

COMPARISON TESTING IN A SIMULATED DATA PROCESSING/ TELECOMMUNICATIONS FACILITY: FM-200[®] AND AUTOMATIC SPRINKLER SYSTEMS

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INTRODUCTION

Data processing and telecommunication facilities are commonly protected against fire with a gaseous clean agent system, an automatic sprinkler system, or with both a clean agent and an automatic sprinkler system. The degree of protection provided by these systems is vastly different, as is the cost incurred in employing these systems.

The test comparison reported here was performed in order to illustrate the differences in the protection provided by automatic sprinkler systems and gaseous agent systems. The tests were performed in a simulated data processing/telecommunications facility, and examined the performance of the suppression systems on a plastics fire located inside a metal electronic equipment cabinet.

EXPERIMENTAL

TEST ENCLOSURE

The test enclosure is shown schematically in Figure 1. The test enclosure was designed, constructed and outfitted to simulate a typical data processing or telecommunications facility. The tests were performed in a 32.8 ft x 32.8 ft x 12 ft enclosure equipped with a 1.5 ft deep subfloor and a suspended ceiling located 2 ft below the drywall ceiling. The chamber was constructed from 0.5 inch gypsum wallboard over a metal stud frame. Access to the room is accomplished via two 2.9 ft x 6.6 ft doors, one at the southern end of the east wall and the other at the northern end of the west wall. Both doors open at the level of the raised subfloor. The enclosure has five 46 inch x 70 inch windows made of 3/16 inch polycarbonate, reinforced with two sets of horizontal braces made from 5/8 inch plywood. Three smaller windows, nominal 1 ft x 1 ft, are located along the southern and western walls.

An area 20 ft x 26 ft was covered with additional floor tiles on top of the plastic covering. The cabinet containing the fuel array was placed upon these tiles. In addition to the cabinet containing the fuel array, three other data processing equipment cabinets were arranged on the partial layer of floor tiles. These cabinets had been gutted prior to placement in the chamber and were not operational. Three file cabinets, two tables and chairs, and a non-operating PC were also arranged in this area.

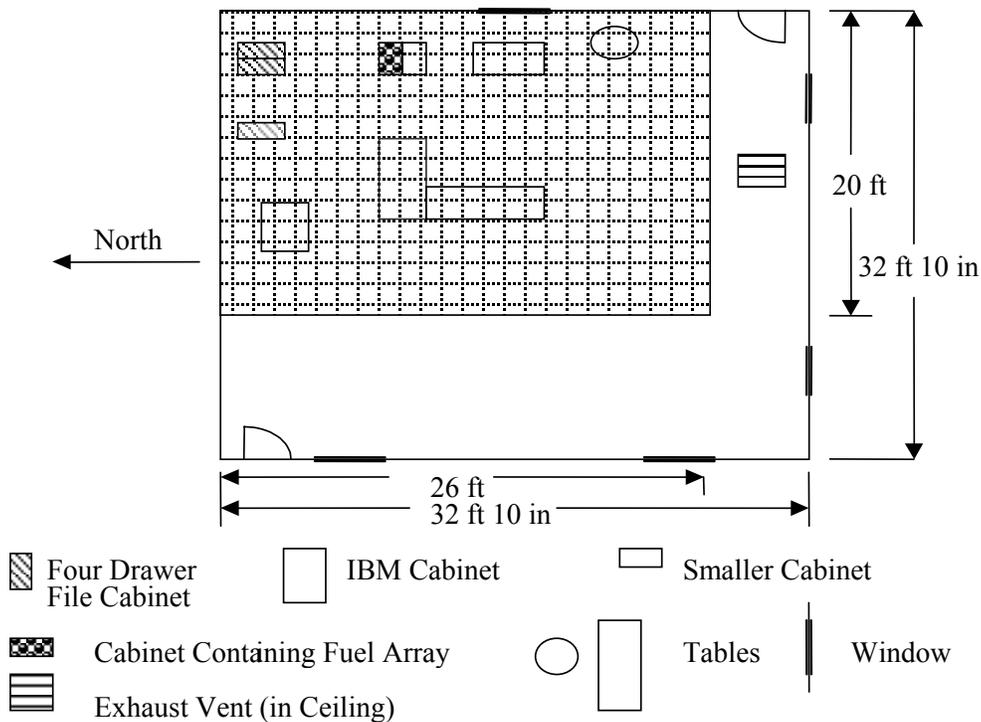


Figure 1. Test Enclosure

TEST FIRE

The test fire set-up is shown schematically in Figure 2, and consisted of eight 8 inch x 16 inch x 0.375 inch sheets of Acrylonitrile-Butadiene-Styrene (ABS), arranged vertically in two rows of four sheets each. The plastic sheet array was placed inside a cabinet equipped with metal mesh doors with the sheets oriented parallel to the solid metal walls of the cabinet.

