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Full-scale experiments of fire suppression in high-hazard storages: A temperature-based analysis of water-mist systems

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ABSTRACT

Water-mist systems have become quite popular over the last two decades as an innovative technology in fire protection. Moreover, insertion of additives to the flow may be applied to provide additional improvements in terms of suppression effectiveness and temperature control. The present work consists of an experimental approach within a real-scale facility, which has been aimed at challenging water mist against severe fire scenarios. Among them, a high-rise storage has been here explored, being it commonly recognized as strongly hazardous even by technical standards in terms of both nominal fire load and designed physical domain. The system configuration presents high-pressure nozzles at the ceiling; the sole-water flow is compared to water endowed with a commercial additive.

The thermal transient within the test chamber has been evaluated during the fire development as the main quantitative parameter; moreover, the fire evolution has been visualized through a post-fire estimation of the damages. Despite the large amount of released smoke and smoldering materials, water mist is shown to be efficient in fire control, if endowed with the chosen additive. On the other hand, the sole-water flow does not appear suitable for such hazardous conditions under the designed nozzle arrangement.

1. Introduction

Water mist has been considered to be very promising in fire protection for more than two decades: as halogenated hydrocarbons (also known as *halons*) were banned in 1987, this technology has been developed in the quest for alternative agents and systems. From a fundamental standpoint, the related heat-transfer and suppression mechanisms are described by Jones and Nolan [1] and Santangelo and Tartarini [2]; these works are largely based upon the early studies by Rasbash and co-workers [3,4] on extinguishment of liquid fires by water sprays. The recognized review by Grant et al. [5] also provides some insights into suppression physics of water mist within a broader discussion on spray-based systems.

The long-term research promoted by the Naval Research Laboratory features applied studies on water-mist response to various fire scenarios and presents both numerical and experimental approaches; among these latter, the work by Adiga et al. [6] was conducted at large scale (cubic steel-walled compartments of 28 m^3 with heptane and methanol pool fires) and serves as a primary source of inspiration for the present study. The experiments by Back III et al. [7] also constitute a prominent reference for this work: they validated a quasi-steady-state model to predict water-mist effectiveness in extinguishing fuel-spray and pool fires through experimental tests in shipboard machinery spaces. Notably, compartment volumes in the range 100–500 m^3 are here considered and various ventilation conditions are also taken into account. Kim and Ryou [8] focused on methanol and hexane fires within a large enclosure (4.0 m × 4.0 m × 2.3 m), showing some remarkable temperature profiles from K-type thermocouples, which are also employed in the here proposed experiments.

However, the already mentioned studies [6–8] present very simple fire scenarios, even though at large scale, because their main scope is to investigate basic phenomena, as also recently performed by Santangelo et al. [9] to better understand flow/flame interaction; pool fires are the most reliable test cases to firmly control initial and boundary conditions, thus yielding to detailed analyses of a restricted set of parameters. On the other hand, the present work is aimed at challenging a water-mist system within an actual fire scenario to evaluate its performance against a set of real variables.

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