THE DEVELOPMENT OF THE FM-200™ GAS-FILLED AFFF FIRE EXTINGUISHER FOR AUTOMATIC FIRE SUPPRESSION SYSTEMS IN THE ENGINE COMPARTMENT OF AUTOMOBILES[1]

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ABSTRACT

In recent years, the number of vehicle fires, as well as the number of motor vehicles, has been increasing rapidly. Therefore, several types of automatic fire suppression systems for the engine compartment of automobiles have been developed to extinguish automobile fires, and most of these systems use halon 1301 as a fire extinguishing agent. Due to environmental concerns, the phase-out of halons has been announced, so now there is a need to replace halon 1301.

For this, a 1,1,1,2,3,3,3-heptaflouropropane (HFC-227ea, FM-200™) gas-filled Aqueous Film-Forming Foam (known as AFFF) extinguisher was devised even though air foam extinguishers could be used. This is because the air in the foam bubbles is a source of oxygen required for the combustion reaction. It can be surmised that it is possible to increase the fire extinguishing efficiency of AFFF by filling in foam bubbles with a gaseous extinguishing agent. The best choice is the FM-200™ gas-filled AFFF, which has the maximum expansion ratio of 62:1. This makes it possible for the expanded foam to rapidly fill the engine compartment.

INTRODUCTION

In cases of passenger car fires, the fire mainly occurs in the engine compartment because there exist many flammable substances such as fuel, engine oil and the other oils, a lot of ignition sources like sparks from the engine ignition system, hot exhaust system components and battery[1,2)], along with sufficient oxygen in the engine compartment.

New high expansion foam systems[3)] are replacing halon systems for shipboard fire protection. High expansion foam systems[4)] extinguish and secure fires by quickly filling ship engine compartments and machinery spaces with high expansion foam. Foam is not generally recommended for fires in electrical equipment since foam is mildly corrosive and difficult to remove. However, it was tested at Lothian and Borders Fire Brigade's Merchant Navy Fire Training School under conditions more arduous than those normally expected. The foam extinguished and secured even the most difficult fires and the performance of electrical equipment was unaffected, Cleaning up the foam afterwards was quick and easy.

On the other hand, Japanese researchers devised a method to increase the fire extinguishing efficiency of fire fighting foams by filling in foam bubbles with halon 1301 gas instead of air. The method is such that when liquefied halon 1301 and aqueous foam solutions are sent together to a vaporization chamber through a pipe, the interior of the vaporization room becomes a state of turbulent flow. This is because liquefied halon 1301 vaporizes rapidly in the vaporization chamber and it forms the aqueous foam solution into foam bubbles filled with vaporized halon 1301 gas. This foam has the fire extinguishing efficiency of halon 1301 and fire fighting foam at the same time. The expansion ratio of the foam solution was 14:1. This method implies that it is possible to

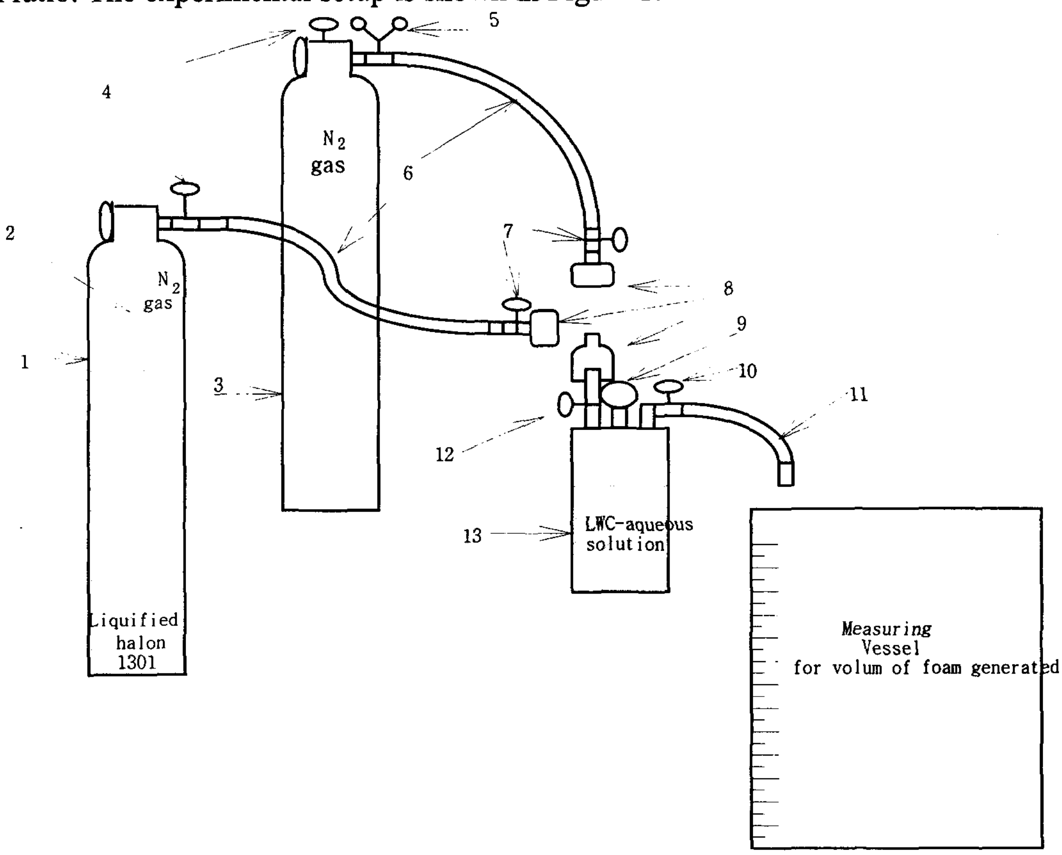
[1]. This thesis is a project report of the development of new generation automotive technology

