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## Discharge Characteristics of a Portable Compressed Air Foam System

Oluwadamilola OKUNROUNMU<sup>1</sup>, Paul LHOTSKY<sup>2</sup> and George HADJISOPHOCLEOUS<sup>1</sup>

<sup>1</sup>Department of Civil and Environmental Engineering, Carleton University, Canada

<sup>2</sup>CIVELEC Consultants, Canada

oluwadamilola.okunrounmu@carleton.ca

### ABSTRACT

Existing portable foam extinguishers generate fire-fighting foam at high pressures with the aid of an air aspirating nozzle. This system could encounter several limitations at the point of application such as poor foam quality due to the use of fire contaminated air for foam generation and insufficient momentum to reach the seat of fire. Research has shown that by incorporating compressed air into a portable foam system, the integrated foam system could generate superior quality foam with high momentum when properly installed with the right components. Several studies had been conducted on the extinguishing performance of compressed air foam systems on multiple fire types, both for small and large fires. Compressed air foam systems mitigate exposure of the operator to heat and provides faster knockdown of the fire plume as compared to air-aspirated foam because of its stronger stability and rheology. Since the expansion ratio of the foam can be regulated to combat specific fire types and sizes, compressed air foam systems can be utilized in protecting a variety of equipment of varied sizes.

The aim of this study is to investigate the discharge characteristics of a portable compressed air foam at low pressure. For this study, the requirements of NFPA 10 and CAN/ULC-S508 for a new system were used to determine the feasibility of the system.

The effect of air pressure on the expansion ratio of the foam was investigated with foam concentrate ranging from 2% to 4% for three different hoses with lengths of 1-m, 2-m and 3-m. Pressure used ranged from 1.72 bar to 5.52 bar. The 3% and 4% solution for the 2-m hose and 3-m hose exhibited similar trend of a rise and fall with pressure by generating fluid foam of medium expansion ratio in the range of 19 to 28. However, the expansion ratio of 3% solution and 4% solution for the 1-m hose increased monotonically with increasing pressure and generated wet foam of low expansion ratio in the range of 8 to 15. While low expansion foams are effective in extinguishing liquid pool fires, medium expansion foams are used for structural protection due to its slow drainage time and its ability to adhere to sloped, vertical, horizontal and slippery surfaces.

Discharge range tests were conducted to investigate the horizontal projection of the foam from the nozzle at a height of 0.9m above the ground. The test was conducted in an open space with little interference of wind. Visual record of the maximum discharge range was taken at intervals. The foam from the 1-m hose projected from 1 m at 2.42 bar to 2.4 m at 5.52 bar while the foam from the 2-m hose projected from 1.8 m at 2.42 bar to 4.5 m at 5.17 bar. Likewise, the foam from the 3-m hose with an initial discharge of 1.85 m at 2.41 bar increased progressively to above 4.5 m at 4.83 bar. The tests demonstrated the relationship between pressure and the momentum of the foam, showing that an increase in pressure leads to an increase in the range covered. Furthermore, flow rates at different pressures were investigated using 3% foam solution with a 2 m hose. The flow rate of the foam ranged from 8 g/s to 20 g/s at 1.93 bar and 5.24 bar respectively, indicating linear progression with pressure. The flow rates correspond to application times of 244 and 102 seconds respectively for the 2-liter solution. Overall, all foams tested met the requirements of the CAN/ULC-S508 standard.

**KEYWORDS:** *low pressure; compressed air foam; portable extinguisher; discharge range test*



## INTRODUCTION

The use of portable fire extinguishers is an important part of the fire protection system in a building. Portable fire extinguishers are fire safety equipment used to extinguish or suppress small fires before they become a threat to life and property. The available combustible materials in a building govern the type of fire that could occur and hence the selection of portable fire extinguisher is important to ensure that it can suppress the expected class of fires. The use of an extinguisher not suitable for a class of fire may contribute to the fire hazard. For instance, the combustible materials in the dining room (such as sets of furniture, interior finishes, and light partitions) would typically generate Class A fires while in the kitchen a fire involving cooking oil is a class B fire. Therefore, it is ideal to have a portable fire extinguisher that is applicable on multiple fire types.

