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N. Piccinini, R. Tommasini, E. Pons. *Large N.G. explosion and fire involving several buried utility networks. S. 73-80.*

This paper describes an accident (explosion and natural gas fire) that occurred in Turin (Italy), in which power distribution cables, tramway network feeding cables and a gas pipe were involved. The described accident is particularly interesting because it occurred in the town centre and lasted several hours, producing a very high risk for the population. Fortunately, nobody was injured, but 120 people were evacuated for 24 h. The sequence of events is described, the involved facilities are examined and the physical processes which led to the different top events are discussed. Actually, starting from a modest event (600 V electric cable loss of insulation), which most likely lasted for months, the aforementioned accident was reached in a crescendo of domino effects. This sequence has been represented by an ISD in which the failure of the different protection systems is highlighted. These protection systems were mostly based upon the strict respect of procedures both in the installation and in the following maintenance of the different utilities. These aspects have been also briefly devised in the light of Italian and foreign regulations concerning the problem of the coexistence of buried utilities.

- **Keywords:** Natural gas; Explosion and fire; Buried utility networks; Accident analysis

R.D. Jones, P.J. Thomas. *Calculating the life extension achieved by reducing nuclear accident frequency. S 81-86.*

Improvements in nuclear safety are often achieved through introducing a new safety measure that reduces the frequency of a hazardous accident rather than its consequences. To carry out a J-value analysis, it is necessary to calculate how a reduction in accident frequency extends the life expectancy of the potentially exposed group of people. The paper presents two methods for calculating the loss of life expectancy associated with accidents of a certain severity occurring with a defined frequency. The first begins by using an equivalent, prolonged radiation exposure to represent the effects of the accident occurring once per year over the given period of operation. The resultant loss of life expectancy is then scaled by multiplying by the frequency of occurrence. The second method calculates the loss of life expectancy brought about by a single accident occurring during the given period of operation and scales this by multiplying by both the length of the operational period and the frequency of occurrence. Results derived using the first method show that there is a relatively small

effect on loss of life expectancy per accident if several accidents are assumed to occur during a typical period of operation. This conclusion permits a simple assessment of the effect of possible, multiple accidents. The accuracy of the second method is found not to be compromised materially by ignoring the possibility of multiple accidents. The second method is shown to be slightly more conservative than the first, and also somewhat more accurate. Calculations of the loss of life expectancy may be carried out before and after the new safety improvement has been implemented, and the difference between the two results will be the life extension brought about by the new safety measure.

- **Keywords:** Health; Safety; Nuclear; Radiation; Accident frequency; Life expectancy; Risk; J-Value

Kai-Tai Lu, Peng-Chu Lin. *Study on the stability of nitroglycerine spent acid.* S. 87-93.

Nitroglycerine has been widely used as an ingredient of explosives and propellants for a long time. It is produced by the glycerine nitration reaction. Many explosions have occurred during handling or storing spent acid after separating nitroglycerine from the reactor in nitroglycerine factories. Safety charts have been constructed by various authors in order to cope with these hazards. In this investigation we construct enthalpy diagrams that correspond with the safety charts produced by earlier researchers. These can be used to evaluate the variation of heat and the safety composition during the handling of spent acid. Furthermore, this study uses practical operating conditions at nitroglycerine factories to evaluate the stability of spent acids in storage.

- **Keywords:** Nitroglycerine; Spent acid; Enthalpy diagrams; Safety; Stability

Fuman Zhao, William J. Rogers, M. Sam Mannan. *Experimental measurement and numerical analysis of binary hydrocarbon mixture flammability limits.* S. 94-104.

The flammability limits of binary hydrocarbon mixtures in air were measured in a combustion apparatus using an innovative method developed for this apparatus. The experimental results were obtained at standard conditions (room temperature and ambient atmospheric pressure) with upward flame propagation. The experimentally determined flammability limits for pure hydrocarbons (methane and ethylene) were compared with existing data reported in the literature. Le Chatelier's Law was fit to all experimental data to obtain LFLs and UFLs for various two-component combinations of saturated and unsaturated hydrocarbons (methane, ethylene, acetylene, propane, propylene, and *n*-butane). A modification of this law was used if experimental observations showed large deviations from Le Chatelier's predictions. Also, experimentally measured flammability limit data of the binary hydrocarbon mixtures were analytically related to the stoichiometric concentrations.

- **Keywords:** Flammability limits; Experimental measurement; Numerical analysis; Binary hydrocarbon mixtures; Le Chatelier's Law

Francis Stoessel. *Planning protection measures against runaway reactions using criticality classes.* S. 105-112.

A systematic approach to the assessment of thermal risks linked with the performance of exothermal reactions at industrial scale was proposed a long time ago. The approach consisted of a runaway scenario starting from a cooling failure and a classification of these scenarios into criticality classes. In the mean time these tools became quite popular and many chemical companies use them. Recently, the international standard IEC 61511 required the use of protection systems with reliability depending on the risk level. Since the criticality classes were developed as a tool for the choice of risk reducing

measures as a function of the criticality, it seems obvious that the criticality classes may be used in the context of the standard IEC 61511, which provides a relation between the risk level and the reliability of protection systems. Firstly, the runaway scenario and the criticality classes will be shortly described. Secondly, the assessment criteria for severity and probability of occurrence of a runaway scenario will be described together with the required data and their interpretation in terms of risk. Thirdly, the assessment procedure is exemplified for the different criticality classes. Finally, the design of protection measures against runaway and the required IPL and SIL are based on the risk assessment obtained from the criticality classes. This approach allows minimising the required data set for the safety assessment and for the definition of the protection system designed in order to avoid the development of the runaway.

