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Evaluation of the Fire Suppression Effectiveness of Manually Applied Compressed-Air-Foam (CAF) System

Andrew Kim and George Crampton

INTRODUCTION

Current foam systems, which incorporate aspirating-type nozzles have several limitations, including poor foam quality due to the use of fire contaminated air for foam generation. Also, since the water flow momentum is used to aspirate air at the nozzle to create foam, the discharge momentum is reduced, which may limit the ability of the foam stream to penetrate fire plumes to reach the seat of the fire.

Recently, several companies have developed mobile compressed-air-foam (CAF) systems for use by fire services. CAF is generated by injecting air under pressure into a foam solution stream. Mobile CAF systems represent a new type of fire suppression system, which is gaining popularity among fire services. Properly engineered CAF systems produce superior quality foam with high momentum. However, until now, there has not been a study to systematically evaluate the fire suppression effectiveness of the mobile CAF systems. It is necessary to compare the fire suppression effectiveness of the CAF systems with traditional fire suppression systems, such as hose stream application, to determine the superior fire suppression effectiveness of the CAF approach.

NRC has conducted a project to evaluate the effectiveness of a mobile CAF system in suppressing fully developed compartment fires. The fire suppression effectiveness of the CAF system was compared with that of a hose stream application using water alone and using water-foam solution, under similar conditions.

EXPERIMENTAL SET-UP AND PROCEDURES

Several full-scale compartment fire tests were conducted to compare the fire suppression performance of manually-applied CAF system, hose stream with water, and hose stream with water-foam solution.

The compartment was built with wood stud walls and a gypsum wallboard interior. The dimensions of the test compartment was 4.26 m by 3.65 m with 2.44 m ceiling height. The total volume of the test compartment was 38 m^3. The test compartment had an access door with a dimension of 0.86 m x 2.03 m. There was a short corridor (hallway), measuring 2.3 m wide and 3.65 m long, just outside of the door. This corridor was built as part of the test compartment to make a more realistic arrangement, because in real residential compartments or office spaces, there is usually a corridor outside of the door. This corridor also acted as a target area in measuring the migration of smoke, fire gases and heat from the fire room to other parts of the building, during the fire development and its suppression.

Several ventilation openings were provided in the test compartment to ensure adequate supply of fresh air for the fire in the room. A simulated window was provided in the test compartment. The window dimension was 0.41 m by 0.48 m. This window was closed during the fire development in the room, but was manually opened at the beginning of fire suppression, simulating window breakage during the fire attack by fire fighters.

The fire load in the test compartment consisted of two wood cribs, a mock-up sofa, and several OSB sheets, that were used to line the lower half of the compartment walls and the floor. Each wood crib was constructed with 48 pieces of 0.038 m x 0.09 m x 0.8 m pine studs. The wood cribs would produce an approximately 1 MW fire. The two wood cribs were covered with 1.22 m by 2.44 m OSB sheets to enhance the growth of a deep-seated fire within the wood cribs. The mock-up sofa was built with a metal frame, and 11 mm thick OSB boards used as a seat and back of the mock-up sofa. The surface of the mock-up sofa was covered with a 100% polyester blanket.

The total number of 1.22 m x 2.44 m and 11 mm thick OSB sheets was twelve, including the ones used on the compartment wall, sofa, and on top of the wood cribs. The estimated heat release rate of the 12 OSB sheet was 3.6 MW. Therefore, the total heat release rate in the test compartment at the time of fire suppression was approximately 5.6 MW.

Thermocouple trees, consisting of five 24-gauge type-K thermocouples spaced 0.5 m apart starting at the ceiling, were located in the fire room and the hallway. A heat flux meter was placed in the fire room near the centre of the back wall, and one type-K, 24-gauge thermocouple was located at the top center of the doorway.

A gas sampling tube was placed at the center of the back wall in the hallway, 1.5 m above the floor. The sampling tube was connected to a smoke meter and gas analyzers, to measure the smoke obscuration and concentrations of O_2, CO_2 and CO in the hallway.

Two digital video cameras were set up outside the test compartment to obtain visual records of fire ignition and development in the test compartment, and its suppression during the experiments.

The same experimental procedure was used for all experiments to minimize the introduction of unforeseen variables that could affect the results. During the tests, the following test procedure was followed:

1. Data system was activated at time zero.
2. At 45 s after the data system activation, the two wood cribs were ignited using four small pans containing methyl hydrate, located underneath the cribs. As the fire grew in the cribs, eventually flashover occurred in the compartment and the mock-up sofa and lower wall and floor of the compartment caught fire.
3. Approximately 120 s was given beyond the flashover point to produce a deep seated wood crib fire and an intense fire in the compartment, before fire attack was attempted by the fire fighter with either CAF or hose-stream application.

4. When knock down of the fire in the compartment was achieved, the fire fighters sounded a horn, and the amount of water used to that point was recorded.
5. When complete fire extinguishment was achieved, the total amount of water used for fire suppression was recorded and the data system was turned off.

EXPERIMENTAL RESULTS

Several full-scale fire suppression experiments were conducted in the test compartment using CAF or hose stream application with water or foam solution. Fire control time, the amount of water used and the temperature data in the fire room and in the hallway, as well as the smoke density and gas concentrations in the hallway were measured.

Reviewing the test results indicated that smoke obscuration and gas concentration data in the hallway and heat flux measurement in the fire room did not provide data, which could be used to determine the fire suppression effectiveness of the suppression systems. The most useful data for this purpose was the temperature measurements in the fire room and the total amount of water used to control the compartment fire.

Temperature data and the water consumption rate showed that CAF was much more effective in suppressing the compartment fire than hose stream with water only or with foam-water solution.

Comparing the average temperatures in the fire compartment for Tests #6 (water only), #8 (foam-water solution) and #10 (CAF) showed that, at the time of fire attack by fire fighters, the average temperature in the fire room was almost equal in the three tests. However, after the fire attack, the average room temperature dropped much quicker with CAF than with foam-water solution or with water alone. If we take 200ºC as the critical temperature in the fire room, it took 35 s for the average room temperature to drop to the critical temperature when CAF was used compared to 45 s for foam-water solution and 60 s for water alone. CAF was able to control the fire and reduce the room temperature much quicker with much less water flow (95 L/min (25 GPM)) compared with the foam-water solution and water alone, both of which used 360 L/min (95 GPM) flow rate.

The amount of water used to control (knock down) the compartment fire was also much less with CAF than with foam-water solution or water alone. It required approximately 114 L (30 US gallons) of water to control the fire with water alone, and approximately 57 L (15 US gallons) with a foam-water solution. With CAF, it required only approximately 23 L (6 US gallons) of water to control the fire.

The test results clearly showed that CAF was much more effective in suppressing compartment fires than with water alone or with foam-water solution.