While some of the existing fire extinguishers can be used for two or more fire classes, their suppression effectiveness and adverse consequences after application is a concern. For example, water extinguishers can be used for Class A fires materials but could create a hazard when used on electrical equipment, or in laboratories containing flammable liquids and combustible metals [1]. Likewise, it contaminates chemical materials by reacting with the substance and water damages to water sensitive equipment. Therefore, it is advisable to be utilized on only unreactive materials, ordinary combustible materials and in locations that don't require major clean-up. On the other hand, dry powder extinguisher is suitable for electrical equipment combustible liquids but not applicable to cooking oil fire due to its poor cooling property [2]. In addition, application of dry powder type fire extinguisher in large quantity might reduce visibility in the environment and might require thorough clean-up process.

Several studies had been conducted on the extinguishing performance of compressed air foam system on multiple fire types, both for small and large fires. NRC Canada investigated the feasibility of using a fixed pipe CAF system for the protection of aircraft hangar in place of foam-water sprinkler system [3] while Rie et al [4] investigated the suppression performance of a CAF system at different air-to-aqueous foam solution mixing ratios on class B fires. In other studies, Weinschenk et al [5] investigated the suppression capacity of CAF for interior firefighting. Since the expansion ratio of the foam can be regulated to combat specific fire types and sizes, compressed air foam systems can be utilized in protecting a variety of equipment of varied sizes.

Existing portable foam extinguishers generate fire-fighting foam at high pressures with the aid of an air-aspirating nozzle [6]. However, the system could encounter several limitations at the point of application such as poor foam quality due to the use of fire contaminated air for foam generation and insufficient momentum to reach the seat of fire. Kim and Crampton [7] compared the extinguishing performance of a manually operated CAF system with hose stream application of water only and water-foam solution on a full-scale compartment fire tests. The results showed that the mobile CAF system was more effective in suppressing the fire compared to the other two systems. The mobile CAF system generated superior quality foam with high momentum when properly installed with the right components. In addition, it reduced exposure of the operator to heat and provided faster knockdown of the fire plume as compared to air-aspirated foam because of its stronger stability and rheology. However, the mobile CAF generating system operated at high pressure with little consideration to the quantity of foam solution used.

While the existing foam systems operate at high pressures, the study of operating portable CAF system at low pressure has not been studied. The aim of this study is to investigate the discharge characteristics of a portable compressed air foam at low pressure. For this study, the requirements of NFPA 10 and CAN/ULC-S508 for a new system was used to determine the feasibility of the system.

## DESCRIPTION OF TESTS

The tests were conducted outdoors in a clear weather with little interference of wind. The temperature was fairly consistent, averaging about 18 degrees Celsius at the time of the experiment. The compressed air foam generating system for this study is shown in Figure 1. The set-up consists of an air compressor, 3-L container, 8-mm diameter plastic hose, nozzle and a tarp. A 2-L premixed foam solution in the designated proportion was prepared and poured into the 3-L container. The 3-L container was then pressurized by air at different pressures to create compressed air foam. The compressed air foam passes through an 8-mm diameter plastic hose, which was expected to be fully developed inside the hose and finally discharged through a nozzle. The foam concentrate used for the tests was Alcohol-Resistant Aqueous Film Forming Foam (AR-AFFF) and the concentrates was varied from 2 to 4%.

