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# Fire Suppression Performances of Manually Applied CAF and other Water Based Systems

Andrew Kim and George Crampton

## INTRODUCTION

Recently, several new mobile fire suppression systems are available to fight structural fires by fire services. Some of the newly developed mobile fire suppression systems are; Compressed-Air-Foam (CAF) system, Medium and Ultra High Pressure Water (MPW/UHP) system, and High Expansion Foam (HEF) system.

CAF is generated by injecting air under pressure into a foam solution stream. One significant advantage of the CAF system is the increased momentum of the foam, enabling it to penetrate fire plumes and reach the seat of the fire. MPW/UHP system uses relatively high water pressure, typically in the range of 500 psig for MWP and 1500 psig for UHP. HEF system uses highly expanded foam, which is injected into a compartment in a short period of time.

Even though they are claimed to have far superior fire suppression performances over the traditional manual systems, there is no information available on the fire suppression performances of these new systems. Therefore, NRC has carried out a project to evaluate the fire suppression effectiveness of several new mobile fire suppression systems, such as CAF, MPW/HPW and HEF systems, and the fire suppression performances of these new mobile systems were compared with that of foam solution or water hose stream application using the same flow rates.

## EXPERIMENTAL SET-UP AND PROCEDURES

The compartment was built with wood stud walls and a gypsum wallboard interior. The dimension 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<sup>3</sup>. 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.

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<sub>2</sub>, CO<sub>2</sub> 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 fighters.
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 time and the total amount of water used for fire suppression was recorded and the data system was turned off.

## EXPERIMENTAL RESULTS AND DISCUSSION

A total of seventeen full-scale fire suppression experiments were conducted in the test compartment using CAF, MPW, UHP, HEF or hose stream applications with water or foam solution. The fire control time, the amount of water used and the temperatures in the fire room and hallway, as well as the smoke density and gas concentrations in the hallway were measured. In this test series, two flow rates (25 GPM and 12.5 GPM) were used.

These tests involved manual fire fighting, and human factor was involved, thus it was difficult to get repeatable results. The effectiveness of the system depended on the fire fighting technique used by the firefighters.

The fire compartment was instrumented to measure temperatures, heat fluxes, smoke obscuration and gas concentrations, which could possibly show the difference in fire suppression effectiveness of manually-applied CAF, MPW, UHP, HEF systems. However, reviewing the test results showed that smoke obscuration and gas concentration data in the hallway and heat flux measurement in the fire room did not provide results which could be used to determine the fire suppression effectiveness of the systems tested. The test results showed that the most useful data for this purpose was the temperature measurements in the fire room and the time and the total amount of water used to control the compartment fire.

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

Figure 1 shows the average room temperature curves for the CAF, water and foam-solution tests with 25 GPM water flow rate. The graph shows that the CAF test has a quicker temperature drop than the tests with foam-solution or water only. Figure 2 shows water consumption curves for the three tests (CAF, foam-solution and water only with 25 GPM). It clearly shows that the CAF knocked down fire much quicker and with far less water compared to foam-solution and water only. CAF knocked down the fire in 10 s using 13.8 L of water, while foam-solution used 32 L of water in 20 s to knock down the fire. Using the water hose stream only, it took 25 s to knock down the fire, requiring 39 L of water.

The difference in the effectiveness of the CAF compared to water is much more prevalent when a low flow rate (12.5 GPM) was used. The CAF knocked down the fire in 35 s using 25 L of water, while foam-solution required 57 s to knock down the fire using 46 L of water. Using the water hose stream only, it took 74 s to knock down the fire, requiring 60 L of water.

The effectiveness of the Medium Pressure Water (MPW) system was difficult to compare with other systems because the MPW system had only one flow setting which was different than the flow rates used in other systems. However, its performance was similar to that of the water alone. Its knock-down time was a little better than the hose stream water system with 25 GPM flow, however, its water consumption was more than the water alone. This is reasonable because the MPW system used 43 GPM flow instead of 25 GPM flow used by the water hose-stream test.

When 0.3% foam-solution was used instead of water, MPW system performance improved substantially. It knocked down the fire at 13 s with 18.2 L of water, which is much better than using water. However, it is difficult to compare the performance of MPW system using foam-solution with the performance of other systems because different flow rate is used in the MPW system test.

Ultra High Pressure (UHP) system was very effective in suppressing the compartment fire, knocking- down big flames quickly with a small amount of water. Comparing with water only tests, the UHP system with 17.4 GPM performed better than the hose-stream water only system with both 12.5 GPM and 25 GPM. The UHP system, with 17.4 GPM flow, knocked-down the fire in the compartment in 18 s with 20.6 L of water, compared to 25 s and 39 L of water for 25 GPM, and 74 s and 60 L of water for 12.5 GPM, when hose-stream water was used. It clearly shows that the UHP system is more effective than the hose-stream water system in extinguishing compartment fires.

When 0.3% foam-solution was used instead of water, no significant improvement was observed in the performance of UHP system, which was different from the case of MPW system. In fact, UHP system performance with water and foam-solution were very similar, almost like a repeat test.

