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Availability of fire pumping systems under periodic inspection

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ABSTRACT

Fire pumping systems are often used for firefighting in the majority of buildings, can they be residential, commercial, industrial or any other type. These systems are responsible for the needed water flow and pressure on manual or automatic devices installed for building protection purposes. Thus, it is very important to assure their availability when an undesirable fire event occurs. This paper focuses fire pumping systems' availability when they are submitted to regular periodic inspections or tests. These inspections or tests are performed to observe the system behavior and detect potential hidden failures of some component or subsystem. The methodology proposed in this paper is focused in the first stage on the analysis of the probability of failure on demand of critical equipment and analyzing the probability of success of this important stage. It is also shown the influence of inspection or tests frequency on the desired availability of the fire pumping system.

1. Introduction

Fire has always been an important event for human beings. Its power to create, transform and destroy means something useful or evil, depending if it is controlled or not. Fire left its sacred and mysterious meaning for humans and became a common and economic element. When a fire is uncontrolled it is most of times an undesirable event.

At the same time, water is also an important element for humankind and due to its abundancy and opposite properties in relation to fire it has been used along the centuries to control fire events. Sometimes, due to the high power of a fire, a huge amount of water is needed. Fire pumps are very useful means to assure that the required quantity of water will be near the fire event. Usually manual (fire hose reels) or automatic (sprinklers) equipment are used as protective devices. Some standards and regulations have been developed to assure a proper design, installation, maintenance and operation of such systems and avoid, limit or mitigate fire events. The National Fire Protection Association (NFPA) has the leadership in the research and development of these measures and in publishing documentation about it. In Europe the coordination of these issues has been carried out by the Comité Européenne des Assurances (CEA).

Although these standards and efforts to find effective solutions for the design of equipment it is very important to assure that all these devices are properly installed and well maintained. Usually most of these safety barriers (firefighting systems) stay in a dormant mode until they are real needed or an inspection or test is performed. Hidden failures are often detected in these inspections or tests indicating a warranty for a well succeeded operation of the firefighting equipment. Thus, it is assumed that the longer the period between inspections or tests the higher the risk of a failure of some component, subsystem or system.

Concerning a fire pumping system, it is very important to find a method to assess their availability on demand and their reliability during the fire combat period. The objective of this work is to propose a method to assess these key performance indicators and evaluate if the inspection or test frequency is adequate. Based on this information it is possible to evaluate the inherent risk for the building not being protected.

This paper is structured into five sections. The second section refers to fire safety regarding fire risk assessment and fire safety barriers behavior while section three points out fire pumps and some of their characteristics. In section four the approach or methodology to assess availability is proposed as well as the presentation of a demonstrative example. In section five some conclusions about the work are presented.

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2. Fire safety

Due to the general concern all over the world about the occurrence of a fire in a residential, commercial, industrial or other type of building it is assumed that fire safety issues and fire risk assessment are important topics and an open field for research and development of new approaches. In most of the cases a fire event can lead to catastrophic consequences for human lives, business, building structure, infrastructures and equipment, or even with environmental impact. The importance of this topic can be expressed by the huge amount of money demanded by insurance companies to cover this type of risk.

2.1. Fire risk assessment

In general the potential risk of a fire can be presented as the product of two factors: the probability of fire and the severity of its consequences. Adopting adequate measures it is possible to reduce any of these factors, raising the level of safety. When reducing the probability of a fire one is acting in "prevention", when trying to reduce the severity of its consequences one is acting in the context of "protection".

The probability of a fire is usually related to the type and quantity of combustible present in the space under consideration and to the existence of sources of ignition, while the severity of consequences is strictly connected to the protection measures or safety barriers and their efficiency. In the next paragraphs follows a brief description regarding some studies about the probability of occurrence and the severity of a fire showing the importance of this thematic.