The ABS plastic array was ignited by 3 ml of n-heptane in a 2 inch square pan located 0.5 inches below the array. This fire set-up is similar to that adopted by Underwriters Laboratories, Inc in their standard on Halocarbon Clean Agent Extinguishing System Units, UL 2166 [1].

Heat release data for the fuel array were obtained by burning the fuel array under a 10 ft x 10 ft hood equipped and instrumented to determine heat release rates based upon oxygen consumption. This hood and heat release rate determination is similar to that described in NFPA 265 for the determination of the heat release rate and fire growth contributions of wall coverings [2].

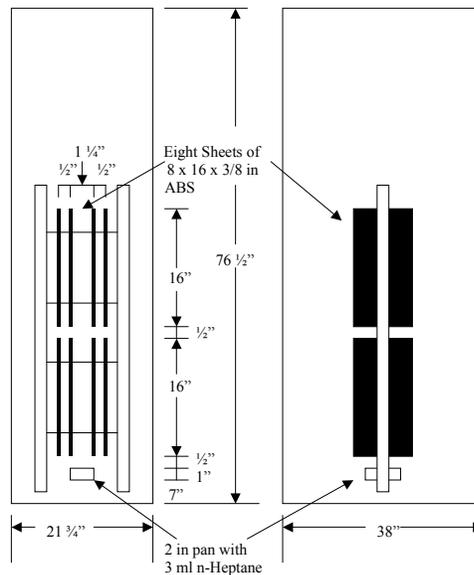


Figure 2. Fuel Array

SMOKE DETECTION SYSTEMS

Air Aspirating Smoke Detection System. The air aspirating detection system employed was a Fenwal AnaLASER II air sampling type detection system, designed and installed by an approved Fenwal distributor. The AnaLASER II was installed with a 0.061 % obscuration per foot alarm threshold. This alarm threshold is a mid-range value for an AnaLASER II unit, which can be set for alarm thresholds between 0.00075 and 0.3 % obscuration per foot.

Ionization/Photoelectric Smoke Detection System. The ionization/photoelectric smoke detection system consisted of an array of Simplex 4098 series True Alarm ionization and photoelectric smoke detectors. Six detectors, three ionization detectors (Part number 4098-9717) and three photoelectric detectors (Part number 4098-9714) were monitored during these tests. The alarm thresholds for these detectors were set at industry standard thresholds of 1.3 % obscuration per foot for the ionization detectors and 2.5% obscuration per foot for the photoelectric detectors.

All detection/alarm systems were installed in accordance with NFPA 72, National Fire Alarm Code [3].

FM-200[®] SUPPRESSION SYSTEM

The FM-200[®] suppression system was designed to simulate a typical data processing/telecommunication facility installation, and employed the Fenwal AnaLASER air aspirating detection system. The FM-200[®] system was designed in accordance with NFPA 2001 [4]. The system was designed to discharge 297 lb of agent into the main area of the enclosure in 9.5 seconds to provide a 7 % by volume concentration inside the enclosure. A 30 second delay from

full alarm of the Fenwal AnaLASER detection system to suppression system actuation was employed.

AUTOMATIC SPRINKLER SYSTEM

The automatic sprinkler system was designed and installed in accordance with NFPA 13 [5], based upon an Ordinary Hazard Class I classification. Nine sprinkler heads were employed in the main space and an additional nine above the suspended ceiling. The sprinkler heads were arranged with a symmetrical 11 ft spacing, corresponding to a coverage area of 121 ft². The sprinkler heads utilized were recessed pendent, standard response glass bulb sprinkler heads with a temperature rating of 155 °F and a K value of 5.6 gpm/psi^{0.5}.

