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Experimental study on the extinction of liquid pool fire by water droplet streams and sprays

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Abstract

This paper provides evidence about the interaction between the water droplet stream and the flame, and explains how the interaction affects the suppression effectiveness. Two purpose-built gasoline pools were used to generate different open fires. The mono-disperse water droplet streams and water sprays were used as the flame suppressant. The first pool with a circular shape was equipped with a concentric pipe to allow the droplet stream to pass through the flame without impinging the gasoline. The second pool with a long narrow shape was equipped with expandable sides and allowed to extend the fire size. The passing ways of the droplet stream were systematically varied. The results clearly show two modes of flame inhibition; one is by blocking or interfering with the mixing of gasoline vapor and fresh air, and the other by cooling down the flames. For the stream case, the direction of the stream passing through the flame can affect the effectiveness of the suppression which increases as the angle is changed from vertical to horizontal. Also, there is an optimum distance between the stream axis and gasoline surface for flame inhibition. Moreover, the ability can be affected by the droplet size. On the same volume flow rate, the larger the droplet size, the more effective the flame suppression. For the water spray passing through the flame in the long groove pool, whenever the quantity of water vaporization reaches a critical value, the effectiveness of flame suppression by combining the obstructing and cooling effects becomes better.

Keywords: Mono-disperse water droplet stream; Water spray; Pool fire; Extinction; Droplet size; Obstructing; Cooling

1. Introduction

The pressure to discontinue the use of halons has provided the impetus for finding alternative agents, which in turn has forced attention and resources to the development of fine water sprays for fire suppression. It is known that the water is used to extract heat directly from the flame, the hot products of combustion or the surface of the fuel and this fact can be attributed to water's thermal characteristics such as heat capacity and latent heat of vaporization. The vapor from water may also contribute to physical suppression by reducing the oxygen concentration of the surrounding atmosphere. Moreover, the complete vaporization of the small-sized droplet in the fine water spray is suitable for avoiding the water damage and fire spread. In the literature there is voluminous research work regarding the use of water sprays for the suppression and extinguishment of typical Class 'A' compartment fires; for a review, see Grant et al. [1]. For the Class 'B' hydrocarbon pool fire, Rasbash and Rogowski [2] conducted extinction experiments about 50 years ago. They let liquids burn in circular open vessels of various diameters and then cooled them by projecting water sprays downwards from fixed nozzles to a horizontal surface on the surface of the burning liquid. They correlated the extinction time (t) with the spray and the fire properties and suggested an expression based on the mass median drop size (D) of the spray, the rate of flow of water to fire area (M), the pre-burn time (Y) and the difference between the fire point and

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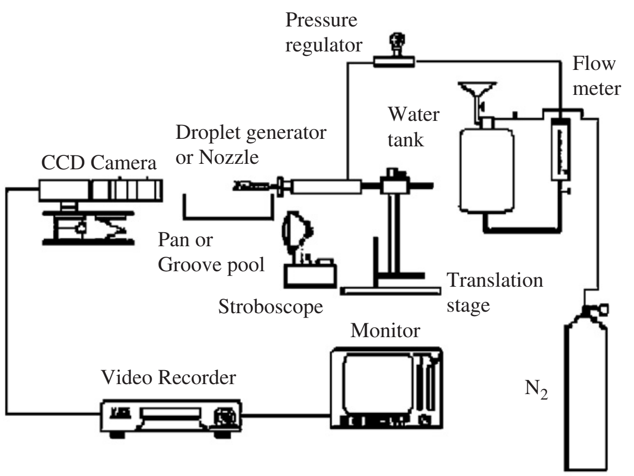

Fig. 1. Schematic of the experimental apparatus.

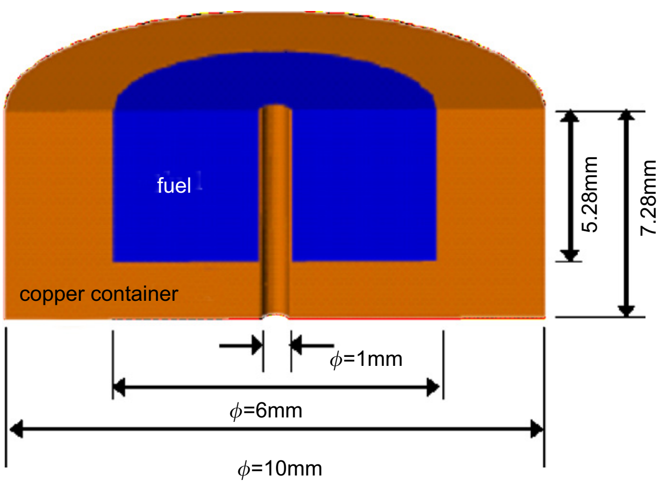

Fig. 2. Schematic diagram of the circular copper pan with a concentric pipe inside.