The High Expansion Foam (HEF) system was not an effective system to suppress compartment fires. It has no discharge momentum, thus firefighters cannot attack the compartment fire using this system. It can only be used when the HEF nozzle is placed into the fire compartment through an opening on the wall (in the current project, through a window opening). Even with the HEF nozzle stuck into a window opening, and a high expansion foam discharging into the fire compartment, it had difficulty suppressing the test fire in the compartment. It took approximately 110 s to control the fire, which is the longest amongst all the systems tested. The amount of water used to control and extinguish the compartment fire was also the largest, using 147.2 L and 182.4 L, respectively.

The test series showed that the CAF and UHP systems performed better than the other systems, knocking-down fires quicker with less amount of water. However, each system - especially the CAF system - requires a unique way of operation to get optimum results.

When the performance of the UHP system was compared to that of the CAF system, neither one is clearly superior to the other. The performances of the UHP and CAF systems cannot be compared directly because the flow rates used were different. However, test results indicate that their performances are similar. The UHP system, with 17.4 GPM flow, knocked-down the fire in the compartment in 18 s with 20.6 L of water, compared to 10 s and 13.8 L of water for 25 GPM and 35 s and 25 L of water for 12.5 GPM when the CAF system was used. The flow rate of the UHP system was in between the 12.5 and 25 GPM flows used by the CAF, and the results are also between the two, showing that the performances of the UHP system is similar to that of the CAF.

## CONCLUSION

An experimental study was carried out to compare the fire suppression performances of manually-applied CAF, MPW, UHP and HEF systems with that of a hose stream application using water alone and using foam-solution, under similar conditions.

The test results showed that the CAF is more effective in suppressing a compartment fire than hose stream with water only or with foam-water solution. The difference in water consumption to knock-down the fire with the hose-stream water and the CAF is approximately 2 - 3 times. The difference in the total amount of water used to completely extinguish all flames in the fire compartment between the CAF and the hose-stream water is smaller than the difference in the amount of water used to knock-down the fire.

The CAF system requires a different firefighting technique than the hose-stream water application. It is important that firefighters get some training to learn the proper technique of using the CAF system to optimize its performance.

The effectiveness of the MPW system was difficult to compare with other systems because the MPW system had only one flow setting which was different than the flow rates used in other systems. However, its performance was similar to that of the water alone.

The UHP system was very effective in suppressing the compartment fire, knocking down big flames quickly with a small amount of water. In comparison with water only tests, the UHP system, with a 17.4 GPM flow rate, performed better than the hose-stream water only system with both 12.5 GPM and 25 GPM flow rates.

When the performance of the UHP system was compared to that of the CAF system, neither one is clearly superior to the other. The performances of the UHP and the CAF systems cannot be compared directly because flow rates used were different. However, test results indicate that their performances are similar.

The HEF system was not an effective system to suppress compartment fires. It has no discharge momentum, thus firefighters cannot attack compartment fires using this system. It can only be used when the HEF nozzle is placed into the fire compartment through an opening on the wall (in the current project, through a window opening). Even with the HEF nozzle stuck into a window opening, and high expansion foam discharging into the fire compartment, it had difficulty suppressing the test fire in the compartment.

This test series provided many details on a variety of attack methods with various extinguishment systems to knock down and extinguish fully developed and deep seated compartment fires. Some systems provided superior knock down but were too energetic in close quarters to efficiently extinguish the embers and took considerably longer to complete the extinguishment by dislodging and moving the burning brands.



