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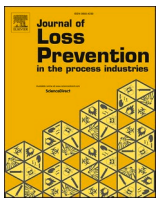

Process & occupational safety integrated inherently safer chemical plant design: Framework development and validation

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ABSTRACT

Chemical plants encompass diverse chemical and non-chemical hazards that can potentially lead to accidents. Consequently, it is imperative to implement appropriate risk management strategies to effectively reduce these hazards. Inherent safety, with its emphasis on eliminating hazards at source, has resulted in notable success in generating safer process routes. Conventional inherent safety methodologies are limited to optimizing process designs by reducing chemical and process hazards; however, occupational safety hazards (e.g., burns, electrocutions, drowning, and vehicle incidents) associated with ancillary services and working environments are not commonly scrutinized in the inherent safety framework. To this end, this work developed a dedicated tool called Safety Metric for Plant Design (SMPD), integrating occupational safety and process safety aspects, to generate a holistic safer chemical plant via inherent safety oriented modifications. Firstly, the index framework was constructed based on the safety consideration of chemical and process, ancillary services, and working environments. Then, the index framework was integrated with the Fuzzy Risk Rating (FRR), Precedence Chart (PC), and Bayesian Network (BN) to develop SMPD, and the Systematic Risk Reduction Framework (SRRF) was proposed to implement the inherent safety oriented design. Lastly, the SMPD was demonstrated using the case study of a methanol plant. The results revealed that the overall safety level increased from 2.7 to 3.39 after SRRF-based design modifications, implying that the revised chemical plant design is inherently safer than the base design. The proposed SMPD addresses both process hazards and occupational hazards by inherently safer approaches. This work provides a new perspective for designers to shift from inherently safer process design to plant design, aiming to establish a safety design framework for chemical plants oriented towards inherent safety.

1. Introduction

In recent years, the safety issues in chemical plants have gained increasing attention due to a significant number of reported accidents resulting in injuries, fatalities, and property damage. As an intricate system that encompasses a variety of chemical reactions, manufacturing operations, and equipment functions, a chemical plant may involve handling daunting Process Safety Hazards (PSHs) and Occupational Safety Hazards (OSHs) (Friend and Kohn, 2023). Clearly, the presence of these mixed hazards renders chemical plants inherently risky, which may result in the formation and escalation of various unwanted loss-control scenarios (Kletz and Amyotte, 2010). To prevent such situations, experts in academia and industry are committed to developing advanced risk reducing measures aimed at achieving total safety excellence in the process industry.

1.1. The necessity of integrating process safety and occupational safety

Historically, process safety and occupational safety are typically considered separately due to their differences in hazard types and causation mechanisms (Clay et al., 2020). In essence, process safety focuses on issues that are process-oriented, with a higher level of

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