produce a gas-filled foam[5] with halon alternatives[6, 7] such as FM-200™ and NAF-S□ □M.

The purpose of this research is to devise a gas-filled AFFF fire extinguisher for automatic fire suppression systems in the engine compartment of automobiles by using both a foam extinguishing agent, and a halon alternative. This is done to make the systems more effective against fire and secure against environmental concerns.

EXPERIMENTAL

There are various types of foams available with characteristics for specific fire situations, and alternatives to halon 1301, that have been developed in recent years since the phase-out of halon was announced. When a foam extinguishing agent for the engine compartment of automobiles is chosen, it is essential that this agent must not be affected by the temperature of the engine compartment. It also must apply to both Class A and Class B fires. In addition, it's expansion ratio must be high to fully cover the engine compartment. Hence, "Light Water Concentrate" (LWC), 3M Corp., Product FC-203™, was chosen as the AFFF agent. FM-200™ which has zero of ODP value was chosen as a halon alternative compound and NAF-S III™, which has a low ODP of about 0.44, was chosen as a halon alternative blend in order to produce a gas-filled AFFF and raise its expansion ratio. The experimental setup is shown in Figure 1.



1. Halon 1301 Cylinder | 2. Siphon Tube | 3. Nitrogen Cylinder
4. Main Valve | 5. Pressure Regulator | 6. Charge Tube
7. Middle Valve | 8. Coupling | 9. Pressure Gauge
10. Discharge Valve | 11. Releasing Valve | 12. Control Valve
13. Fire Extinguishing Agent Container

Figure 1. Experimental assembly for producing a halon 1301 gas-filled aqueous film-forming foam.

The steps of this experiment are as follows:

1 - An appropriate amount of LWC solution was mixed with water and then the LWC-aqueous solution was put into the fire extinguishing agent container, which was made of SUS 304.
2 - A proper amount of liquefied halon 1301, which was supper pressurized with a "dome"of nitrogen gas at 600 psig. in the halon cylinder, was charged into the fire extinguishing agent container through the charge tube. The inside pressure of the container can be adjusted by charging N_2 gas from the nitrogen cylinder into the fire extinguishing agent container.
3 - In a few minutes, both the aqueous solution and liquefied halon 1301 were released together at the same time from the container, passing through the releasing hose (0.80 cm ID ; length , 55.00 cm) without any nozzle.
4 - Discharge time and the volume of the gas-filled aqueous film-forming foam generated were measured.
5 - This experiment was performed, changing the LWC solution's concentration in water and the amount of liquefied halon 1301 in order to find out maximum expansion ratio of the halon 1301 gas-filled AFFF.

As noted, there is a need to replace halon 1301 with a halon alternative because of environmental concerns. NAF-S III™ and FM-200™ were used as halon alternatives in the following experiments. The experimental steps were identical to the experimental steps of the former experiments.

Experiment for raising the expansion ratio of the FM-200™ gas-filled AFFF

The fire extinguishing agent container was remodeled to minimize the size and weight of the container. It was made to have an inside volume of 2.0 L because the engine compartments of automobiles are too small to accommodate larger containers.

Two siphon tubes were equipped in the container to raise the expansion ratio and to shorten the discharge time of the foam. The inside pressure of the container was fixed at a pressure of 9 kg/cm^2 during this experiment. The experimental steps were identical to the experimental steps of the former experiments.

Experiment for installing the FM-200™ gas-filled AFFF extinguisher in the engine compartment of automobiles

For installing the FM-200™ gas-filled AFFF extinguisher in the engine compartment of automobiles, it is important to find out if the inside pressure of the extinguisher will rise due to variations of the temperature of the engine compartment of automobiles. The following experiment was performed in order to determine the variations of the inside pressure of the extinguisher depending on variations of temperature.

After charging the 18 vol-% LWC-aqueous solution 1.0 L and 0.4 kg of liquefied FM-200™ into the extinguisher, the extinguisher was put into a dry oven , the inside temperature of the oven was raised to 80 ℃ and the inside pressure of the extinguisher was measured every 30 minutes. In this experiment, the 18 vol-% LWC-aqueous solution of 1.0 L and 0.6 kg of liquefied FM-200™ were used together and only 0.4 kg of liquefied FM-200™ was also used.

