NISTIR 6242

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Book of Abstracts
November 2-5, 1998

Kellie Ann Beall, Editor

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U.S. Department of Commerce
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Submitted to the Annual Conference on Fire Research, NIST, November 2-5, 1998

A DISPERSED LIQUID AGENT FIRE SUPPRESSION SCREENING METHOD[1]

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ABSTRACT

The recent ban on halon 1301 (CF_3Br) production (as a result of its ozone depleting potential) has resulted in an extensive search for replacements and alternatives. The applications of fire suppression efficiency screening methods constitute an important aspect of this search process because good screening methods can facilitate the identification, comparison, and selection of potential candidates for halon replacement. Most of the current methods for fire suppression efficiency screening (e.g., cup burners) are designed for evaluating fire suppressant agents that can be delivered in the form of vapor. Potential uses of liquid agents as replacements have been recently proposed in several applications (*e.g.*, shipboard machinery spaces, engine compartments in armored vehicles). Therefore, there is a need for the development of a reliable screening method for liquid agents that can be delivered in droplet form. The objective of our work is to design, construct, and demonstrate a laboratory-scale apparatus to screen liquid agents in a well-controlled experimental setting.

There are two major elements in the apparatus: (1) a burner and (2) a droplet generator. Several design parameters for these two elements have been carefully considered. The burner should be versatile enough to accommodate the screening of liquid and gaseous agents as well as solid particulates (with the addition of a powder delivery system), if possible. A counterflow cylindrical burner is selected. This type of burner has been extensively used in the past to characterize flame extinction and suppression using inert gases, halons, and powders (sodium bicarbonate and Purple K) due to the ease of maintaining a stable flame over a wide range of fuel and oxidizer flows and the ease of introducing condensed phase materials in the carrier (oxidizer) stream. The burner, which is replaceable and is made of sintered stainless steel and water-cooled, is located across the test section of a vertical wind tunnel. Air is supplied to the tunnel via a frequency-controlled blower and a series of flow straighteners. Propane is used as fuel.

Since some potential new liquid agents may only be synthesized and available in minute quantity, the application of a commercial spray may not be ideal or feasible to perform a test. In addition, the fan-out of a spray due to its angle could cause collision of droplets with the wind tunnel wall. Therefore, a droplet generator is specifically designed and used in the proposed screening in lieu of a spray because all the droplets can be directed to the flame zone, thus minimizing droplet loss to the wall of the wind tunnel. A piezoelectric droplet generator is used to create liquid droplets (< 150 μm) from controlled breakup of jets emerging from a sapphire orifice. The droplet generator consists of a liquid chamber which is connected to a reservoir, a bleed port (for eliminating any air bubbles trapped inside the chamber during priming), a 25 μm sapphire orifice mounted on a set screw, and a piezoelectric transducer. The droplet generator is located in the settling chamber and is approximately 42 cm upstream of the burner. The presence of the droplet generator in the wind tunnel does not create any significant perturbation or blockage effect on the oxidizer flow field near the burner. The air stream in the wind tunnel facilitates the dispersion of the single droplet stream into a small droplet cloud. By adjusting the location of the droplet generator with respect to the burner, droplet loss to the wind tunnel walls can be eliminated or minimized because the resulting dispersed droplet cloud is confined to a very narrow region near the burner.

[1] Supported by DoD/SERDP/NGP

The stability limits, which delineate the operating modes (enveloped and wake flames) of the burner, were constructed using various fuel and oxidizer flows. The stability envelopes compared favorably with those reported in the literature. The screening apparatus was first characterized using inert gases (argon, helium, and nitrogen), which were gradually added in the oxidizer stream until extinction occurred. The relative fire suppression efficiency ranking of these three gases was found to be commensurate with that from cup-burner tests. In all the experiments, extinction is defined as the conditions when blow-off occurs (an abrupt transition from a stable enveloped flame to a wake flame). For liquid droplet experiments, water was used as a representative liquid suppressant to evaluate the feasibility of using such a burner for screening liquid agents. Extinction tests were performed by gradually increasing the air flow until blow-off occurred at a fixed water flow. Figure 1 shows the mass fraction of water added as a function of $2V_O/R$ at blow-off, where V_O is the velocity of air and R is the radius of the burner. As shown in the figure, it is easier to blow-off the flame with water droplet addition than without. For low water droplet mass loading, higher air flow is required to cause blow-off. The effect of water became more pronounced when its application rate was increased. Suppression experiments using water with and without nitrogen dilution in the air stream were also performed. The combined effect of nitrogen and water on blow-off is illustrated in Figure 2. With water addition, the blow-off stagnation velocity gradient ($2V_O/R$) is higher than that with air diluted with nitrogen. For a given nitrogen dilution, the blow-off velocity gradient without water application is higher than that with water.

Future work will involve the refinement of the methodology. The droplet sizes and number densities at various locations near the burner forward stagnation point are currently being measured by using a Phase Doppler Particle Analyzer (PDPA) in order to assess the uniformity of the droplet size and number density. Such information is needed to better understand the performance of the droplet generator. Potential liquid suppressants that are of interest, including water with additive(s) (*e.g.*, aqueous potassium acetate or lactate solutions), will be evaluated because these fluids have been found in preliminary testing to exhibit better fire suppression effectiveness than pure water.

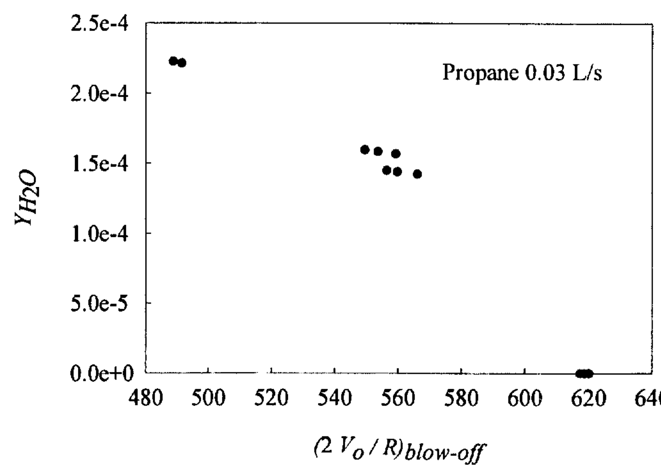

Figure 1. Mass fraction of water added in air as a function of stagnation velocity gradient at blow-off.

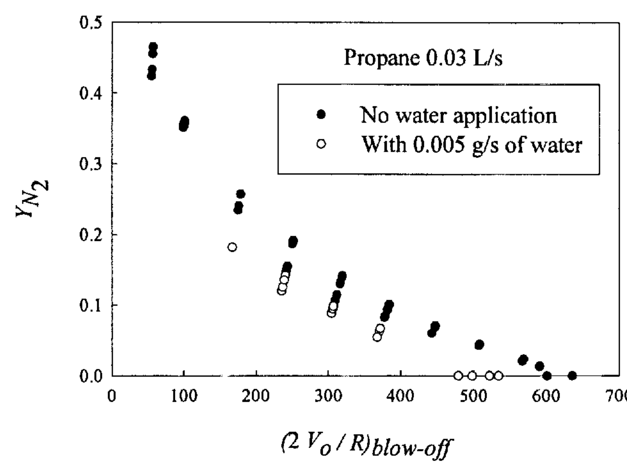

Figure 2. Mass fraction of nitrogen added in air with and without water application as a function of stagnation velocity gradient at blow-off.