MIXED PHASE FIRE SUPPRESSION SYSTEMS: APPLICATIONS AND BENEFITS

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ABSTRACT

Fire extinguisher systems that use a liquefied gas to disseminate a fire suppressing powder offer substantial advantages over traditional technologies. The simultaneous application of two modes of fire suppression produces a synergy that results in a substantial improvement in efficacy over single-phase systems. Historically, these systems have consisted of a monoammonium phosphate-based powder thixotropically gelled with halon 1211 and 1301. Now, Cease Fire, LLC is developing a new mixed phase system that uses C_3F_7H (Dupont FE-227) in place of the discontinued halons. Quantum Laboratories, Inc. is currently engaged in the research, design, and testing of this system.

This paper reviews the technical challenges involved in developing the new formula, discusses the laboratory techniques used to characterize the system, and summarizes the potential applications and benefits of mixed phase fire suppression.

BACKGROUND

Mixed phase fire suppression technology was first developed by William Tarpley in the late 1960's. This system used proprietary gelling agents to thixotropically suspend a monoammonium phosphate (MAP) powder in a blend of halon 1211 and 1301. The suspension was capable of maintaining liquid-like flow characteristics over long periods of time without significant agitation. When discharged, these units dispensed a uniform cloud of MAP powder and halon. The halon acted as a carrier agent for the powder, providing a much more uniform dispersion than would be the case with a single agent dry chemical system.

Additionally, the fire suppression capabilities of the halon component produced a chemical synergy with the MAP powder. At the molecular level, the two agents attack the combustion chain reaction by different mechanisms. It is this simultaneous application of two fire suppression mechanisms that is responsible for the efficiency of the system. A blended agent system requires substantially less total agent than either single agent system of the same fire suppression capacity.

Throughout the 1970's and 1980's, handheld aerosol extinguishers containing this formula were marketed under the Cease Fire name. In 1988, large automatic units were introduced. These self-contained, pre-engineered extinguishers were listed and approved for total flooding applications in spaces up to 2700 cubic feet.

With the discontinued availability of halon in 1994, the future of mixed phase fire suppression was uncertain. Quantum Laboratories, Inc. was engaged by Cease Fire to develop a new mixed phase system based on heptafluoropropane (Dupont FE-227). The considerable differences in chemical and physical properties between FE-227 and the halons used in the original formula provided a number of technical challenges. In addition to extensive modifications to the chemistry of the powder, the physical design of the extinguisher had to be altered to better accommodate the characteristics of the new formula. Although the proprietary nature of this technology limits the amount of detail that can be revealed, a more general discussion of laboratory techniques, testing criteria, and product applications can yield considerable insight into the current state of mixed phase fire suppression.

FORMULA DEVELOPMENT

Our first task was to determine the suitability of FE-227 as a halon replacement in this application. In order to qualitatively evaluate the propensity of the test mixtures to form thixotropic gels, a series of high-pressure glass reaction vessels was employed. Into each vessel, measured quantities of powder components were added. A pressure loading burette was then used to add FE-227 to each vessel. The mixtures could then be evaluated for thixotropic behavior according to a specific set of criteria. An acceptable formula would yield a free-flowing suspension with no clumping or adhesion of powder to the vessel walls. Although some settling of the suspension may occur over time, the mixture should quickly reliquify with only slight agitation. Using these criteria, dozens of formulations were tested.

To establish a performance baseline, a vessel was prepared containing only MAP powder and FE-227. Initially, the powder flowed freely within the liquefied gas. After being allowed to settle for several hours, the MAP powder formed a solid mass at the bottom of the vessel. Considerable agitation was required to return the powder to its free-flowing state. Clearly, a chemical modifier would be required to promote and maintain a truly thixotropic suspension. A number of physical and chemical factors contribute to the formation of such a suspension. These include the relative polarity of the ammonium salt and the organic liquid; the size and shape of the powder particles; and the density and volatility of the liquefied gas. Through the addition of gelling agents, the polarity and viscosity of the system is modified in a way that inhibits the ammonium salt from forming dense, semi-solid masses within the organic liquid matrix.

Several different gelling agents were evaluated at different concentrations. Combinations of agents were tested in order to address specific performance characteristics. The overall ratio of powder to FE-227 was also varied. Test vessels were exposed to different temperatures for varying lengths of time and the effects of time and temperature were qualitatively evaluated for each of the candidate formulas. Some formulations resulted in the formation of stable but highly viscous suspensions. Others yielded thin, free-flowing suspensions that eventually settled into solid masses. A few formulations produced good combinations of stability and liquidity.

