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Identification of fireproofing zones in Oil&Gas facilities by a risk-based procedure

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ABSTRACT

Fire is among the more dangerous accident scenarios that may affect the process and chemical industry. Beside the immediate and direct harm to workers and population, fire may also cause damages to structures, which may trigger escalation resulting in severe secondary scenarios. Fireproofing is usually applied to improve the capacity of structures to maintain their integrity during a fire. Past accidents evidenced that the available standards for fireproofing application in onshore chemical and process plants do not consider all the fire scenarios that may cause structural damage. In the present study a methodology was developed for the identification of the zones where fireproofing should be applied. The effect of both pool fires and jet fires was accounted. Simplified criteria, based on radiative heat intensity, were provided for the identification of the fire protection zones. A risk-based procedure was proposed for the selection of significant reference release scenarios to be used in the evaluation of worst credible fire consequences.

1. Introduction

Fire scenarios in the process and chemical industry have the potential to harm people, pollute the environment and cause severe damages to the assets. In particular, accidents involving fire may cause direct damages (e.g., injuries, fatalities, asset loss, etc.), as well as accident escalation to secondary and more severe scenarios (domino effect) [1–5]. Structural elements exposed to high temperatures during a fire event may undergo a significant loss of mechanical properties that may cause failures and loss of containment. In particular, the collapse of the support structures of equipment and piping is a well known critical issue [6], as well as the failure of pressurized vessels exposed to fire [7–10]. Reducing the risk of structural collapse due to the exposure to fire requires the adoption of specific mitigation systems.

Fireproofing is a passive fire protection based on the application of a protective coating that delays the temperature raise of structural elements exposed to fire [1,3,11,12]. All active mitigation systems require a start-up phase to be fully effective. When properly implemented, fireproofing delays the effects of fire exposure providing additional time for the implementation of active protection measures. Thus, fireproofing plays a fundamental role in the reduction of losses, in the protection of personnel and equipment, and in the effectiveness of firefighting operations [13].

Cost and maintenance issues require to identify fire protection zones where the risk reduction justifies the application of fireproofing materials. Technical standards provide criteria for the application of fireproofing in onshore chemical and process plants [13,14]. However, most of these standards do not consider the effect of jet-fires and are based on deterministic approaches for the assessment of damage distances of the reference fire scenarios considered. As an example, protection from jet-fires falls out of the scope of American Petroleum Institute (API) 2218 standard. Prevention of potential escalation from jet-fire scenarios falls out of the scope of the standard, even if several past accidents pointed out the potential severity of domino effects triggered by jet fires (e.g., see the Valero accident, occurred in Texas in 2007 [15]).

In the present study a risk-based methodology was developed for the identification of fireproofing zones, aimed at extending and improving the criteria for fireproofing application provided by the current standards. A risk-based approach was introduced to allow a more detailed approach to the identification of the reference accident scenarios considered for the identification of fire protection zones, taking into account also the credibility of the different scenarios, not considered in consequence-based approaches.

The method developed considers the consequences of both jet-fire and pool-fire scenarios in the evaluation of fire damage and uses a risk-based approach for the selection of the relevant reference scenarios. Simplified criteria are proposed for fire damage estimation, based on fire impingement and on thresholds for radiative heat flux. An application to the analysis of two case-studies of industrial interest is also discussed, in order to understand the potentialities of the technique and to compare the results

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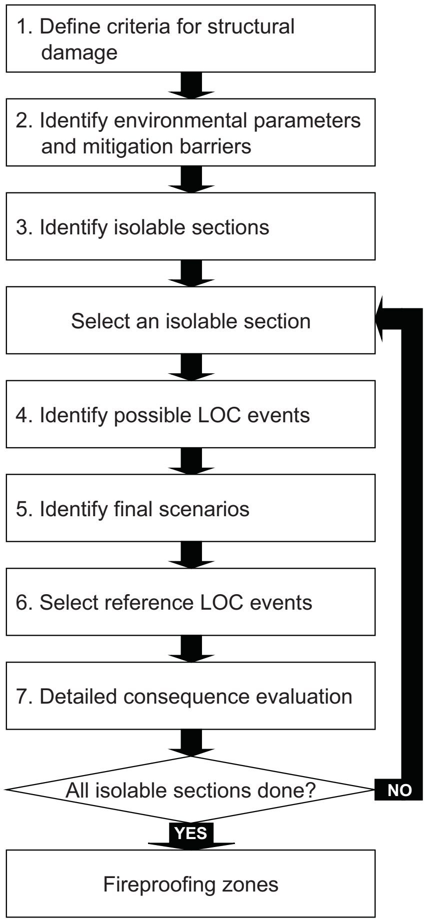

Fig. 1. Flow diagram of the developed methodology.

obtained with those deriving from the application of the API 2218 standard.

