White Paper

Dual Agent Extinguishing System: Victaulic Vortex

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Abstract

The dual agent fire extinguishing system generates a homogeneous suspension of sub-10 micron water droplets and nitrogen gas that is delivered at relatively high momentum with very low operating pressures relative to existing fire suppression technologies. The combined extinguishing characteristics of water and nitrogen enhance the individual components: coupled with high delivery momentum, the suspension has demonstrated fire extinguishment capabilities and benefits that extend the boundaries of existing single fluid systems. The science of generating the homogeneous extinguishing agent is presented followed by a brief explanation of the theory of fire extinguishment using the system. Fire test results are then presented that demonstrate the Vortex capabilities in total flooding and local applications.

1) Introduction

Fire protection systems are available today in a large variety of configurations and with varying complexities. From traditional water based sprinkler systems, the simplest and most widely used, to the halocarbon agents and high pressure water mist systems. Each system has unique advantages and disadvantages, depending on the hazard application.

After an in-depth analysis of all existing fire suppression systems, the researchers identified specific desired characteristics of the new suppression system. The criteria called for minimal wetting of protected surfaces, full fire suppression capabilities, zero environmental impact, extended safe egress time for occupants in case of discharge, simplified system design for multiple zones and scalability that surpasses current water mist technologies.

In order to achieve this, the design team decided that water droplet size should be as small as possible thus reducing the required water volume and simultaneously maximizing heat absorption efficiency. It was recognized that a new water delivery and atomization method would need to be developed in order to produce very small water droplets while overcoming the drag effect inherent with the projection of small water droplets. The resultant provides enough agent momentum that the system can be effectively applied to local application hazards for both combustible and flammable liquid hazards.

The adiabatic flame temperature equation is used to demonstrate the theoretical advantage of a dual agent extinguishing system. The assumptions made are discussed and analyzed against actual fire test data with interesting results that may, with further testing and analysis, explain some limitations associated with typical water mist systems and lead to greater fire extinguishment efficiencies.

2) Atomization

The atomization of water droplets is strongly tied to a parameter called the Weber number,

$$We = \frac{\rho \Delta U^2 L}{\sigma} \qquad \text{[Eq. 1]}$$

where
ρ is the liquid density (kg/m3)
ΔU is the relative gas-liquid velocity (m/s)
L is the characteristic dimension of the stream (m)
σ is the surface tension coefficient (kg/s2)

At high Weber numbers the aerodynamic forces on the water droplets dominate, causing the water stream to distort and disintegrate in a process known as atomization. The atomization process continues in a cascading manner until a critical value of the Weber number is reached at which point the atomization process is complete. As the Weber number decreases with smaller droplet size the relative velocity also decreases.

The challenge is to create very small water droplets while maintaining high momentum capable of over coming the aerodynamic forces that would normally decelerate the droplets. This is essential in the case of fire suppression where the system must be able to deliver the water droplets to a fuel source while potentially overcoming the fire plume velocities.

2.1) Agent Emitter

The agent emitter was developed using theory analogous to the aerodynamic forces seen on a supersonic aircraft wing.

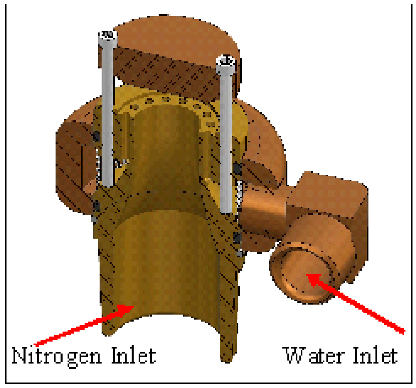

Figure 1: Victaulic Vortex emitter cross-section

Figure 1 is a cross section of the Vortex emitter. Nitrogen at 25 psig enters the emitter while water at <5psig enters the water jacket external to the nitrogen flow. The emitter is configured to accelerate the nitrogen flow to a supersonic velocity thus exiting the emitter as under expanded gas flow.

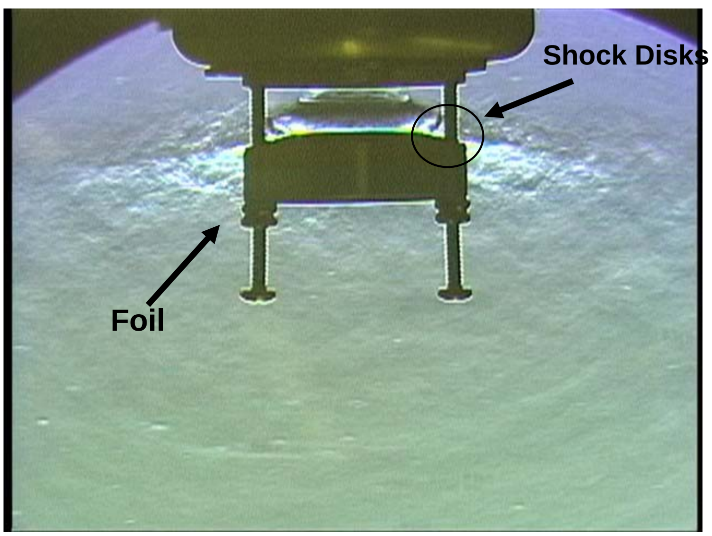

Figure 2: Schlieren Photograph of Nitrogen Flow

Figure 2 is a picture, taken at the Penn State Gas Dynamics Laboratory, which demonstrates the nitrogen density patterns in the critical flow field.

