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SHORT NOTES

Fire Safety Concerns and Operational Reliability of Automatic Sprinkler Systems

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Abstract - ***This study discusses the effectiveness of fire protection systems in major buildings. The key features of the work is, it considers active and passive systems and the interaction between them. It also considers and comments on the relationship between the effectiveness of systems and the environment in which fire engineering is practised.***

Keywords : Sprinkler Systems, performance reliability, Fire safety

I. INTRODUCTION

Fires in major buildings are expected (if not adequately controlled) to have significant consequences. Depending on how major buildings are defined these consequences may be in terms of loss of life/injury, financial loss, cultural loss, loss of utility, or a combination of these. Fires in major buildings may have repercussions beyond the building itself if as in the case of lifelines buildings the building provides a vital function. This is particularly acute in the event of a civil defence emergency. Experience has showed that uncontrolled fires in major buildings have prompted inquiry from regulators and have often been a catalyst for change of regulations. Major buildings are also of particular interest for research into fire system performance as the fire protection for these buildings is more likely to involve specific fire engineering design and thus understanding the nature of the fire risk in these buildings is particularly relevant to the design process. Major buildings attract a significant proportion of the costs associated with fire protection; both in terms of systems (active and passive) and also fire service response resources [1].

Level of Fire Risk : The level of fire risk in major buildings is not well understood. Whilst there is an implicit assessment of risk in the protection and there may be implicit or explicit assessment of risk in the required level of fire protection there is generally no explicit assessment of the level of fire risk. The 'feeling' is that for major building the increased level of fire protection required compensates in some way for the increased level of hazard. There is no robust objective basis for assessment and practice relies heavily on precedent and engineering judgment. Even as a qualitative analysis there is little evidence of assessment of the levels of fire protection, particular where there are multiple layers of defence, used against a range of credible fire scenarios. Some assessments have been made of cost benefit of increased levels of fire protection for regulation of single systems (e.g. mandating installation of sprinklers in certain occupancies) but even for this simplified case the analysis is far from trivial [2].

Operational Reliability Of Systems: Reliability depends on the potential for a system to fail on demand. It is analogous to the research presented for on-demand reliability for system components. For detection systems the operational reliability of the system will be highly dependent on the on-demand reliability of detectors. For sprinkler systems the detectors themselves are less important and operational reliability is impacted by factors such as the water supply. Smoke management systems being complex would be expected to have their operational reliability be dependent on the interactions of the on-demand reliability of the component parts which is the approach used when estimating reliability of smoke pressurisation and zone control systems using fault tree techniques. The literature data on system effectiveness (overall reliability) does not identify the relative importance of efficacy, availability and operational effectiveness. The relative importance will vary depending of the sample type and the method of analysis. For some data the reported figures are probably close to the system operational reliability [3].

II. SPRINKLER SYSTEMS

For sprinkler systems the normal performance measure is that they control the fire (or suppress it in the case of suppression mode sprinklers). This in turn provides the required property protection or life safety performance for the design. For some situations such as high challenge fires or residential sprinklers specific testing is used to confirm the specific performance. For other situations sprinklers may be accepted on a simple basis of water distribution and density. In general for sprinkler systems functional effectiveness is considered to be high. None of the research considers the specific relationship of sprinkler system parameters on functional effectiveness. Intuitively it would be expected that increasing water density would increase the probability of effective control or suppression but no quantification of such a relationship in the literature has been discovered. What can be found in the literature is testing results indicating failure when the density is reduced too low (notably the halt on the trend towards lower and lower densities for residential sprinklers). Likewise other results provide qualitative insight into the relationship between functional effectiveness and parameters such as ceiling height. The performance of systems is also a function of the fire scenario. Research exists which considers the functional performance of sprinkler systems for fire scenarios with low heat release rate fires. Automatic sprinkler systems and fire detection systems are a key component in saving many buildings from fires. In many incidents an automatic sprinkler system has prevented fires from spreading across a building or even extinguished a fire before it can spread. Automatic sprinkler systems are designed to control or extinguish a fire in its incipient stage before the arrival of the fire department or fire brigade. Automatic sprinkler systems can be found in many commercial buildings and even in some residential houses. The fire loss data reveals that in buildings with automatic sprinklers, 96% of all fires were controlled or extinguished by these systems. Fire detection systems alert individuals when a fire has started and typically activate before the automatic sprinkler system. Fire detection systems, which could consist of smoke detectors and/or smoke alarms, are considered a life safety device. These two systems are not required to be installed in fire stations unless a particular county, city, or department requires them in their area. Fire detection and automatic sprinkler systems are important for saving property and lives. They are also necessary for the protection of fire fighters who aid the public [4].