2. Methodology

Fig. 1 reports a flow chart of the methodology, that may be divided in seven sequential steps. The first three stages of the methodology are applied to the entire plant, while the remaining steps are applied recursively to each isolable section of the plant, as defined in Step 3.

2.1. Step1 – definition of the criteria for structural damage

In this step simplified threshold criteria are defined for the classification of fireproofing zones. Two fireproofing zones should be defined, according to the different requirements for fireproofing materials and/or strategies: (i) the zone interested by far-field heat radiation form non-impinging flame; (ii) the zone of possible fire impingement or engulfment.

The detailed assessment of the potential for structural damage during a fire scenario would require the complex modelling of wall temperature and induced stress transients [8,9,16–18]. However, the aim of the present methodology is only the identification of zones where damage due to fire should be considered likely. Thus, simplified but conservative damage criteria may be adopted. Several technical sources suggest values between 10 and 15 kW/m^2 as damage thresholds for steel structures exposed to fire heat radiation [19]. In the case-studies discussed below a threshold of 12.5 kW/m^2 was adopted [13].

In the case of flame engulfment or impingement, the exposed materials are loaded by heat fluxes having the order of magnitude of the surface emissive power (SEP) of the flame. Sensitive targets should not be present within these areas or, if present, should be specifically protected from flame impingement (e.g., fire resistant coating, fire resistant walls, bunds, etc.).

The duration of the scenario should also be accounted. Structural damage due to fire is also related to fire duration, being negligible for scenarios having a limited time duration [3,20]. In the case-studies discussed below, a minimum reference time of 10 min was adopted for the radiative heat flux zone, while a minimum reference time of 3 min was considered in the zone where flame impingement or engulfment is possible [1,13].

2.2. Step 2 – identification of the relevant environmental parameters and of mitigation barriers

In this step, a set of representative meteorological conditions, each defined by an atmospheric stability class and an average wind velocity, is identified from the meteorological data available for the site [3,21]. Further data that should be collected are the relevant mitigation barriers present or considered in plant design (containment basins, fire walls, etc.).

2.3. Step 3 – identification of isolable sections

In this step, the plant should be divided in "isolable sections", defined herein as a section which, in the event of emergency, can be isolated completely from the other parts of the plant (e.g., by emergency shut-down valves (ESDVs), by check valves, etc.). Examples of the features of an isolable section are provided in Section 4. Only isolable sections where flammable substances are present should be further considered in steps 4–7.

2.4. Step 4 – identification of possible loss of containment (LOC) events

For each isolable section, the possible LOC events involving flammable substances should be identified. Potential release modes can be identified by standard hazard identification techniques [22] as well as by pre-defined sets of release categories available for specific equipment types [23,24]. The release categories suggested by API 581 standard [23] are widely used in the Oil&Gas sector and may be easily applied, as well as those provided by the MIMAH procedure [25] or by the "Purple Book" [24]. Clearly enough, any other alternative method for the identification of release categories may be applied within the present methodology.

Starting from the analysis of the general release categories identified by the above procedures, the actual LOC events need to be identified. A single LOC event is considered for any release that, independently of the actual position of the leak point, has the same:

- substance or mixture released
- phase (or multiphase mixture) released
- pressure and temperature at the release
- equivalent release diameter or release mode and duration of release
- total quantity of substance available for release

One or more than one "reference stream" (RS) should then be defined for the section. A RS identifies the phase, the composition and the operating conditions (temperature and pressure) of any release stream due to a LOC that may take place from a given set of components (pipes, flanges, equipment items). The case-studies discussed in Section 4 report examples of LOC and RS definition.