Ramachandran [1] refers that the probability of a fire ignition is related to the area of the building and according to its category of risk. Rahikainen and Keski-Rahkonen [2] state that the frequency of ignition follows a variation in accordance with the month, week or day of the week, as well as with the specific hour of the day. In accordance to another study [3], in the period 1985–2001 were registered at industrial establishments in Taiwan an average of 1578 fires per year and, making a relationship with the area where they occur (around 117.809 m^2), it gives a rate of 1.34E-2 fires/m^2 (year), the highest relatively to other type of buildings (residential, shops, public buildings and others). In accordance to Orbeck [4] in terms of ignition sources the statistics show that electric causes are on the top of the list, corresponding the consequences of these fires in the USA to approximately 272 million dollars of losses by year.

Tillander [5] presents a fire risk analysis based on a national database (Pronto) of accidents in Finland since 1996, obtaining new information on fire risk and presenting quantitative methods for its assessment. This study was focused in the frequency of ignitions, economical losses and performance of the safety department. In this approach the author distinguishes buildings having automatic extinction and buildings without it. It was concluded that the most important factor is the lead time since the beginning of the fire until the arrival of the firefighters. In this scope missing fault detection and/or a slower answer will reduce significantly the hypothesis of success.

Fontana et al. [6] refer a study carried out in Switzerland (1986–1995) including around 335.000 fires in buildings. Only in Berna's canton occurred 1538 fires in the industrial sector, corresponding to damages about 45,070 million dollars. In accordance to another study performed in the Great Britain [7], around 800 persons die and around 15,000 are injured per year due to fire incidents. On average, every year about 1.2 million pounds of direct losses and around 120 million pounds of indirect losses are registered. In Great Britain the losses due to fire occurrences represent 0.21% of the British GDP (gross domestic product). Shaluf et al. [8] state that in the 12 bigger fire accidents in refineries were registered 101 deaths, 111 severe injured and around 150,000 persons needed to be evacuated, not referring material damages and economical losses. In accordance to Kim et al. [9] between 1983 and 1997 were reported about 40 fire incidents at chemical facilities resulting 1617 million dollars in equipment loss and 2370 million dollars in production loss.

2.2. Fire safety barriers

Safety barriers assume a fundamental role in risk reduction once they can influence the severity or significance of the consequences of a fire. Thus, it is very important to assure their maintenance during their lifecycle just to increase the probability of success when demanded.

Dieken [10] states that in fire situations one third of the safety barriers do not work properly just because of improper inspection, test or maintenance. The author also refers that due to improper maintenance around 49% of the fire extinguishing systems of combustion turbines failed when needed and because of that property damages reached 15.9 million dollars.

In general it is possible to consider that the state of a safety barrier corresponds to the condition or the ability to carry out its function at a precise moment. Basically two situations may occur regarding safety barrier availability (unavailable or available).

It is known that this type of equipment often relies in a dormant state for long period during its lifecycle being on its operational and normal configuration, but not in effective operation. Thus, failures of safety barriers are only revealed when a demand occurs in a real situation or when performing an inspection or test.

Concerning safety barriers in dormant state it is important to refer the probability of occurrence of "safe failures" that result from the inopportune actuation of these safety barriers without motive. Due to its low criticality they are not analyzed and not considered in the present study.

The frequency of tests is an important factor to be considered on safety barrier analysis. It is expected that the higher the frequency, sooner hidden failures are revealed. However when the frequency increases also raises the hypothesis of introducing a human error during the test and higher maintenance costs must be considered.

3. Fire pumps

The first known references to pumping systems under the form of codes or recommendations belong to National Fire Protection Association (NFPA), and were published in 1896. Nowadays some particular characteristics are required for pumps to be used in firefighting systems.

When a fire takes place and something goes wrong, the operability of the fire pumping system is one of the first issues to be analyzed by insurance companies. Nolan [11] states that 12 of the major 100 fire industrial accidents are related with the failure of fire safety barriers. The same author refers the causes of failure for fire pumping systems in accordance with Table 1.

For fire pumping systems the frequency of inspections and tests is very important. NFPA 25 [12] made recommendations for inspection, test and maintenance of water based fire protection systems and it is a reference in several countries despite other specific and local regulations. In Europe there is an increasing use of CEA 4001 [13] referred as a technical rule to the planning and installation of sprinklers systems, specifying requirements and giving recommendations for the design, installation and maintenance of fixed fire sprinkler systems in buildings and industrial plant. It covers the classification of hazards, provision of water supplies, components to be used,