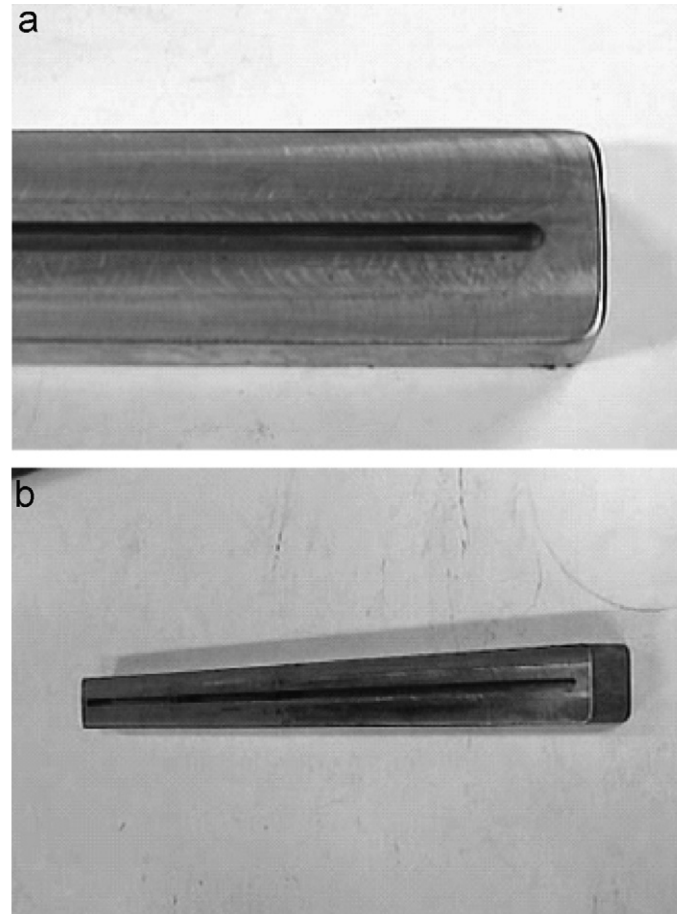

Fig. 3. Photographs of the groove pool: the groove's dimensions are (a) $3 \times 10 \times 300$ mm and (b) $6 \times 10 \times 300$ mm.

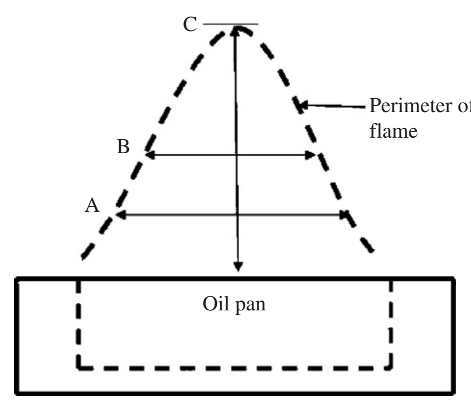

Fig. 4. Schematic drawing of the dimensions of the flame; prior to injecting the droplet stream, the lengths of line A and B are about 7.60–8.00 mm and 4.74–5.04 mm, respectively. The positions of line A and B are on the quarter and the center of the flame height C, respectively.

ambient temperature (ΔT), i.e.

$$t = 34\,000\,(D/M)(Y/\Delta T^{1.75}). \quad (1)$$

To understand the effects of water sprays on the fire intensity with an oil fire, Kim et al. [3] conducted experiments by using downward-directed sprays to interact with a small-scale opposed gasoline pool fire in an open environment. Their results show that the burning rate of fuel is always greater under their opposed spray-fire plume arrangement compared to the freely burning condition when fire extinction does not arise. They claimed that water sprays are able to enhance an oil fire and very small droplets are ineffective for fire extinction by cooling. They concluded that the mechanism of fire extinguishment by water sprays is the cooling of the fuel surface, which will lead to the suppression of fuel evaporation, rather than cooling of the fire plume itself. Followed the above work, Kim et al. [4] investigated the extinction limit and enhancement for a gasoline pool fire interacting with a water mist and found that there are two distinct regions in the relationship between the distance from the nozzle to the fuel pan and the injection pressure; a fire extinction region and a fire enhanced region. They also concluded that the water flux is a more useful parameter than the injection pressure for the extinction limit and the larger the spray thrust the larger the burning rate is in the fire enhanced region.