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EFFECTS OF AUTOMATIC SPRINKLER PROTECTION ON A SMOKE CONTROL SYSTEM

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A series of experiments at the National Fire Laboratory (NFL), measured the effects of water spray from automatic sprinklers on the temperature, pressure, oxygen, carbon dioxide and carbon monoxide levels in a building under fire conditions. The project was jointly funded by the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE) and the National Research Council of Canada.

Sprinklers act quickly to extinguish fires before they become large enough to create dangerous smoke conditions in a building. In these tests, however, particular attention was paid to shielded fires, in which an obstacle prevented water spray from extinguishing the burning fuel. In an office occupancy, for example, shielded fires could develop in combustible materials stored under a table or in a closet, or in compact mobile shelving units for paper filers. In shielded fires, sprinklers restrain the burning rate, prevent fire spread and reduce temperatures, but are not able to eliminate the smoke hazard in the building.

Testing involved two phases. In the first phase, wood cribs were burned in a one-storey test room 6 m × 6 m × 3.6 m high. The second phase involved creating wood crib fires on the seventh floor of the NFL's ten-storey experimental tower; the fire floor was mechanically exhausted, while air was supplied to pressurize the floors above and below the fire floor. The stairshaft was not actively pressurized. The presence of carbon dioxide (CO_2) in concentrations greater than normal ambient levels, at any location outside the fire floor, was interpreted as evidence of "smoke" spread.

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The fire intensity was varied by reducing or increasing the sprinkler spray density so that the effects hotter or cooler fires on the building could be assessed. The supply of combustion air to the fires was limited to less than what the fire would need for fully unconfined burning.

The ten-storey building was pressurized as a zoned smoke control system, in conformance with the recommendations in the ASHRAE Smoke Control Design Manual. Three levels of design pressure difference between zones (DPdesign) were tested: DPdesign = 25 Pa, 12.5 Pa and 0. The last case represented no smoke control other than the sprinklers, and corresponded roughly to "Measure A—fully sprinklered building" in the National Building Code of Canada. Doors to the stairshaft were opened in various sequences to increase or decrease the likelihood of smoke spreading into the stairshaft.

HEAT RELEASE RATE

Figures 1 and 2 show the effects of sprinklers on heat release rate (HRR) for the one-storey and ten-storey tower tests. A sprinkler spray density of 0 Lpm/m^2 represented an unsprinklered fire. The HRR of the unsprinklered one-storey crib fires was about twice the rate of the tower fires, due to the difference in size of the cribs. In both cases, increasing the sprinkler spray density reduced the burning rate. For spray densities around 4.1 Lpm/m^2, the minimum acceptable by the sprinkler design standard (NFPA 13) for light hazard fuel arrays, the HRR was

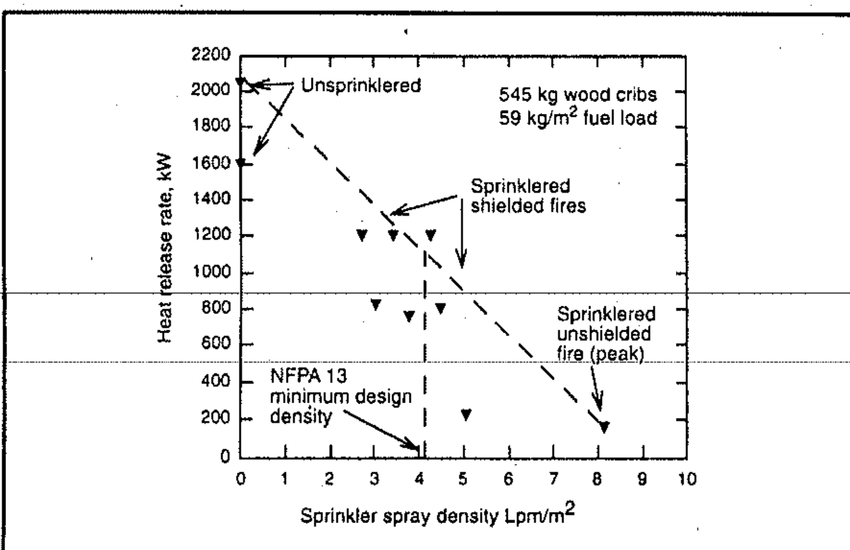

Figure 1. Effect of sprinklers on heat release rate, one storey test room.