The water supply for the sprinkler system was contained in two Burch Manufacturing Co. Kolaps-A-Tanks, Model FDA-98MT, with a capacity of 525 gallons each. The water from these two tanks was drawn by a 7.5 hp Teel centrifugal pump model number 3P703A.

The application density required under NFPA 13 for Ordinary Hazard Class I rooms less than 1500 ft² in floor area is 0.15 gpm/ft² [5]. Hence, for the enclosure (area 10⁷⁶ ft²) employed in these tests, NFPA 13 would require an application rate of 161 gpm in both the main room and in the suspended ceiling area, corresponding to a flowrate of 18.2 gpm from each nozzle. Hence, in these tests the design flowrate for each nozzle was set at the NFPA 13 requirement of 18.2 gpm.

NFPA 13 also requires that the water supply be adequate to supply all of the sprinklers within the design area for a minimum duration of 60 minutes [5]. This would require a water supply of (18 nozzles x 18.2 gpm per nozzle x 60 minutes) = 73,224 L (19,656 gallons). The provision of a storage tank capable of storing this quantity of water was impractical for the test facilities available, and as a result the water supply employed for this system did not meet the NFPA 13 requirement of providing a water supply capable of delivering water from all 18 sprinklers for 60 minutes. This deviation from NFPA 13 does not, however, impact the test results. The water supply employed was able to supply the two sprinklers nearest the fire location for a period of 29 minutes at the design flow rate of 18.2 gpm from each sprinkler. As only these two sprinklers were expected to operate (and in fact only these two sprinklers did operate), and the effects of these sprinkler flows on the fire and the compartment environment would be evidenced well before the water supply was exhausted, the impact of the non-compliant water supply on the test results is negligible.

ENCLOSURE INSTRUMENTATION

The chamber was instrumented to allow monitoring of temperatures, smoke densities, species concentrations and the operation of the FM-200[®] and sprinkler systems. Four thermocouple trees were installed in the enclosure, each tree consisting of three type K thermocouples, one at the level of the raised floor, one mid-way between the raised floor and the suspended ceiling, and the last at the height of the suspended ceiling. These thermocouple trees were located at the center of the eastern wall, the center of the southern wall, in the northeast corner, and at the center of the northern wall. Type K thermocouples were located at each of the sprinkler head locations to monitor the ceiling jet temperature at the heads.

Smoke optical density was measured with a white light meter with a 1.52 m (5 ft) path length located 1.83 m (6 ft) above the raised floor at the center of the southern wall.

TEST PROCEDURE

FM-200 System. Data acquisition was commenced with the ignition of the n-heptane pan below the ABS plastic array. The extinguishing system was actuated 30 seconds after the AnaLASER II smoke detection system went into full alarm. The enclosure remained sealed with the doors and vents closed and the exhaust blower shut down until 20 minutes after FM-200[®] system actuation.

Automatic Sprinkler System. For the sprinkler system test, the water supply pump was started prior to the start of data acquisition. After ignition of the n-heptane pan, the room remained sealed for 17.7 minutes. At that time, the vents were opened and the exhaust blower started. At 22 minutes from ignition, the water supply pump was shut down and the fire extinguished with a portable extinguisher.

RESULTS

FM-200[®] SYSTEM

In the FM-200[®] test, the AnaLASER air sampling smoke detection system went into full alarm at 78 seconds after fuel ignition, and the FM-200[®] system was actuated 30 seconds later; from Figure 4, the fire size at the time of activation of the system can be estimated to be approximately 25 kW. The fire was observed to be completely extinguished 17 seconds after system actuation.

Damage to the enclosure and its contents was limited to the dislodging of several ceiling tiles and the slight bending of some of the ceiling tile runners. Post-test examinations revealed that the cross tee supporting the ceiling tiles just south of the nozzle had been bent slightly, and that the two north-south runners on either side of the nozzle were slightly bent near where the bent cross tee joined these runners. It was also noted that the base of the FM-200[®] nozzle was flush with the lower edge of the ceiling tiles, and hence the nozzle orifices were only 2.5 inches below the suspended ceiling. The close proximity of the nozzle to the ceiling is the likely cause of the dislodging of the ceiling tiles and the bending of the ceiling tile support runners. Most FM-200[®] equipment manufacturers would recommend either a greater distance between the ceiling and the nozzle orifices, e.g., approximately 4 to 8 inches, the use of deflector plates around the nozzles, or both. An additional test of the FM-200[®] system was carried out wherein the ceiling tiles near the discharge nozzle were secured; this eliminated the dislodging of the ceiling tiles, and hence in this case no non-fire damage was observed following extinguishment of the fire.