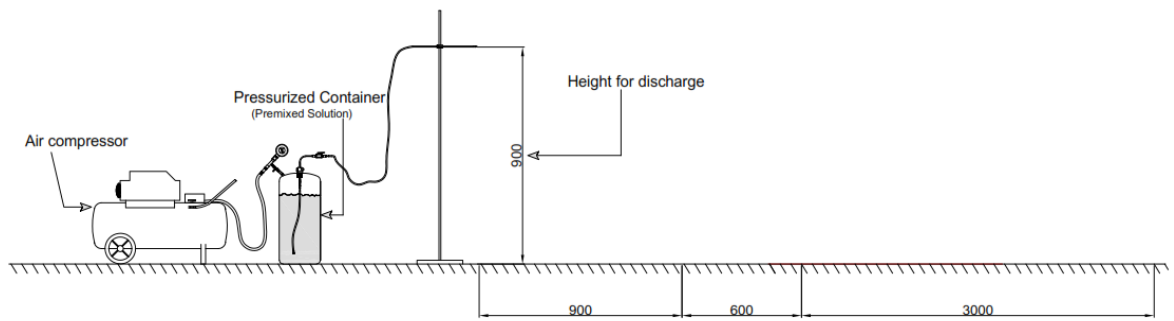


Figure 1: Schematic diagram of the discharge range test

To achieve a 3% foam solution, 60 mL of foam concentrate was combined with 1940 mL of water to obtain 2000 mL foam solution. The 2-L foam solution was poured into the 3-L container and pressurized at the designated pressure to create compressed air foam. The generated foam was formed inside the plastic hose and ejected through the nozzle. This procedure was repeated for the 2% solution test and 4% solution tests.

A weighing scale was used to determine the foam expansion ratio the foam expansion ratio, which is the ratio of the volume of the expanded foam to the volume of the foam solution. The expanded foam was collected in a 2000 mL calibrated container and filled to the brim while excess foam was removed by sliding a smooth plank over the top of the container. The weight of the expanded foam was determined on a calibrated scale to a precision of 0.5 g. Subsequent data was collected to ascertain the result. The obtained data was used to classify the foam into low, medium or high expansion ratio while visual observation was used to describe the physical properties of the foam.

The discharge range test was conducted to investigate the horizontal projection of the foam. The discharge nozzle was placed horizontally at a height of 0.9 m above the ground. Specific locations were marked on a tarp to measure the horizontal projection of foam at different pressures as illustrated in Figure 1. Two digital video cameras were positioned around the experiment to obtain visual records, while high resolution digital cameras were used to capture images of the foam and the effect of the wind. The dispersion of the foam was slightly affected by the wind which altered the horizontal discharge of the foam with minor variation. The discharge test was conducted in accordance to CAN/ULC-S508, "Rating and Fire Testing of Fire Extinguishers", [8]. It is required that an extinguisher with a capacity under 2.3 kg of agent solution should have an initial discharge of not be less than 1.5 m from the nozzle and a minimum of 90 percent of the discharged foam agent solution shall be effectively discharged beyond a point of 0.9 m from the nozzle. This enables the system to generate foams with sufficient momentum to penetrate a fire plume and reach the fuel surface as well as provide heat exposure protection to the operator. The discharged foam was evenly dispersed from the nozzle and the foam flow rate was measured at different pressures.

## RESULTS AND DISCUSSION

This section describes a series of test conducted to study the discharge characteristics of a portable CAF system. The experiment investigated the foam expansion ratio of different hose length, discharge range of the foam and foam flow rate as a function of pressure.

### Effect of air pressure on expansion ratio

A series of tests were conducted to determine the effect of air pressure on the expansion ratio of the foam. Foam solutions ranging from 2% to 4% with three different hoses with lengths of 1-m, 2-m and 3-m were subjected to pressures in the range of 1.72 bar and 5.52 bar. The results of these tests are illustrated in Figures 2 and 3.