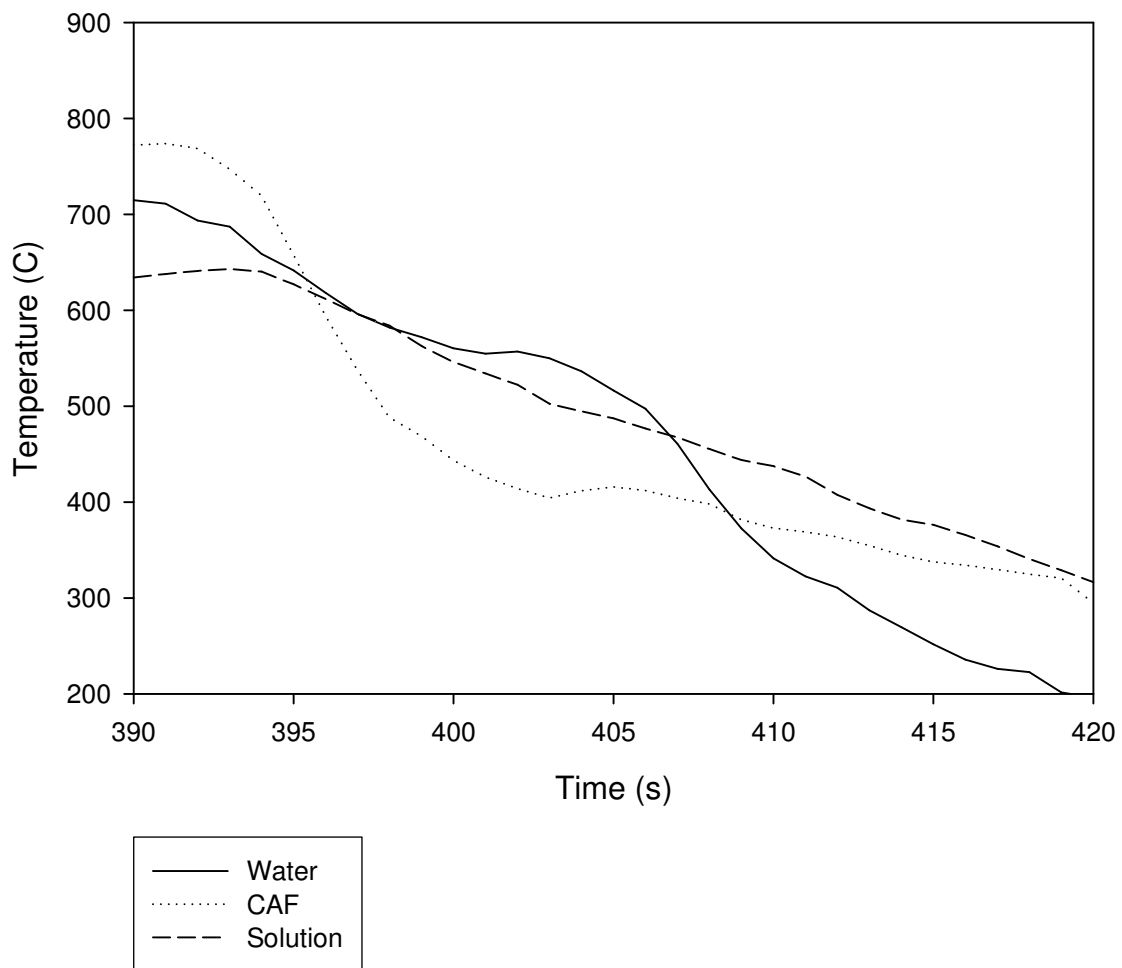


Figure 1 Average room temperature for 25 GPM tests (Test # 2, 9 and 12)

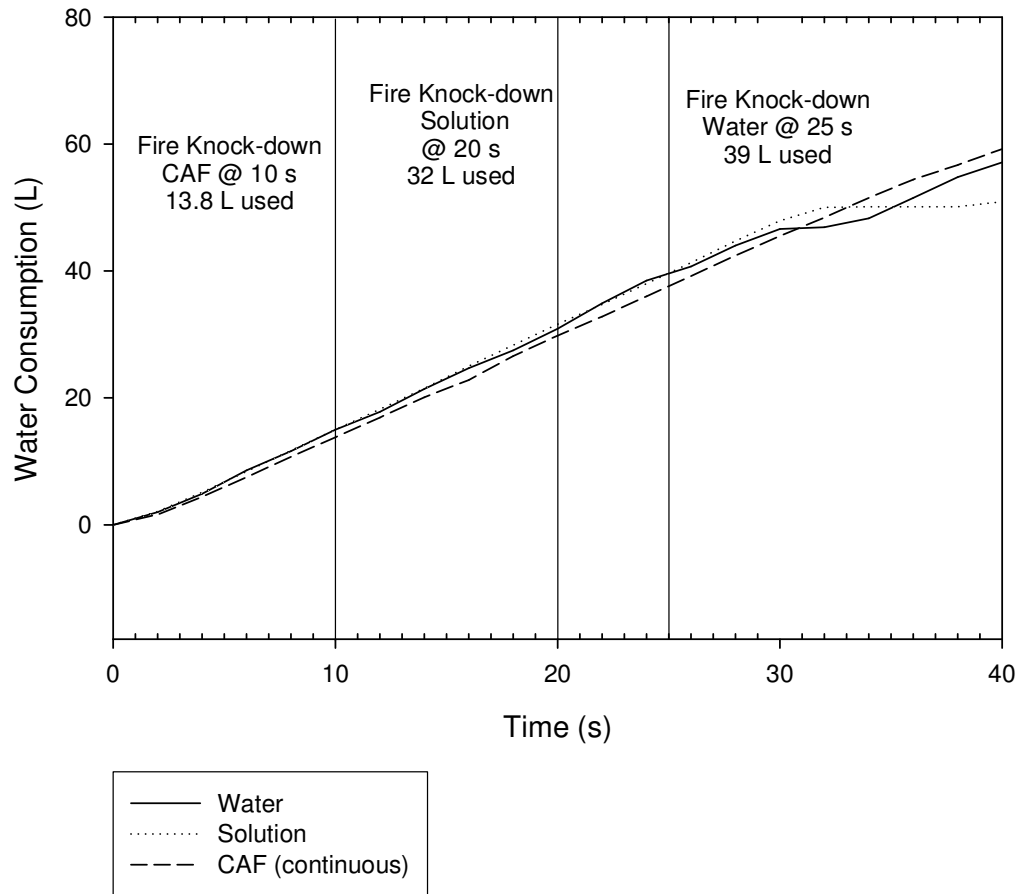


Figure 2 Water Consumption 25 GPM tests (Test # 2, 4 and 9)