Following the extinguishment of the fire with the FM-200[®] system, the room could be occupied immediately and any operations continued.

As can be seen from Figure 3, the ceiling temperatures at the sprinkler locations never reached more than 75 °F. Figure 4 shows that the maximum ceiling temperature observed in the enclosure was less than 85 °F.

AUTOMATIC SPRINKLER SYSTEM

In the automatic sprinkler system test, the Simplex photoelectric detector in the northeast corner went into full alarm at 94 seconds after ignition of the ABS array. At 112 seconds after ignition, the ionization detector in the northeast corner went into full alarm. At approximately 180 seconds from ignition obscuration due to the smoke generated began to increase rapidly, and at approximately 240 seconds from ignition the entire room was filled with thick smoke and vision into the room was completely obscured. The sprinkler head in the northeast corner actuated at 273 seconds after ignition, followed by the east sprinkler head 74 seconds later. From Figure 4, the heat release rates at the time of activation of the northeast and east sprinkler heads can be estimated as approximately 200 kW and 350 kW, respectively. Infrared cameras confirmed that the fire continued to burn throughout the entire experiment and was not extinguished by the sprinkler system. At the conclusion of the test, 17.8 minutes from ignition, the room was entered by personnel in breathing gear and the fire extinguished with a portable extinguisher.

Damage to the enclosure was extensive, consisting of both fire and water damage. Post-test examination of the room revealed a black “ring” around the enclosure extending 2 to 3 feet below the suspended ceiling, which was more pronounced near the fire location. All of the ceiling tiles were discolored and the two tiles located at the sprinkler heads which actuated were warped and sagging. The spray pattern from the two sprinkler heads which had actuated was evidenced on the northern and eastern walls as clean spots. The plastic globe on the fluorescent light above the fire location had fallen from the light.

The water on the floor at the end of the test was approximately 2 inches deep and contained a large amount of floating soot particles, scrubbed from the smoke layer as the water spray passed through the smoke layer. Paper items located within the enclosure suffered extensive water damage, and the enclosure floor was covered in water containing large amounts of soot.

As seen in Figures 5 and 6, at all locations with the exception of the southwest sprinkler, ceiling temperatures at the time of system actuation were above the 155 °F temperature rating of the sprinkler heads. However, only the northeast and east sprinkler locations got hot enough and remained hot for a sufficient time to cause activation. The east wall thermocouple tree was closest to the fire, and the ceiling level thermocouple on this tree peaked at a temperature of 560 °F at 480 seconds after ignition.

