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Book of Abstracts
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Kellie Ann Beall, Editor

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Water Mist Suppression of Fires in Underground Diesel Fuel Storage Areas

by

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Introduction

A fire risk associated with mobile diesel-powered equipment in underground mines is the storage and transfer of large quantities of diesel fuel in underground storage areas. Research by the Pittsburgh Research Laboratory (PRL) and others has shown that water mist technology, developed as a replacement for above ground halon extinguishing systems, may be applicable for fighting diesel fuel fires. The National Institute for Occupational Safety and Health/PRL is investigating the application of this technology for controlling and extinguishing fires in underground diesel fuel storage areas in order to develop design criteria for the use of these systems in underground mines. A large-scale fire suppression test facility was constructed to simulate an underground fuel storage area. Experiments were conducted to determine the relationship between the extinguishing effectiveness of water mist and the drop size and distribution and the location, geometry, and size of the fire for restricted diesel fuel fires.

Large-Scale Fire Suppression Facility

A large-scale fire suppression facility (FSF) was constructed to simulate an underground diesel fuel storage area. The Code of Federal Regulations, Part 75.1903 requires that permanent underground diesel fuel storage facilities be constructed of noncombustible materials and ventilated with intake air. The areas must be provided with self-closing doors and an automatic fire suppression system that initiates the means for closing of the doors. Typically, these areas are located off a main mine entry in a crosscut that is isolated from the adjacent entries by a permanent-type mine stopping. The main entry of the FSF is 153-ft long and the crosscut is 40-ft-long. Each entry is 18-ft-wide and 7-ft-high. Self-closing doors are located in the main entry, 30 ft from the crosscut. The storage area is fire-proofed and instrumented with thermocouples, gas monitoring instrumentation, and video equipment to monitor the fire tests in progress. The FSF is equipped with a closed water system in which the water is collected, filtered, and reused. The system has a 2,000 gal capacity with a pump that can provide a flow of 100 gal/min at 175 psi.

Experimental Procedure

To conduct the extinguishment experiments, the water mist nozzles were installed in the crosscut area in accordance with manufacturers specifications to ensure total water spray coverage of the area. The fires were contained in either 3-ft by 3-ft by 0.5-ft or 5-ft by 7-ft by 0.5-ft metal trays producing fire sizes of about 0.5 or 2.0 MW, respectively. Five gallons of low sulfur diesel fuel were used in each experiment. The fires were ignited and allowed to burn for 1 minute before the water mist suppression system was turned on. Depending on the parameter under study, the tray fires were located either directly under a nozzle in the center of the entry, geometrically centered between nozzles in the center of the entry, against the wall between two nozzles, or in the corner of the crosscut against the permanent stopping. The tray fires were monitored using 5 Type K thermocouples mounted just above the fuel and were considered extinguished when all 5 thermocouples showed temperatures below 30° C and the fire did not reignite when the water mist was turned off. Temperatures were also recorded at each nozzle, along the center-line of the roof, in the cross-sectional area of the crosscut, and on the permanent stopping.

Experimental Results

Droplet size: To determine the relationship between droplet size and extinguishing effectiveness, experiments were conducted with 0.5 and 2.0 MW fires at 4 different locations; in the center of the crosscut, either directly under a nozzle or between nozzles, against the wall, or in the corner. Similar type nozzles were used that produced droplet sizes ranging from 200 to 800 μm. Droplet size or droplet diameter refer to the $Dv_{0.9}$ of the nozzle, defined as 90 pct of the droplets being less than the droplet diameter specified. The results indicated that the extinguishing effectiveness of the water mist decreased with increasing droplet diameter, independent of fire location. At droplet diameters above 500 μm, there appeared to be a change in the effectiveness of the water mist resulting in longer times to extinguishment.

Pressure and flow rate: Experiments were conducted at different water system pressures and flow rates, using the same nozzle, fire size, and fire location, to determine if water pressure or flow rate had an effect on extinguishment. In tests with droplet diameters less than 500 μm, no effect of pressure was observed. However, in tests with droplet diameters greater than 500 μm, the mist was more effective at higher water pressures. This is probably due to the generation of a larger number of smaller droplets at higher pressures, even though the $Dv_{0.9}$ is greater than 500 μm. The results of the flow rate experiments showed a slight increase in the time to extinguish the fires a flow rate increased.

Nozzle type: Two different types of water mist nozzles, spiral and impingement, were evaluated. Spiral nozzles produce a conical shaped water distribution pattern, with the larger droplets forming the outer edge of the cone, while the impingement nozzles produce a more even droplet size distribution pattern. In experiments with droplet diameters less than 300 μm, no difference was observed in the extinguishing effectiveness of the two types of nozzles. Impingement-type nozzles producing droplet diameters greater than 300 μm were not available.

Fire location: To evaluate the effect of fire location on extinguishment effectiveness, tests were conducted with the same nozzles, flow rate, and pressure conditions on fires located directly under a nozzle, geometrically between the nozzles, against a rib, and in the corner of the crosscut against the rib and permanent stopping. For droplet sizes less than 400 μm, no effect was seen. As the droplet sizes increased from 400 to 800 μm, the water mist was less effective in extinguishing the wall and corner fires.

Fire size: Experiments were conducted on 0.5 and 2.0 MW fires using droplet sizes ranging from 200 to 800 μm to evaluate the effect of fire size on extinguishing effectiveness over a wide range of droplet sizes. In tests with water mists less than 500 μm, no effect was observed. In the tests with the larger droplet sizes, the smaller fires were more difficult to extinguish.

Conclusions

A large-scale fire suppression facility was constructed to simulate an underground diesel fuel storage area. Experiments were conducted to determine the relationship between the extinguishing effectiveness of water mist and the droplet size and distribution and the location, geometry, and size of the fire for restricted diesel fuel fires. The results indicated that the extinguishing effectiveness of the water mist decreased with increasing droplet diameter. The optimum droplet size was between 200 and 400 µm, independent of pressure, flow rate, nozzle type, fire location, and fire size.