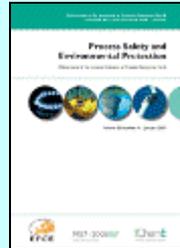


## Process Safety and Environmental Protection

rok 2013, ročník 91

Číslo 3 (May 2013)



**Ahmed Badreddine, Nahla Ben Amor. *A Bayesian approach to construct bow tie diagrams for risk evaluation.* Pages 159–171.**

Bow tie diagrams have become a popular method for risk analysis and safety management. This tool describes the whole scenario of a given risk graphically, and proposes preventive and protective barriers to reduce, respectively, its occurrence and its severity. The weakness of bow tie diagrams is that they are restricted to a graphical representation of different scenarios exclusively designed by experts that ignore the dynamic aspect of real systems. Thus, constructing bow tie diagrams in an automatic and dynamic way remains a real challenge. This paper proposes a new Bayesian approach to construct bow tie diagrams from real data and improve them by adding a new numerical that enables us to implement the appropriate preventive and protective barriers in a dynamic manner.

- **Keywords:** Bow tie diagrams; Risk evaluation; Bayesian networks; Analytic Hierarchical Process

**Ming Yang, Faisal I. Khan, Rehan Sadiq, Paul Amyotte. *A rough set-based game theoretical approach for environmental decision-making: A case of offshore oil and gas operations.* Pages 172–182.**

Environmental decision-making in offshore oil and gas (OOG) operations can be extremely complex due to conflicting objectives or criteria, availability of vague and uncertain information, and interdependency among multiple decision-makers. Most existing studies ignore conflicting preferences and strategic interactions among decision-makers. This paper presents a game theoretical approach to solve multi-criteria conflict resolution problem under constrained and uncertain environments. Uncertainties in the quantification of imprecise data are expressed using rough numbers. A multi-criteria

game is developed to model a decision problem in which three groups of decision-makers (i.e., operators, regulators and service engineers) are involved. This game is solved using the generalized maximin solution concept. With the solution (i.e., optimal weights of the criteria), the rough numbers can be aggregated to an expected payoff for each alternative. Finally, the weights of upper and lower limits of a rough number are employed to transform the expected payoff into a crisp score, based on which all alternatives are ranked to identify the best one. A numerical example is outlined to demonstrate the application of the proposed method to the selection of management scenarios of drilling wastes.

- **Keywords:** Environmental decision-making; Game theory; Rough set; Offshore oil and gas (OOG)

**P. Holbrow. *Dust explosion venting of small vessels and flameless venting*. Pages 183–190.**

Dust explosion venting is an established method of protecting against damaging explosion over-pressures, and guidance is available for many industrial situations. However, there is a need to: (a) establish the venting requirements of small vessels and whether current guidance and predictions in [BS EN 14491:2006](#) need revising, and (b) improve understanding of the potential and limitations of flameless venting. This paper describes initial results from an ongoing programme of research.

Small vessel tests are carried out using cornflour and wood dust on: a commercial sieve unit, a commercial cyclone, and a 0.5 m<sup>3</sup> test vessel with explosion-relief openings without vent covers. Initial 0.5 m<sup>3</sup> vessel tests give reduced explosion pressures that are lower than those predicted. This is because the predicted pressures are based on openings with vent covers. The reduced explosion pressures measured in the sieve unit and the cyclone are also less than predicted: the reasons are discussed.

Flameless venting tests are carried out using cornflour and wheat flour on a commercial flame arrestor unit. Initial tests demonstrate benefits, particularly a high level of flame extinguishment, but a problem of reduced venting efficiency compared to conventional venting.

These initial results indicate that further research is needed.

- **Keywords:** Dust explosion; Venting; Flameless venting

**A.D. Galeev, E.V. Starovoytova, S.I. Ponikarov. *Numerical simulation of the consequences of liquefied ammonia instantaneous release using FLUENT software.* Pages 191–201.**

A mathematical model for the estimation of the toxic impact zones in case of instantaneous release of liquefied ammonia to the atmosphere is presented. The model includes the description of toxic gas inflow due to evaporation and its dispersion in the atmospheric surface layer. The model is based on the numerical solution of three-dimensional transient equations of hydrodynamics, mass and energy transfer. The modeling procedure was implemented by using FLUENT software. The model takes into account the impact of aerosols on cloud dispersion dynamics, as well as the time-varying inflow of ammonia from the pool during boiling and evaporation. A numerical analysis of the wind speed and obstacle influence on the characteristics of the toxic impact zones in case of instantaneous release of liquefied ammonia was carried out. The boundaries of ammonia impact zones were determined by the values of inhalation toxic doses. The function of vaporization rate variation during boiling and evaporation of the pool and the function of the toxic dose calculation are integrated into FLUENT code by means of user-defined functions (UDF).

- **Keywords:** Accidental release; Liquefied ammonia; Boiling; Evaporation; Gas dispersion; Numerical simulation

**L.C. Tsai, C.W. Chiu. *Full-scale experimental studies for backdraft using solid materials.* Pages 202–212.**

The backdraft experiments involved three full-scale room fire tests that used solid furnishing, loveseats. From experimental data, a backdraft caused two temperature peaks. The first one was below 600 °C. Then, an abrupt opening of the front door led to a supply of a large amount of fresh air, followed by an indication of sudden temperature rise. The second peak temperature was over 600 °C. Meanwhile, the deflagration resulted in the gases heating and expanding within the fire space, thus forcing unburned gases out of the vent ahead of the flame front. Comparing both cases with natural gas and solid loveseat as the fuel in backdraft, the former can achieve pre-mixture state and readily create an instant explosion wave phenomenon; however, this wave disappeared immediately. On the other hand, the solid loveseat used as the fuel in this study produced backdraft within 30–50 s after opening of the door. After the occurrence of backdraft, fire maintained a period of fully developed stage, which was consistent with the conditions in actual fires.

