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A risk-based method for determining passive fire protection adequacy

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ABSTRACT

A risk-based approach to determine the adequacy of designed safety barriers in process plants is proposed and implemented to an offshore gas production platform. The scheme employs quantitative risk assessment method to assess the impact of selected process hazards and the adequateness of safety barriers based on a selected ALARP threshold value. The results obtained are further verified using emergency evacuation response analysis. Evaluations carried out on the designed fire/blastwalls for the selected case study confirmed the suitability of the proposed method.

1. Introduction

Firewall and blastwall are examples of important layers of protection in offshore facilities that must be made adequate to satisfy the robust design requirement. This is important because hydrocarbon fires can elevate the temperature of unprotected loaded steel structures to 1100 °C within minutes, leading to structural collapse due to loss of strength. In addition to direct damages such as injuries, fatalities and asset losses, accidents escalation into severe scenarios can have more detrimental effects [1,2]. Typically, fire resistance can be established by adding fire/blastwall with suitable insulation materials or coatings on structure surfaces to reduce the rate of heat transfer to steel surfaces and minimize flame propagation [3].

As part of the safety best practices, API RP 14J recommended that a firewall or adequate space should be considered to separate living quarters from areas containing hydrocarbon sources and if high risk process spaces are confined, blast protection should be considered. However due to limitations such as availability of materials according to the desired specifications as well as time and budget constraints, direct application of the worst case scenario requirement is often found to be impracticable to the overall cost benefit, and some forms of risk assessment are required. Owing to this need, various risk assessment methodologies have been used throughout the planning and design period [4,5] assisted by commercial software [6].

While a full blown QRA provides all the necessary insights required to guide the design, the level of details needed for a QRA is often not available until the project is well into the detailed design phase. This entailed simplified and less complex methods so that safety concerns can be identified earlier and embedded inherently throughout the project phases. Krueger and Smith [7] proposed a simplified scenario-based methodology for fire risk analysis that can be applied early in the design cycle, but their analysis is only useful for preliminary purposes. Shetty et al. [8] described a scheme that integrates the structural reliability analysis with QRA. In this work, models and tools on fire and blast loading are presented and method for estimation of failure frequencies of components and systems for which historical data are not available is proposed. More detailed analyses using finite elements for structural analysis [9], and CFD to study impact of fire and explosions [10–12] on offshore facilities have also been reported, but the approach is far too demanding for smaller projects.

More recently, a seven step risk-based method to allow a more detailed identification of the reference accident scenarios considered for the identification of fire protection zones has been proposed [13]. However, while their conclusion was positive for on-shore facilities, the application to offshore structures with limited space availability is still uncertain. The aim of this paper is to provide a methodology for making a quick judgment required especially for fast track projects. The approach of Dey [14] is adopted with modifications to accommodate the needs of offshore facility as opposed to the nuclear industry. The methodology is demonstrated using a case study involving an offshore gas platform.

2. Framework of coarse risk-based method

The proposed framework applies QRA concept to provide analysis-matching-the-needs requirement for fast-track projects.

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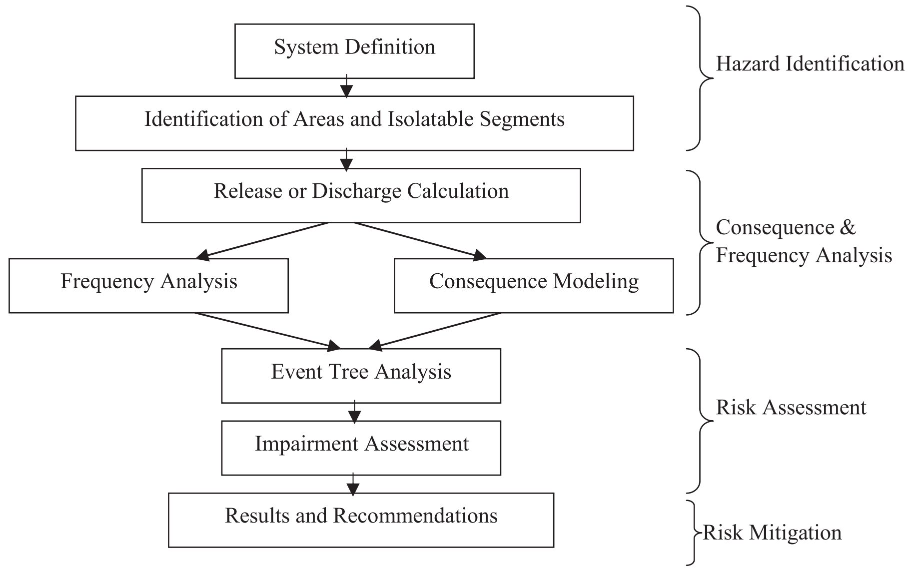

