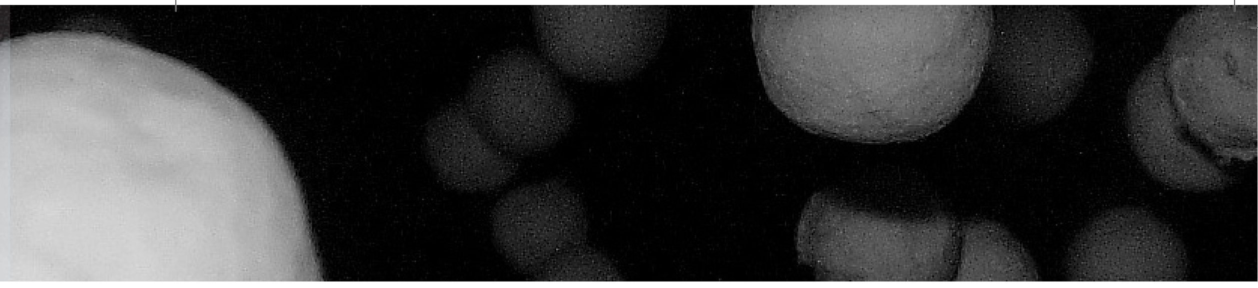

Developing fire suppression systems that meet the requirements of specific fire-fighting applications is an important goal. For certain fires, applying water in a fine spray or mist can be particularly effective, reducing water usage and minimizing equipment damage. In situations requiring fuel isolation, the use of foams is particularly advantageous. A system combining the benefits offered by water mists with those of fuel isolation is one of the aims of current research. This targets difficult environments such as engine compartment fires, which are traditionally extinguished using harmful gaseous suppressants.

This article discusses the importance of particle size characterisation in the analysis of atomised sprays. Advances in modern particle sizing technology allow more in-depth understanding of the mechanisms underlying spray behaviors and enables determination of the impact of surfactants on the effectiveness of water mists.

"Water mist fire suppression systems are attractive, as they generally require less than a tenth of the water used by conventional sprinkler systems"

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Droplet Size Analysis in the Development of Enhanced Water Mist Fire Suppression Systems

WATER MISTS

Water mists are defined by the US National Fire Protection Association code NFPA 750 as sprays with a Dv99 of 1000 µm or less, measured at the coarsest part of the spray in a plane 1 m from a nozzle operating at its minimum design pressure. When a water mist is applied, the water droplets evaporate rapidly, drawing heat of vaporisation from the fire and surrounding area. Simultaneous cooling and oxygen displacement by the resulting vapor suppresses the flames. The particle size of the water droplets in the mist is a critical parameter as this directly influences the effectiveness of the spray. Smaller droplets have a relatively high specific surface area, resulting in better heat transfer and more rapid vaporisation.

Water mist fire suppression systems are attractive, as they generally require less than a tenth of the water used by conventional sprinkler systems. Their low water delivery rate also minimises damage to sensitive equipment and eliminates the splatter of liquid fuel associated with sprinklers. Economic and environmental pressures, and the development of new technology, are driving current interest.

ENHANCING PERFORMANCE

Although water mists are highly effective, the reduced energy available to drive the suppression mechanisms observed as a fire is reduced in size can result in insufficient oxygen displacement, preventing complete extinction of a fire. Even where extinction is achieved, re-ignition from hot surrounding surfaces (burnback) may be a problem. A potential solution is the use of surfactant enhanced water mists.

Surfactants, the principal components of foam concentrates, facilitate the formation and spread of air-water foams. Foams suppress a fire by spreading over the liquid's surface, preventing fuel evaporation and reducing heat transfer to the fuel source. They also impede ignition or re-ignition. As water mists are commonly used to protect machinery spaces containing flammable liquids, a system incorporating the advantages of fuel isolation would have considerable benefits.

MEASURING THE PARTICLE SIZE OF FIRE RETARDANT SPRAYS

The high concentrations, wide plume widths and high exit velocities of fire suppressing mists make accurate measurement of their droplet size characteristics challenging.