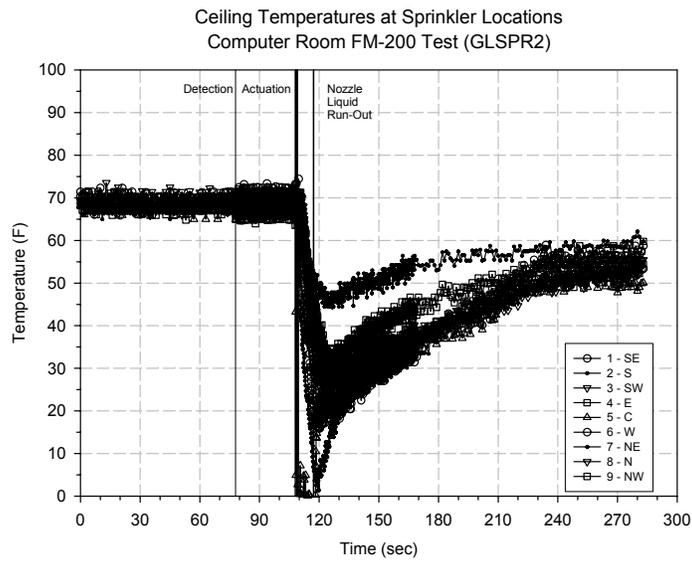


Figure 3. Ceiling Temperatures at Sprinkler Heads: FM-200 System Test

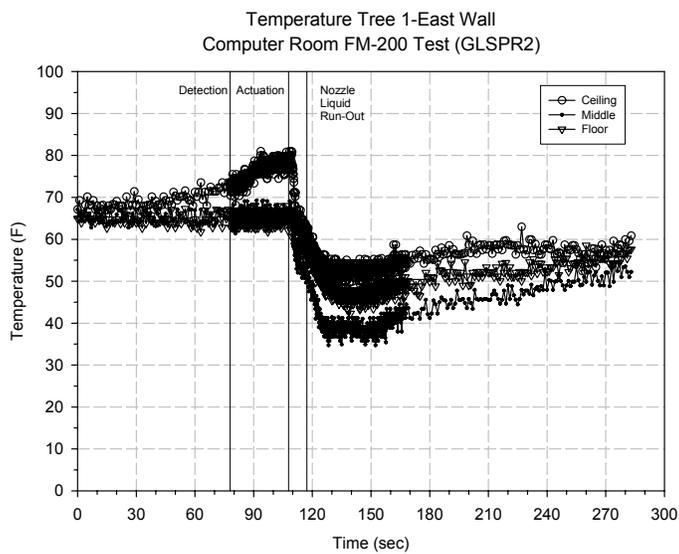


Figure 4. Enclosure Temperatures During FM-200 System Test

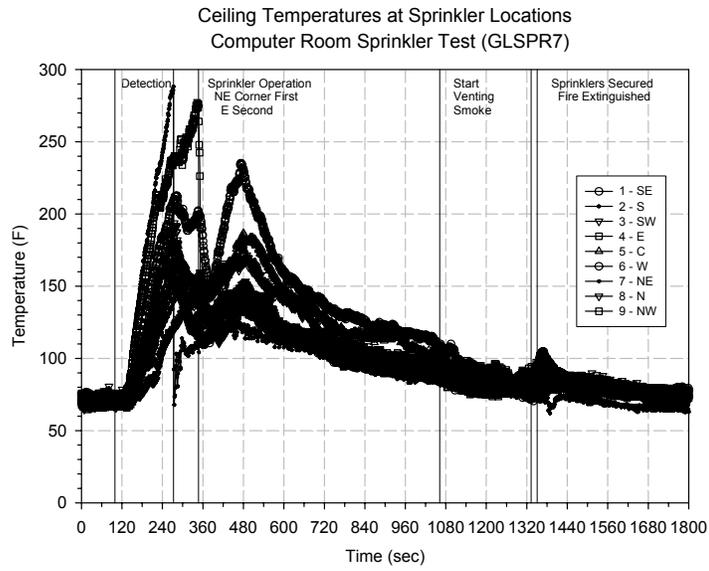


Figure 5. Ceiling Temperatures at Sprinkler Heads: Preaction System

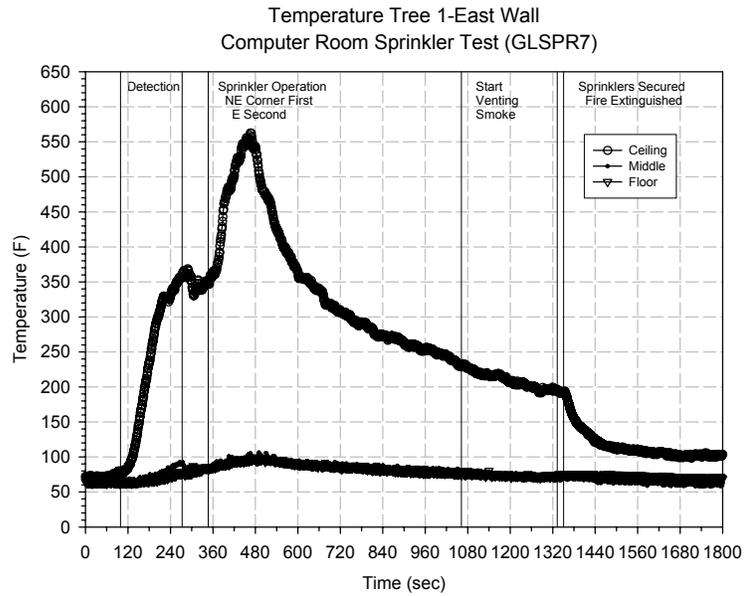


Figure 6. Enclosure Temperatures During Preaction System Test

DISCUSSION

The test results obtained during this study clearly demonstrate the vast differences in protection provided by gaseous clean agent and automatic sprinkler systems. Both systems, designed and installed in accordance with the appropriate NFPA standards, performed exactly as expected based upon the primary design objective of the systems. Table 1 and Figure 7 provide a comparison of the test results.