- **Keywords:** Backdraft; Full-scale; Flame-front; Pre-mixture state; Explosion wave

**Jianfeng Li, Sandra M.Y. Lee, Wenmao Liu. *Emergency response plans optimization for unexpected environmental pollution incidents using an open space emergency evacuation model.* Pages 213–220.**

The objective of this research is to model the crowd evacuation process providing dynamic spatial–temporal distribution information, which can minimize the human exposure risk (death or casualties) on the population implied by a specific evacuation policy when he or she was exposed to adverse effects under accidents. An open space evacuation model based on the stochastic Markov process was introduced here to estimate the spatial–temporal distribution of the evacuees during evacuation covering the estimation of affected areas, space discretization, nodes and links creation, etc. Then, according to the solution of the Markov process providing the expected distribution of the evacuees in the nodes of the area as a function of time and the dose–response relationship, the people's health effects (e.g., death, several kinds of injuries, etc.) suffered in the evacuation process can be calculated, so that the accident's health consequence can be determined. Finally, different emergency response policies can be evaluated with corresponding health consequence, so that the emergency policy can be optimized.

- **Keywords:** Heavy gas diffusion; Numerical simulation; Crowd evacuation; Emergency rescue; Stochastic Markov model

**Rowena Ball, Brian F. Gray. *Thermal instability and runaway criteria: The dangers of disregarding dynamics.* Pages 221–226.**

Two exemplary exothermic processes, synthesis of nitroglycerine in a continuous stirred tank reactor (CSTR) and synthesis of the explosive RDX in a CSTR, are used to demonstrate the dangers of ignoring the system dynamics when defining criteria for thermal criticality or runaway. Stability analyses are necessary to prescribe such criteria, and for these systems prove the presence of dangerous oscillatory thermal instability which cannot be detected using the steady state thermal balances.

- **Keywords:** Thermal runaway; Stability analysis; Oscillatory thermal instability

**Tae-In Ohm, Jong-Seung Chae, Seung-Hyun Moon, Bong-Jin Jung. *Experimental study of the characteristics of solid fuel from fry-dried swine excreta.* Pages 227–234.**

Swine excreta were dried by boiling via immersion in hot oil. In this method, moisture in the excreta is replaced with oil or evaporated by turbulent heat transfer in high-temperature oil. The dried excreta can be used in an incinerator like low-rank coal or

solid fuel. Refined waste oil and B–C heavy oil were used for drying. Drying for 8 min at 150 °C reduced the water content of raw excreta from 78.90 wt.% to 1.56 wt.% (refined waste oil) or 1.62 wt.% (B–C heavy oil) and that of digested excreta from 79.58 wt.% to 3.40 wt.% (refined waste oil) or 3.48 wt.% (B–C heavy oil). The low heating values of the raw and digested excreta were 422 kJ/kg and –2,713 kJ/kg, respectively, before drying and 27,842–28,169 kJ/kg and 14,394–14,905 kJ/kg, respectively, after drying. A heavy metal analysis did not detect Hg, Pb, Cd, As, and Cr in the dried excreta, but Al, Cu, and Zn, which occur in the feed formula, were detected. Thermogravimetric analysis before and after drying revealed that emission of volatiles and combustion of volatiles and fixed carbon occurred at temperatures of 250–500 °C when air was used as the transfer gas.

- **Keywords:** Swine excreta; Combustion; Fry-drying technology; Waste-derived solid fuel

**Hui-Ling Fan, Ju Shangguan, Li-Tong Liang, Chun-Hu Li, Jian-Ying Lin. A comparative study of the effect of clay binders on iron oxide sorbent in the high-temperature removal of hydrogen sulfide. Pages 235–243.**

The purpose of this study is to investigate the effect of clay binder, an important additive, on the performance of iron oxide sorbent in high temperature coal gas desulfurization. The four clay binders chosen for the study were kaolinite, diatomite, bentonite and brick clay. The sulfidation–regeneration cycles were conducted in a fixed-bed reactor. XRD, DTA and FTIR, together with texture characterizing techniques, such as mercury porosimetry and nitrogen adsorption, were adopted to characterize the sorbents and raw materials. The results obtained show that sorbents prepared from various clay binders exhibit different breakthrough behaviors. In addition, a correlation between pore volume and sulfur capacity reveals that sorbents with a greater number of pores larger than 200 nm (diameter), exhibit higher sulfur capacity. The reason for this is that a greater number of large pores can improve diffusion and provide a larger space for relieving heat impact. However, too many large pores may result in weak strength and very low bulk density, thus a balance between large pores and the density must be achieved. This study also reveals that clay binder can contribute to the modification of a sorbent's texture as gas is released when the mineral structure changes during calcination. In addition, a clay mineral with an active interlayer has been shown to be beneficial in improving the dispersion of active components in the sorbent, because of the existence of an interaction between the mineral and red mud.

- **Keywords:** Clay binder; Influence; Iron oxide sorbent; High-temperature desulfurization