The significance of this topic is to demonstrate the need for fire detection and automatic sprinkler systems in fire stations in order to protect the lives of fire fighters and their equipment. Fire stations are as vulnerable to fire as any other building. There have been incidents where fire stations have burned down while others have been saved by a fire suppression system. The cost of apparatus in a fire station is expensive, but a fire station burning down is a significant expense to the taxpayers. In addition to the cost, fire response time is also jeopardized when a station is out of service. When the public needs the fire department and a station is out of service, another station has to cover that station's coverage area. This not only results in a longer response time because the station is located farther away, but it also puts more stress on the covering station due to the higher number of calls. Whether one is preparing a performance design or working with a prescriptive code, the reliability of fire protection systems and features must be considered. The reliability includes both operational reliability and performance reliability. The operational reliability is a measure of the probability that a system or component will operate as intended when needed. The performance reliability is a measure of the adequacy of the system once it has operated. While critical for all fire protection features and systems, this paper will focus on the reliability of automatic sprinkler systems, in particular the operational reliability. When the original paper on this subject was prepared by this same author, critics immediately claimed that the data was manipulated and the operational reliability of sprinkler systems was being represented as being too low. However, many of the critics failed to consider the aspects of uncertainty [5].

III. PERFORMANCE RELIABILITY

In a performance-based design, the ultimate evaluation may be whether the outcome is consistent with the expected performance as documented during the design process. It is understood that most automatic sprinkler systems are designed to control a fire but not necessarily to completely extinguish the fire. The fire data supports the concept that sprinkler systems can control fires but do not necessarily result in complete extinguishment. Fire protection strategies are designed and installed to perform specific functions. For example, a fire sprinkler system is expected to control or extinguish fires: To accomplish this, the system sprinklers must open, and the required amount of water to achieve control or extinguishment must be delivered to the fire location. A fire detection system is intended to provide sufficient early warning of a fire to permit occupant notification and escape, fire service notification, and in some cases activation of other fire protection features. Both system activation and notification must occur to achieve early warning. Construction compartmentation is generally designed to limit the extent of fire spread as well as to maintain the building's structural integrity as well as tenability along escape routes for some specified period of time. In order to accomplish this, the construction features must be fire "rated" and the integrity of the features maintained. The reliability of individual fire protection strategies such as detection, automatic suppression, and construction compartmentation is important input to detailed engineering analyses associated with performance based design. In the context of safety systems, there are several elements of reliability, including both operational and performance reliability. Operational reliability provides a measure of the probability that a fire protection system will operate as intended when needed. Performance reliability is a measure of the adequacy of the feature to successfully perform its intended under specific fire exposure conditions. The former is a measure of component or system operability while the latter is a measure of the adequacy of the system design [6].

Elements Of Reliability Analysis: There is considerable variation in reliability data and associated analyses reported in the literature. Basically, reliability is an estimate of the probability that a system or component will operate as designed over some time period. During the useful or expected life of a component, this time period is “reset” each time a component is tested and found to be in working order. Therefore, the more often systems and components are tested and maintained, the more reliable they are. This form of reliability is referred to as unconditional. Unconditional reliability is an estimate of the probability that a system will operate “on demand.” A conditional reliability is an estimate that two events of concern, i.e., a fire and successful operation of a fire safety system occur at the same time. Reliability estimates that do not consider a fire event probability are unconditional estimates. Two other important concepts applied to operational reliability are safe and failed dangerous. when a fire safety system fails safe, it operates when no fire event has occurred. A common example is the false alarming of a smoke detector. A fire safety system fails dangerous when it does not function during a fire event. In this study, the failed-dangerous event defines the Operational probability of failure. A sprinkler system not operating during a fire event or an operating system that does not control or extinguish a fire are examples of this type of failure.

The overall reliability of a system depends on the reliability of individual components and their corresponding failure rates, the interdependencies of the individual components that compose the system, and the maintenance and testing of components and systems once installed to operability. All of these factors are of concern in estimating operation reliability. Fire safety system performance is also of concern when dealing with the overall concept of reliability. System performance is defined as the ability of a particular system to accomplish the task for which it was designed and installed. For example, the performance of a fire rated separation is based on the construction component’s ability to remain intact and provide fire separation during a fire. The degree to which these components prevent fire spread across their intended boundaries defines system performance. Performance reliability estimates require data on how well systems accomplish their design task under actual fire events or full scale tests. Information on performance reliability could not be discerned directly from many of the data sources reviewed as part of this effort due to the form of the presented data, and therefore, it is not addressed as a separate effect. The cause of failure for any type of system is typically classified into several general categories: installation errors, design mistakes, manufacturing/equipment defects, lack of maintenance, exceeding design limits, and environmental factors. There are several approaches that can be utilized to minimize the probability of failure. Such methods include (1) design redundancy, (2) active monitoring for faults, (3) providing the simplest system (i.e., the least number of components) to address the hazard, and (4) a well designed inspection, testing, and maintenance program. These reliability engineering concepts are important when evaluating reliability estimates reported in the literature. Depending on the data used in a given analysis, the reliability estimate may relate to one or more of the concepts presented above. The literature review conducted under the scope of this effort addresses these concepts where appropriate. Most of the information that was obtained from the literature in support of this paper were reported in terms of unconditional operation reliability, i.e., in terms of the probability that a fire protection strategy will not dangerous.

CONCLUSION

There is no defined level of tolerance for fire system performance under regulation. The expectation is that the fire protection measures will operate within their design intent to limit the impact of fire. It is accepted that systems cannot prevent injury to those persons intimate with the fire. Not explicit in the current regulations but covered in proposed regulation is that concept of redundancy of systems. That a system can fail and still leave the building in a safe state

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