Table 2 summarizes the characteristics of gaseous clean agent and automatic sprinkler systems. The fundamental objective of the two systems is vastly different. The primary objective of an automatic sprinkler system is fire *control*: confining of the fire to the room of origin and controlling the ceiling temperatures to prevent structural damage and/or collapse. This is vastly different from the primary objective of a clean agent system, which is rapid fire *extinguishment*. Figure 7 presents a graphical illustration of the difference between the two systems with respect to the heat release rate over time.

Table 1. Comparison of Test Results

| | Sprinkler System | FM-200 System |
|--|--|----------------------|
| Detection (sec from ignition) | 94 s (photoelectric) 112 s (ionization) | 78 s |
| System activation (sec from ignition) | NE head: 273 s E head: 347 s | 108 s |
| Fire Extinguishment (sec from ignition) | Not extinguished | 125 s |
| Fire Size at activation | NE head: 200 kW E head: 350 kW | 25 kW |
| Ceiling Jet Temperature head at activation | > 121 °C | 24 °C |
| Maximum ceiling Temperature observed | 293 °C | 82 °C |
| Smoke damage | extensive | none |
| Water damage | extensive | none |

The primary objective of a clean agent system is to provide rapid detection and rapid extinguishment. This ensures the fire is still in its incipient stages and that damage is limited to the object(s) undergoing combustion. The FM-200[®] test results demonstrate the attainment of these objectives. The fire was rapidly detected (78 seconds after ignition), and after a 30 second delay the system was actuated, resulting in extinguishment 17 seconds later (i.e., at 125 seconds from ignition). At the time of system actuation, the fire size was 25 kW, and the maximum ceiling temperatures recorded at the time of actuation were less than 85 °F. Damage to

Table 2. Comparison of Clean Agent and Automatic Sprinkler Systems

| | Sprinkler System | Clean Agent System |
|-------------------------|--|--|
| Suppression Agent | Water | Gas |
| Design Objective | Fire Control: Confine fires Control Ceiling Temperature | Fire Extinguishment |
| Activation | Sprinkler head T > 135 °F | Automatic activation following detection (air sampling, smoke detectors) |
| Fire size at activation | Can be 100's of kW | Low as 0.1 kW with air sampling detection system |
| Total Flooding? | No; water not three- dimensional, will not fill entire enclosure | Yes; agent distributed uniformly throughout enclosure |
| Cleanliness | Not clean; water damage can be extensive and exceed fire damage | Yes; no residues to clean up following extinguishment |
| Protection | Protection of the structure, not its high value contents | Protection of high value contents, not the structure |
| Relative Cost | Low | High |

the enclosure and its contents were limited to a scorching of the equipment cabinet containing the fuel array, and the dislodging of several ceiling tiles. The FM-200[®] agent is a clean agent, i.e., no residues are left in the enclosure following extinguishment, and hence no post-extinguishment cleanup of the facility would be required. Business interruption would be kept to a minimum and repairs would consist solely of replacing several ceiling tiles and ceiling tile runners. As indicated above, lowering the nozzle or employing a deflector shield would likely eliminate the need for even these minor repairs.