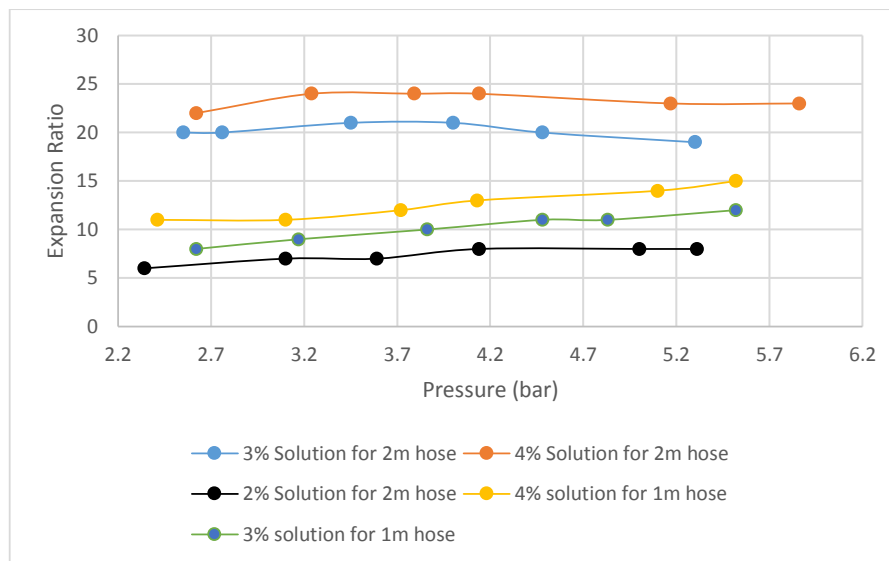


Figure 2: Expansion ratio for 1-m and 2-m hose

Figure 1 shows the foam expansion ratio of 1-m and 2-m hose as a function of pressure. As shown above, the expansion ratio of 3% solution and 4% solution for the 2-m hose were higher than the other combinations for all pressures with the expansion ratios in the range of 19 to 24. However, the 2% solution generated a wet foam with very low expansion ratio ranging from 6 to 8. This illustrates the influence of foam concentration on the quality of the generated foam. While the 3% and 4% solution for the 2-m hose generated fluid foam with medium expansion ratio, the 2% solution generated a low expansion foam. The 3% and 4% solutions for the 2-m hose generated foam with higher expansion ratios than the 1-m hose of the same solution. The expansion ratio of both 3% solution and 4% solution for the 1-m hose increased monotonically with increasing pressure while the same solution for the 2-m hose experienced an initial increase and then decreased with pressure. Low expansion foams are effective in extinguishing liquid pool fires.

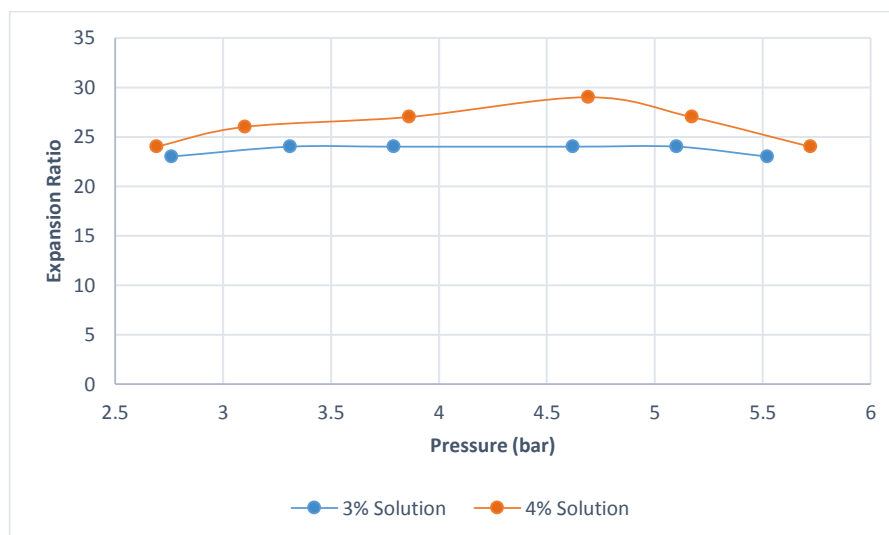


Figure 3: Expansion ratio for 3-m hose

Figure 3 shows the results of the tests with the 3-m hose. The expansion ratios of both solutions show similar trends as the results of the tests with the 2-m hose but with higher expansion ratios in the range of 19 to 28. The generated foam can be categorized as a fluid foam with medium expansion ratio. This demonstrates the influence of hose length on the expansion ratio as the hose length increases, the more the fluidity of the foam resulting in higher expansion ratios. Medium expansion foam can be used for structural protection due to its slow drainage time and its ability to adhere to sloped, vertical, horizontal and slippery surfaces. The 3% and 4%

solution of the 2-m hose and 3-m hose generate steady and uniform compressed air foam at low pressures. Hence, they are both suitable for a portable fire extinguisher.

