

3D RISK MANAGEMENT FOR HYDROGEN INSTALLATIONS (Hy3DRM)

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ABSTRACT

This paper introduces the 3D Risk Management (3DRM) concept for hydrogen installations (Hy3DRM). The 3DRM framework entails an integrated solution for risk management that combines a detailed site-specific 3D geometry model for a system, a computational fluid dynamics (CFD) tool for simulating accident scenarios involving dispersion, fire and explosions, and a methodology for frequency analysis and quantitative risk assessment (QRA). In order to reduce calculation time, and to cover escalating accident scenarios such as structural collapse and projectiles, the CFD-based consequence analysis can be complemented with reduced order models or finite element analysis (FEA). The paper outlines the background for 3DRM and presents a proof-of-concept risk assessment for a hypothetical hydrogen filling station. This first prototype focuses on dispersion, fire and explosion scenarios resulting from loss of containment of gaseous hydrogen. The approach adopted here combines consequence assessments obtained with the CFD tool FLACS-Hydrogen from Gexcon, and event frequencies estimated with the Hydrogen Risk Assessment Models (HyRAM) tool from Sandia, to generate 3D risk contours for explosion pressure and radiation loads. For a given population density and set of harm criteria it is straightforward to extend the analysis to include personnel risk, as well as risk-based design such as detector optimization. The discussion outlines main challenges and inherent limitations of the 3DRM concept, as well as possibilities and prospects for future development.

1. INTRODUCTION

1.1 Hazards and safety

Extraction, conversion, storage and use of energy play a fundamental role for the advancement of modern societies, and will continue to do so in the foreseeable future. Humankind will consume energy commodities at a growing rate due to population growth and improvements in the standard of living. While the global reserves of fossil fuels diminish, continued release of carbon dioxide on a massive scale is likely to influence the global climate. Hence, the energy infrastructure needs a shift towards increased use of renewable energy sources, such as wind, hydroelectric and solar, as well as more sustainable use of conventional hydrocarbons (e.g. carbon capture and storage). In this perspective, the International Energy Agency (IEA) [1] and the European Commission (EC) [2] foresee that hydrogen will play an increasingly important role as energy carrier, providing environment-friendly energy to end-users. However, widespread acceptance and use of hydrogen in society will require significant progress in the field of hydrogen safety – the discipline of science and engineering that deals with safe production, handling and use of hydrogen in industry and society in general [3]. Several characteristic properties of hydrogen differ significantly from conventional fuels: a tendency to cause embrittlement in metals, very low boiling point and density, very low ignition energy, wide flammability range, high rate of combustion, and a propensity to undergo deflagration-to-detonation-transition (DDT). Hence, fires and explosions represent a significant hazard for hydrogen installations, and special measures are required for reducing the risk to an acceptable level. This applies to relatively simple systems, such as fuel cells, vehicles and filling stations, as well as complex industrial facilities, such as nuclear power plants. The recurrence of low-probability high-consequence events in complex systems is well documented and possibly ‘normal’ [4]. Common features of many industrial disasters include a relatively limited understanding of the actual hazard prior to the event, an escalating chain of sub-events, severe losses, and significant changes to safety standards and legislation for industry [5].

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