The primary objective of a sprinkler system, whether wet-pipe or pre-action, is fire control, and the attainment of this objective was demonstrated during the automatic sprinkler test. The fire was contained to its place of origin, and the ceiling temperatures controlled sufficiently to prevent structural damage and/or collapse. Actuation of sprinkler systems does not occur until the temperature at the glass bulb or the fusible link of a sprinkler head exceeds its temperature rating, in this case 155 °F. Actuation of the northeast and east sprinkler heads occurred at 273 and 347 seconds after ignition. At the time of the head activations the room was entirely filled with smoke and vision completely obscured. Ceiling jet temperatures at the northeast and

Fire Size of ABS Array used in GLCC Sprinkler Comparison Tests

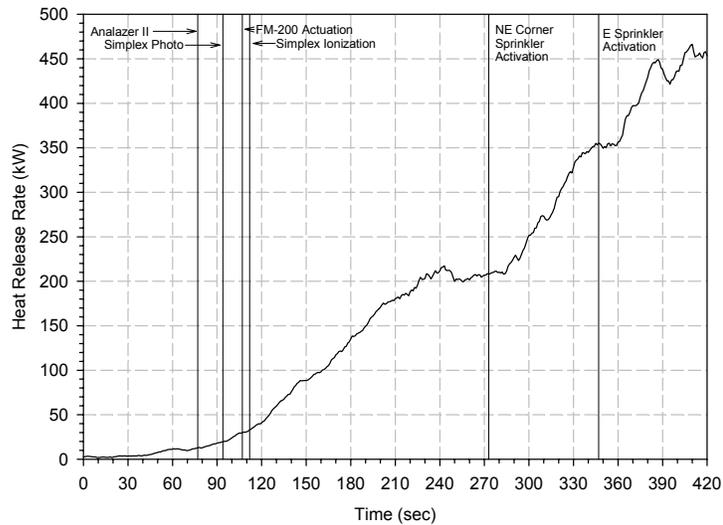


Figure 7. Comparison of FM-200 and Preaction Systems

east sprinkler heads at the time of activation were in excess of 250 °F. A maximum ceiling temperature of 560 °F was observed at the thermocouple tree nearest the fire (compare to a maximum ceiling temperature of 82 °F in the case of the FM-200[®] system test).

The sprinkler system failed to extinguish the fire, but this was an expected result, as the primary objective of the system is fire control. Unlike gaseous agents, water is not three-dimensional in nature and does not completely fill the enclosure, i.e., it does not act as a total flooding agent. Hence, fires in locations where the water spray does not directly impinge upon the fire would not be expected to be extinguished, but would be controlled by a properly designed automatic suppression system.

Although the initial cost of an automatic sprinkler system is much lower than that of a clean agent system, the results seen here demonstrate the potential risk associated with relying on a sprinkler system to provide protection for both the structure and its contents. In this case of an in-cabinet fire, both the asset and the structure suffered extensive damage when an automatic sprinkler was provided as the only protection. Extensive cleanup and repair of the structure would be required before the facility could be re-occupied and business resumed. As seen from the FM-200[®] system test, this same in-cabinet fire could be readily extinguished without any accompanying damage to the structure or its contents. The higher price of the clean agent system is justified by the protection it provides for very sensitive and expensive equipment, and the ability of the clean agent system to minimize cleanup and business downtime.

CONCLUSION

A series of tests were performed in a simulated data processing/telecommunications facility to illustrate the difference in protection afforded by clean agent and automatic sprinkler systems. The results of these tests clearly demonstrate the vastly different nature of these systems. The purpose of a sprinkler system is to *protect the structure*, and to confine the fire to its room of origin. The purpose of a gaseous clean agent system is to *protect the valuable and/or sensitive assets* within the enclosure. As seen in this study, relying on a sprinkler system for protection of the enclosure's assets can be ineffective and costly: not only can the asset which initially caught fire be destroyed, but extensive smoke and water damage to the enclosure and its contents can also result. At the same time, gaseous clean agent systems are not ideally suited for the protection of structures, but for the protection of the enclosure's contents, typically very sensitive and expensive equipment, and provide a minimum of downtime and cleanup in the event of a fire. As a result, for applications involving expensive and sensitive equipment, the use of a gaseous clean agent to protect the assets, in combination with a sprinkler system to protect the structure, is a logical and viable solution to the fire protection needs of such facilities.

REFERENCES

1. Underwriters Laboratories, Inc. "Standard for Halocarbon Clean Agent Extinguishing System Units", UL 2166, Underwriters Laboratories, Northbrook, IL, 1999.
2. National Fire Protection Association, "Standard Methods of Fire Tests for Evaluating Room Fire Growth Contributions of Textile Coverings on Full Height Panels and Walls", NFPA 265, National Fire Protection Association, Quincy, MA, 2002.
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