Through this process, the number of possible formulations was narrowed until a candidate formula had been developed which appeared to provide the necessary flow characteristics to produce a successful mixed phase fire extinguisher.

EXTINGUISHER DEVELOPMENT

Although the new FE-227 based formula exhibited similar thixotropic behavior to the halon-based formula, there were differences that could affect the performance of the system in real-world conditions. These differences stem from the lower vapor pressure and boiling point of FE-227 as compared to the original halon blend. During discharge, the flow characteristics of the new formula required modifications to the extinguisher cylinder and nozzle in order to achieve equivalent efficacy.

Extinguishers charged with the new formula were prepared using a variety of cylinder geometries and nozzle hardware. These units were then manually discharged. Several performance factors were evaluated including discharge time, agent distribution, and amount of residual agent. It was determined that the original extinguisher designs were not ideally suited to the new formula. After exploring many possibilities, a taller, narrower design with a convex bottom surface and a larger orifice was chosen. This design provided excellent discharge efficiency and improved powder distribution.

The sprinkler head hardware was also modified. In order to maximize area coverage, an upright sprinkler head was employed in the pendant mounting position. This adaptation provided a concave surface that deflected the blended agent upward and outward from the extinguisher nozzle. The expanding and circulating gas then carried the powdered agent evenly throughout the protected space.

Finally, the materials used in the system were evaluated for long-term stability in the presence of FE-227. All o-rings, gaskets, and seals were chosen for their purported compatibility with the agent formula. Long term leak and stability tests were then conducted at extreme temperatures. In these tests, completed units are subjected to the maximum and minimum rated temperatures for periods of time ranging from five days to six months. Pressure and discharge performance are then measured to determine if any degradation has occurred.

Months of testing and development ultimately yielded a prototype mixed-phase extinguisher that combined novel agent chemistry with a compatible extinguisher design.

APPLICATION TESTING

It was now important to determine whether the new system was capable of meeting the rigorous requirements of the UL 1254 specification for Total Flooding applications. This specification contains a number of performance criteria that must be met in order to achieve certification. Of particular concern was the Class B fire test, in which twelve heptane fires must be simultaneously extinguished throughout the protected space. Several test cells were constructed in order to evaluate and define the extinguisher's performance. Through a series of fire tests, the coverage and performance parameters of the test units were defined. Factors such as operating temperature, ceiling height, and coverage areas were tested using different cell configurations and test protocols. These data were then used to develop performance specifications for manufacturing and certification.

Once the capabilities of the prototype unit were defined, comparative fire tests were performed with single agent extinguishers under the same test conditions. One unit was prepared using pure FE-227 in the same quantity as the blended agent. A second unit was prepared containing pure MAP powder under nitrogen pressure. This unit contained 30% more powder than the mixed agent unit. Neither of these units could successfully extinguish all fires in the Class B test. The mixed phase unit could repeatedly extinguish all fires in spite of the smaller quantity of each agent employed. These tests provided an effective demonstration of the synergistic advantages of mixed phase fire suppression.

Additional aspects of performance were also evaluated including Class A fire tests, local application tests, and automatic activation tests. Test results obtained here were used to develop a certification program that will ultimately lead to listing and approval of a variety of commercial products.

CONCLUSION

Our testing has clearly demonstrated that mixed phase fire suppression will continue to be a viable alternative to traditional technologies, in spite of the unavailability of halon agents. We have developed a mixed-phase formula using MAP powder thixotropically gelled in FE-227 which when deployed in an appropriate extinguisher will meet the requirements of the UL 1254 specification for total flooding applications.

An extinguisher thus configured offers substantial benefits over competitive systems in certain applications. Because the units are pre-engineered and self-contained, no piping or electrical connections are required. This allows protection of enclosed spaces in which the installation of a conventional system is impractical or impossible (e.g. bank vaults or shipping containers).

The smaller quantities of agent required reduce the toxicological concerns sometimes associated with clean agent systems. The concentration of FE-227 after discharge of a mixed-phase unit is about one third of what would be expected from a clean agent system of the same fire-fighting capacity. This would also reduce any corrosivity effects from FE-227 breakdown products.

Of course, these units are not clean agent systems, but they are "cleaner" than equivalent dry chemical systems. Substantially less powder is employed to provide the same suppression capacity, and the residual powder is easily vacuumed.

Currently, we are continuing to refine and expand the range of mixed-phase products. New sizes and types of units are being developed for an expanding scope of applications. For each of these new units, rigorous testing will be performed in order to assure optimal performance and consistent quality.

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