimensions of the outcome of risk calculations in order to make feedback possible. It is recommended to incorporate additional, safety-relevant information into planning and decision-making processes. It is envisaged that a more far-reaching change of Dutch QRA practice is needed (medium to long term). In this context, a number of interesting elements have been noticed in decision-making procedures in other EU Member States.

- **Keywords:** Risk evaluation; Land-use planning; Safety relevance; Relative vs. absolute use of risk calculations; Hazardous substances; BLEVE