Fire Protection Engineering Department
PhD Defense

Inert Gas Discharge and Extinguishing Dynamics of Total Flooding Systems

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Zoom link:
https://wpi.zoom.us/j/92585399947

Committee
Prof. Albert Simeoni (Advisor and Department Head; FPE WPI)
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Fred Penden (Kidde-Fenwal, LLC)
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Abstract

Total flooding clean agents help solve the fire protection problem of suppressing compartment fires without the use of water. Recently, there has been an increased interest in inert gas discharge systems as the Montreal Protocol and its amendments are incentivizing the industry away from halocarbon agents. However, significant questions remain regarding how the standardized extinguishing test used to certify inert gas systems for use translates to real-life property protection.

Inert gas suppression systems are tested to the UL 2127 and FM 5600 or similar standards. These standardized testing protocols use prescribed fire threats, such as wood cribs, to replicate the fire threat of Class A ordinary solid combustibles. The standardized test contains two criteria:

extinguish the test article and prevent test article reignition after a 10-minute soaking period followed by exposure to fresh air.

Test article suppression was studied using an inert gas discharge system with IG-100, pure nitrogen, and industry-standard components provided by Kidde-Fenwal, LLC. Two scales were used to research suppression and extinction dynamics: the full 100 m3enclosure and a novel 33 m3 with a scaled test article and discharge system. The reduced-scale was proposed to decrease the time, resources, and cost of experimentation. Additional non-standard test articles were utilized at the reduced-scale to increase its validity as a tool for industry use and research.

During an inert gas discharge, the test article is subjected to the joint effects of a flow of agent and entrained air and a systematic oxygen reduction. No theoretical framework exists for studying the coupled effects simultaneously. To address this problem, the in-depth heat and mass transfer phenomenon is examined, and a general mass transfer B-Number is proposed for wood cribs. The methodology presented in this work encapsulates the oxygen reduction effects through the B-Number and the forced flow effects through the heat transfer coefficient.

The requirements, constraints, and scientific interest of this work formed four natural goals to structure this research. A theme throughout each goal is identifying differences between the industry standard discharge periods of 60 s and 120 s. The first goal is to quantify the full-scale discharge dynamics in terms of the flow of agent and entrained air, oxygen concentration uniformity and rate of change, and test article extinguishing effects. The quantification and characterization of the full-scale will greatly influence further testing as well as inform the industry of what is fundamentally occurring during an inert gas discharge. The second goal is to scale the discharge system, test article, and enclosure while maintaining similarity to the previously defined full-scale discharge dynamics. With the reduced-scale, far more data and understanding can be collected in which to better study inert gas discharges. The third goal is to model the burning rate of the wood crib during the suppression period. This model accounts for the joint effects of forced flow through the crib and the systematic reduction in oxygen concentration. The fourth goal is to investigate the extinction dynamics at the end of the discharge period. Extinction dynamics include the minimum oxygen concentration required for extinguishment, defined as the disappearance of visible flames for more than 3 s.