- **Keywords:** Runaway reaction; Risk assessment; Criticality; Safety integrity level

Ozcan Arslan. *Quantitative evaluation of precautions on chemical tanker operations.* S. 113-120.

Large quantities of liquid chemicals are carried by chemical tankers all over seas. Chemical cargoes have different properties and chemical tankers are complex ships that are designed to carry different types of chemical cargoes. Carriage of chemical cargoes contains different hazards both for human life and marine environment. There are several cargo operations that are regularly done on chemical tankers such as loading, discharging, inerting, washing tanks, sampling, and freeing gas. These operations constitute their own risks. Therefore, risk assessment has become a critical issue in maritime industry. The present investigation of this study is attempting to examine the priorities of precautions that are taken by chemical tankers before, during, and after cargo operations. Analytic hierarchy process (AHP) is used for prioritizing the precautions in order to clarify the risk assessment option that will be used for pro-active approach to prevent marine casualties. The main aim of this study is to identify an appropriate management tool to increase the level of safety for chemical tankers during cargo operations at a terminal by using the results of AHP application.

- **Keywords:** Safety; Chemical tanker; Risk assessment; AHP; Maritime; Transportation

M.A. Batiha, A.A.H. Kadhum, A.B. Mohamad, M.S. Takriff, Z. Fisal, W.R. Wan Daud, M.M. Batiha. *Modeling the fate and transport of non-volatile organic chemicals in the agro-ecosystem : a case study of Cameron Highlands, Malaysia.* S. 121-134.

Many pesticides used in agricultural activities are considered environmentally non-volatile. The main purpose of this paper is to develop multimedia model to be used as a tool to predict the overall fate and transport of non-volatile organic chemicals (NVOs) dynamic in the agro-ecosystem. The model was developed based on the Equilibrium Criterion (EQC) model for type 2 chemicals introduced by Mackay and colleagues in 1996. Mackay's model only considered four environmental compartments, which are air, water, soil and sediment. The present model adds the vegetation compartment, in addition to previous compartments that shape the agro-ecosystem. The vegetation compartment is described by two sub-compartments consisting of the above ground plant (AGP) and roots. The model was parameterized for the Cameron Highlands region, Malaysia, and runs with an illustrative emission rate of 1 kg h^{-1} into the air for three selected pesticides, namely, mancozeb, spinosad and chlorosulfuron. The simulation results with and without vegetation compartment were compared. The estimated results indicating that the AGP captures 99.9% of introduced NVOs (i.e., of 100% or 1 kg h^{-1}) and transfers them to the ground below due to the slight degradation losses of $10^{-4}\%$ and the non-volatility property of the evaluated chemicals. Root uptake of chlorosulfuron accounted the highest removal process from soil while degradation of spinosad in the soil

is the major loss mechanism. Leaching to groundwater loss for mancozeb is about 2-fold greater than that of degradation, which together accounted the major removal process from soil. Based on the estimated results of mass distribution on the overall system, vegetation compartment accumulates 0.04%, 0.5% and 2.02% of the mancozeb, spinosad and chlorosulfuron, respectively.

- **Keywords:** Agricultural pollution; Mass balance model; NVOCs; Pesticide; Vegetation

R. Kikuchi, Y. Pelovski. *Low-dose irradiation by electron beam for the treatment of high-SO_x flue gas on a semi-pilot scale : consideration of by-product quality and approach to clean technology.* S. 135-143.

Attention has been focused on the treatment of lignite-fired flue gas in order to use lignite in an environmentally friendly way – (i) low-CO₂ emission, (ii) production of a valuable by-product, (iii) no discharge of wastewater, (iv) direct removal of SO₃ (strong toxicity), and (v) treatment of high SO₂ concentration. Based on these criteria, electron beam irradiation with ammonia injection was tested on a semi-pilot scale: 800 Nm³ h⁻¹ flow rate, 5500 ppm SO₂, 70 ppm NO_x, 22% flue gas moisture, and 75–80 °C at the reactor outlet. As an energy-saving measure, a low dose (5 kGy) of irradiation was applied: the problem lay in the by-product quality. It is considered that (NH₄)₂SO₃ and NH₄HSO₃ produced by thermal reactions are oxidized to form (NH₄)₂SO₄ (fertilizer) by an electron beam. However, not all reactions were complete because the by-product contained small amounts of H₂SO₄ and NH₂SO₃NH₄ (herbicide), so a vegetable pot test was performed to study the by-product quality: no adverse effect was observed. It is inferred from the pot test that slightly acidic soil may protect vegetables from disease and a small amount of NH₂SO₃NH₄ probably affects woody species and not herbaceous species. It is concluded that the electron beam system is noted as a multi-component pollution control process (removal of NO_x, SO₃, SO₂ and dioxins) and this system will contribute to environmentally friendly use of lignite as well as agricultural productivity via fertilizer supply.

- **Keywords:** Electron beam processing; Emission control; Flue gas desulfurization; Lignite combustion; Nitrogen fertilizer