Fig. 1. Study methodology (Reproduced from [15]).

The method demonstrates the use of ALARP region as one of the design decision tools in evaluating the safety layer proposed. The framework is as summarized in Fig. 1. The steps include [15]:

- **System definition** with regards to fire and explosion credible hazards on the installation that may be capable of threatening life or platform integrity;
- **Identification of areas and isolatable segments** of hydrocarbon inventory in process piping and equipments, i.e. isolated inventories between the Emergency Shutdown Valves (ESDVs);
- **Release or discharge calculation** according to probable leak sizes (categorized into 'Small', 'Medium' and 'Large');
- **Frequency assessment** to estimate the initial frequency (i.e., hydrocarbon leak/release frequency), which will be used as key inputs to Event Tree Analysis (ETA);
- **Consequence modeling** to analyze fire and explosion impacts on topsides and riser/pipeline;
- Carry out fire and explosion probabilistic analysis and **Event Tree Analysis (ETA)**;
- Carry out probabilistic **impairment assessment** against fire and blast rating (i.e. J15, H60 and 0.4 barg) using second level of Event Tree Analysis (ETA); and
- **Results and recommendations** of the analysis suggesting alternative approach of analysis.

The results of the analyses are further verified using the Escape and Evacuation Response (EER) methodology. The indicator, the EER time is defined as the required travel time from the working area to a 'safe place' during major accident event.

3. Case study: offshore gas platform

The objective of the case study is to demonstrate the use of the proposed framework in a real case situation. As an example, the adequacy of a proposed fire/blastwall in an offshore gas production platform is investigated. The platform is located in a gas field with 60 m water depth, and is meant to export gas and condensate to an onshore reception facility located more than 100 km away. The platform is equipped with living quarters and fitted with process facilities and utilities system. The processing units include:

- Separation system;
- Gas compression system;
- Fiscal metering facility for sales gas and condensate;
- Pig launcher;
- Condensate export pumps;
- Fuel gas treatment system;
- Seal gas system;
- Flare system; and
- Diesel storage and distribution system.

3.1. *Basis of fire/blastwall impairment criteria*

The following impairment criteria of fire/blast are laid for the analyses:

- Fire wall (J15 and H60 rated)

  1) Criterion "FW1": The wall is impinged by jet fire for continuous 15 min; or the wall is exposed to pool fire continuously for 60 min;
  2) Criterion "FW2": The impairment frequency of the firewall (i.e. the total escalation frequencies of the fire events that can impinge onto the firewall) is not exceeding 1×10^{-4} per year [16].

- Fire/blast wall (J15, H60 and 0.4 barg explosion rated)

  1) Criterion "FBW1": The wall is impinged by jet fire for continuous 15 min; and the wall is exposed to pool fire for continuous 60 min; and the wall is exposed to an explosion overpressure of more than 0.4 barg;
  2) Criterion "FBW2": The impairment frequency of the fire and blastwall (i.e. the total escalation frequencies of the fire and explosion events that can impinge or expose onto the fire and blastwall) is not exceeding 1×10^{-4} per year [16].