### Discharge range tests

Discharge range tests were conducted to investigate the horizontal projection of the foam from the nozzle at a height of 0.9 m above ground. The test was conducted in an open space with little interference of wind. Figure 4 shows a photo captured during a live test with the nozzle located at a height of 0.9m above ground. The yellow lines represent distances of 0.9 m and 1.5 m from the nozzle. Visual record of the maximum discharge range was taken at intervals. For the 1-m hose, the initial discharge at 2.42 bar was in the range of 1.0 m from the horizontal nozzle and increased progressively to 1.9 m at 3.45 bar. The discharge steadily increased to 2.25 m at 4.48 bar and finally to 2.4 m at 5.52 bar. However, the initial discharge exhibited a longer projection at 2.42 bar for the 2-m hose by starting off at 1.8 m and increased to 2.7 m at 3.45 bar and to 4.5 m at 5.17 bar. A similar pattern was observed for the 3-m hose with the initial discharge of 1.85 m at 2.41 bar, 2.6 m at 3.31 bar and above 4.5 m at 4.83 bar. Overall, the discharge range test for the three hoses met the requirements of the CAN/ULC-S508 standard.



Figure 4: Photo of a discharge range test

### Flow Rate Tests

A series of tests was performed to investigate the flow rate of the compressed air foam at different pressures. These tests were conducted using a 3% foam solution with a 2 m hose. As expected, the flow rate of the foam increased with increase in pressure ranging from 8 g/s to 20 g/s as shown in Figure 5. These flow rates correspond to application times for the 2-liter foam solution of 244 and 102 seconds respectively.



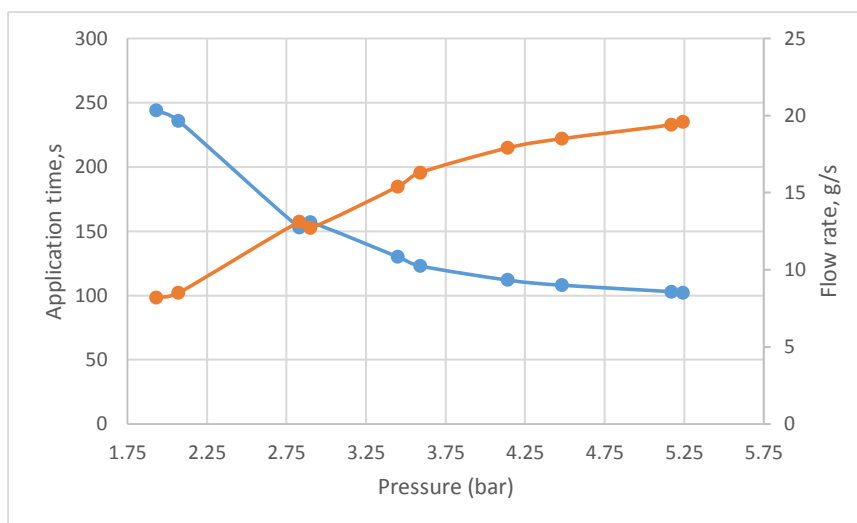


Figure 5. Effect of pressure on application time and flow rate

## CONCLUSION

This study investigates the discharge characteristics of a portable CAF system by considering foam expansion ratio of varied hose length, discharge range of the foam and foam flow rate as a function of pressure. Compressed air foam was generated by injecting air under pressure into a foam solution stream.

The result showed that with the right combination of foam concentrate, hose length and nozzle, the portable CAF system can discharge over a long distance at low pressure. The CAF system generated a uniform and steady foam with expansion ratio of over 20 by using a combination of 3% foam solution and a 2-m hose at a pressure of 2.41 bar. With this pressure, the flow rate of the foam was at 12 g/s resulting in an application time of 150 seconds. Hence, it is suitable for a portable system.

From the results of the discharge tests performed, it can be concluded that the portable fire extinguisher meets the discharge requirements of the CAN/ULC-S508 standard for new extinguisher.

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