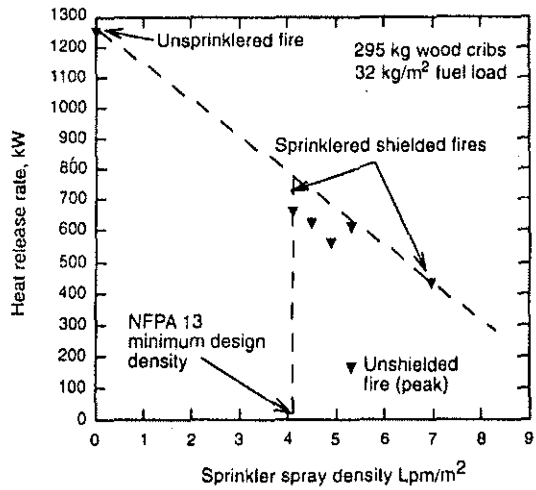

Figure 2. Effect of sprinklers on heat release rate, ten storey tower.

reduced to about 50 percent of its unsprinklered value, although the fires continued to generate smoke. The unshielded wood crib fires were extinguished within a few minutes of sprinkler operation. Sprinklers operating near minimum densities are able to restrain the HRR to about 50 percent of an unsprinklered fire. NFPA 13 recognizes control of HRR and reduced temperatures as acceptable fire suppression performance of a sprinkler system. However, from the point of view of smoke control systems, continued burning of the shielded fire results in a significant smoke hazard in the building.

RADIANT HEAT FLUX AND TEMPERATURES

Sprinkler spray was very effective at reducing the radiant heat from these fires. At even very low spray densities, a dramatic reduction in radiant flux to the walls was recorded. One significant benefit of reduced radiant heat is the reduced likelihood of windows breaking. From the point of view of smoke control then, sprinklers improve confidence that the integrity of the fire compartment will be maintained, even with only marginal sprinkler performance.

Figure 3 shows that sprinklers were very effective in reducing room temperatures, even when the spray density was too low to significantly reduce the heat release rate. Without sprinklers, temperatures exceeded 800°C throughout the room. With sprinklers, average temperatures were reduced to less than 150°C, and even peak ceiling temperatures never exceeded 210°C. Only two sprinklers were

Heat release rate, radiant heat, room temperatures and buoyancy pressures caused by fires in shielded wood cribs were reduced significantly by the sprinklers. Despite the shielding, the sprinklers achieved "control" of the fire, as defined by the sprinkler system design standard, NFPA 13. Fire-induced buoyancy pressures, for example, were in the range of 2 to 3 Pa, or about one-quarter the pressure difference recommended by the ASHRAE Smoke Control Manual for sprinklered buildings. The tests also demonstrated, however, that shielded, sprinklered fires can burn for extended periods of time and produce large quantities of smoke. Concentrations of carbon monoxide in the smoke may be very high, depending on ventilation conditions of the fire. Although the zoned smoke control system prevented smoke spread to adjacent pressurized floors, it did not prevent smoke spread into the stairshaft after the door to the fire floor was opened, unless the stairshaft had been pre-pressurized by prior opening of other doors.

Smoke from shielded, sprinklered fires will spread through a building if no measures are taken to stop it. A zoned smoke control system conforming to current design practice will prevent smoke spread into zones protected by positive pressurization. Current practice, however, allows the designer to rely on mechanical exhaust of the fire zone to protect the stairshaft from smoke contamination. Under those conditions, when the door to the stairshaft was opened, the stairshaft was rapidly contaminated. The stairshaft needs to be independently pressurized, and provided with a source of free-flowing air to develop a counter-flow through the doorway to the fire zone.

Note: Both the final experiment report and a technical paper discussing the implications of this research have been submitted to ASHRAE. The Technical Paper, authored by J. R. Mawhinney and G. T. Tamura, will be presented at an ASHRAE symposium in the near future.

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THE SHIFT IN EARTHQUAKE PROTECTION REQUIREMENTS

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The earthquake protection requirements of NFPA 13—Installation of Sprinkler Systems, have been in motion for the past decade. In the 1983 edition of the standard, clarification was provided for minimum clearances provided by pipe sleeves and through frangible construction. In the 1985 edition, the maximum 40 ft. between lateral sway bracing was moved to the text to become a requirement, and the use of flexible joints was recognized as an alternate to clearance for piping into a building through a basement wall. A number of changes were made in 1987, with new requirements for maximum slenderness ratio of braces, maximum distances between longitudinal sway bracing, restraint of the end sprinklers on branch lines, and restrictions on C-type clamps. This was also the year in which brace and fastener load tables were added to the appendix, providing much-needed guidance in this area. In 1989, the tables were moved to the text of the standard as part of a major reorganization. The assigned load table was established as an alternate to determining the zone of influence of each brace. Swing joints assembled of multiple flexible fittings were required wherever sprinkler piping crossed building seismic joints.

In the 1991 reorganization of the sprinkler standard, the earthquake protection provisions were moved to section 4-5.4.3. In the aftermath of the Loma Prieta earthquake, a new requirement was added for restraint of branch lines where upward or lateral movement of sprinklers would result in an impact against the building structure, equipment, or finish materials. However, the option was also added to permit the use of splayed seismic brace wire for this purpose. The

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