The technique of laser diffraction calculates droplet size distributions by measuring the intensity of light scattered by particles, and can operate in the size range from 0.1 – 2000 microns. An intense laser light source enables measurements over a wide range of spray concentrations. The laser output is expanded and passed through the spray measurement zone. Scattered light is collected using a Fourier lens system and focused onto a silicon diode detector array, which measures the intensity of scattered light as a function of angle. Modern instrument lenses can achieve working ranges of more than one meter, allowing the characterisation of wide spray plumes within a single measurement. Rapid detection rates - up to one measurement every 100 microseconds - allow atomisation dynamics to be followed in real time.

Developed specifically for the characterisation of sprays, the Spraytec (Malvern Instruments), uses patented algorithms to automatically correct potential inaccuracies caused by multiple scattering between particles; a common difficulty, where particle concentration is high.

STUDYING THE IMPACT OF SURFACTANTS ON WATER MIST EFFECTIVENESS

To combine the benefits of surfactants and water mists, the resulting system must behave both as a vaporising spray when it leaves the injector, and as a spreading foam at the fuel surface. Researchers at Maryland University carried out experiments using water and various concentrations of proprietary surfactant solutions containing fluorinated compounds (Forafac™). Fire suppression and burnback experiments were conducted using a Tyco AM4 intermediate pressure nozzle in a burn room, using different experimental configurations representative of conditions used in machinery spaces. The particle size of the water mist was monitored using the Spraytec.

General Nozzle Performance

The nozzle system's general performance was pre-determined using water. Changes in particle size over time were measured at a distance of 0.5m from the nozzle, at a pressure of 3 bar (*Figure 1*). The transmission value reported during the measurements relates to the concentration of spray, with lower values correlating with high spray concentrations. In this case, the water reservoir was exhausted in 40 seconds. Nozzle output was relatively stable in terms of the median droplet size (Dv50), although at the end of the spraying process the droplet size became larger because of unstable flow of liquid through the nozzle. There was also a tendency towards the formation of some larger droplets at higher liquid flow rates, as evidenced by the gradual increase in the Dv90 as the transmission decreased.

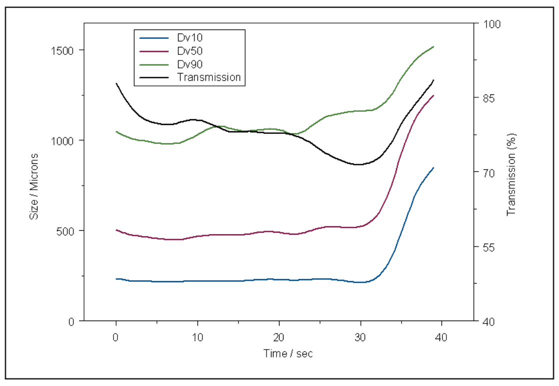

Figure 1: Size history showing the evolution in the droplet size over time for operation of the injector nozzle at 3bar pressure.

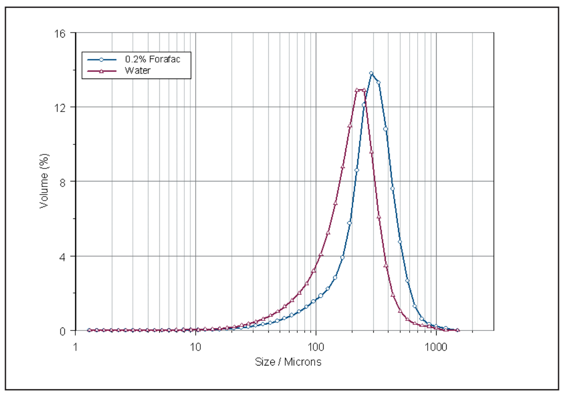

Figure 2: Measured volume distributions for pure H_2O and 0.2% Forafac™ in a plane 0.5 m below the Tyco AM4 nozzle.

Fire suppression performance

Droplet sizes for different surfactant formulations were tested successfully, using the Spraytec system - at 0.5 m below the nozzle and five points extending out 0.6 m from