As nitrogen exits the emitter at a supersonic velocity a shock disk is formed. This is the result of the instantaneous transition from sonic to sub sonic velocity and is seen as the dark area between the emitter outlet and the emitter foil. As the nitrogen contacts the emitter foil it is re-accelerated to localized supersonic velocities which then creates additional shock disks perpendicular to the flow field. Water exits the emitter through the ring of concentric holes (see Figure 1) external to the nitrogen outlet of t he emitter.

This water is injected into the nitrogen flow field in the area of the shock disks shown in Figure 2. At this point the water is exposed to a region of very high Weber number and thus rapid atomization. The resulting water droplet distribution shown in Figure 3 is for the most part comprised of < 10 μm size water droplets with a very tight distribution.

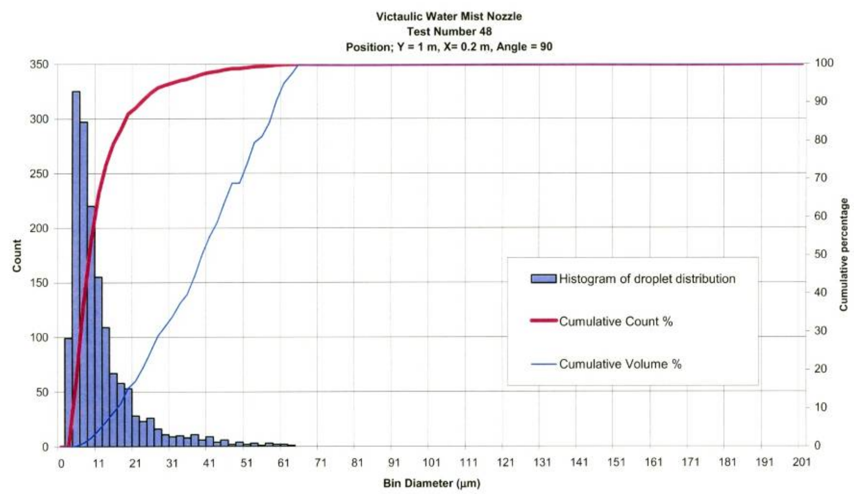

Figure 3: Droplet distribution density, Underwriters Laboratories

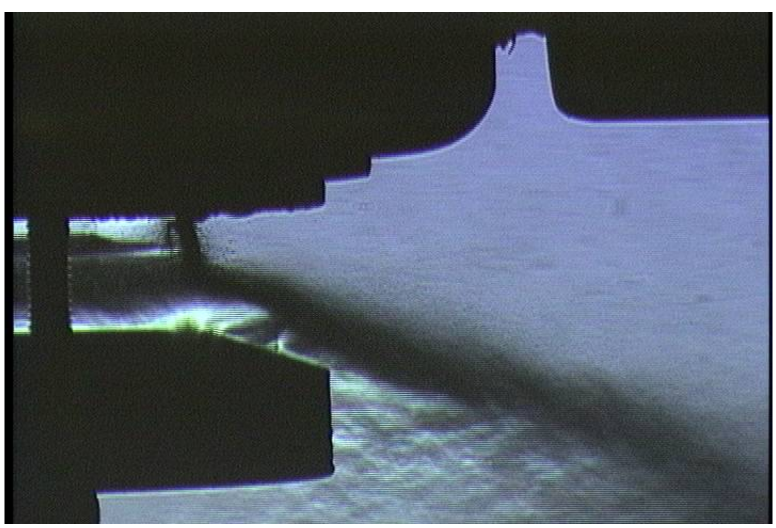

Figure 4: Water atomization or entrainment

The Victaulic Vortex system uses equal moles of water and nitrogen in producing a homogeneous suspension of water and nitrogen. Figure 4 shows water being injected into the nitrogen flow and the subsequent atomization. Of particular importance is the understanding that after the water is atomized it is carried in the nitrogen flow at equal partial pressures. At this point relative velocity between the water and nitrogen is negligible, resulting in a very small Weber number. Since the water is suspended in the nitrogen, it maintains its momentum and is capable of being projected for relatively large distances and in the process becoming entrained in fire plumes.