Experiment for testing the effectiveness of the FM-200™ gas-filled AFFF fire extinguisher

This experiment was performed to test the fire extinguishing ability of the FM-200™ gas-filled AFFF extinguisher. Figure 2 shows a model picture of a square pan used in this experiment. The square pan was made of ferrous steel. In Korea, this test is classified as a B-4 unit of fire extinguishing ability in Class B fires.

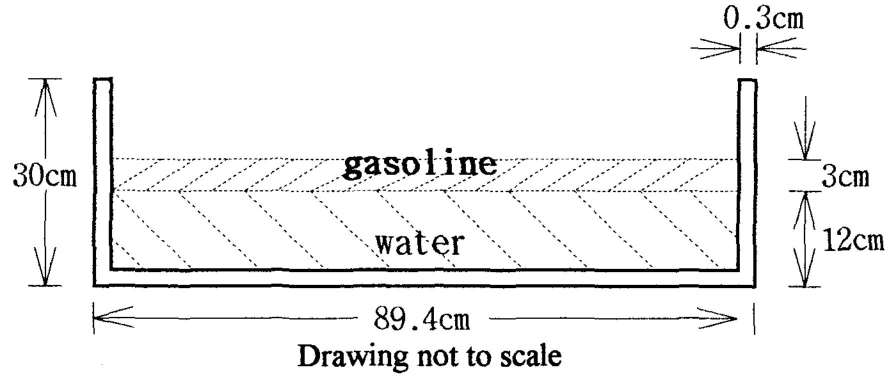


Figure 2. A model picture of a square pan for testing the fire extinguishing ability in Class B fires.

RESULTS AND DISCUSSIONS

It was observed that the heat of vaporization of the liquefied gaseous fire extinguishing agent affected the expansion ratio of the gas-filled AFFF. The higher the heat of vaporization of the liquefied gas used to produce the gas-filled AFFF, the lower the gas-filled AFFF expansion ratio. This relationship is shown in Figure 3.

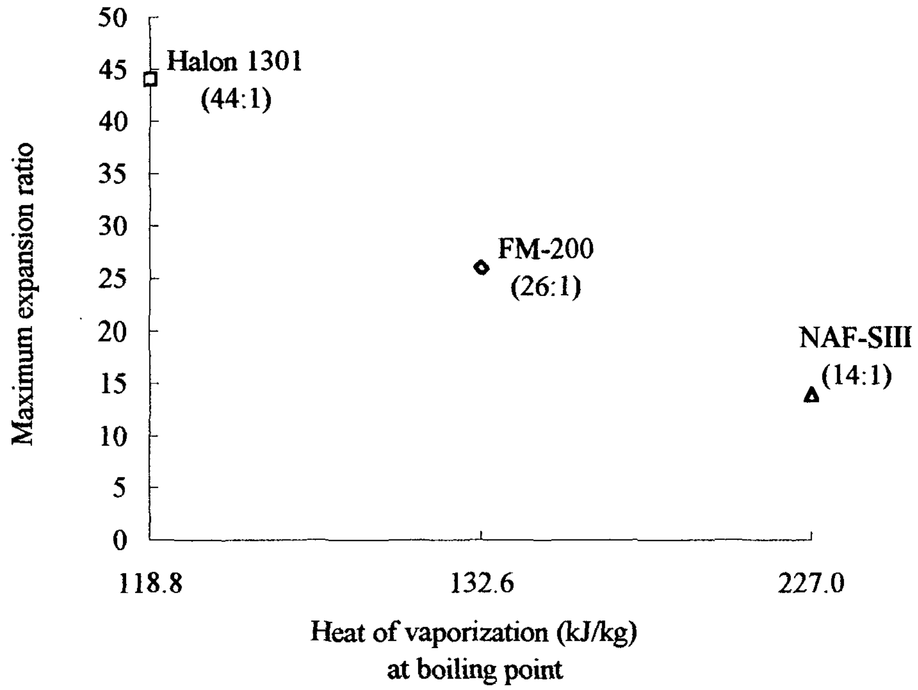


Figure 3. Maximum expansion ratio vs. heat of vaporization of the liquefied gaseous fire extinguishing agent used to produce the gas-filled AFFF.

The maximum expansion ratio of the FM-200™ gas-filled AFFF was found to be higher than the NAF-SIII™ gas-filled AFFF. Hence it was decided to replace the halon 1301 with FM-200 ™, but the discharge time of the FM-200™ gas-filled AFFF was lower than the NAF-SIII™ gas-filled AFFF. To solve this problem, two siphon tubes were equipped in the fire extinguishing agent container.

Figure 4 shows that when 18 vol-% LWC-aqueous solution was used at the volume of 1.0 L, the expansion ratio of the foam was maximum (48:1). The liquefied FM-200™ was used at an amount of 0.4 kg.

Figure 5 shows that when the 18 vol-% LWC-aqueous solution was used at an volume of 1.0 L, and the liquefied FM-200™ was used at the amount of 0.6 kg, the expansion ratio of the foam was maximum (62:1)

it was observed that the amount of the liquefied FM-200 ™ greatly affected the expansion ratio and average discharge time of the foam generated. When a 2.0 L container equipped with two siphon tubes was used, the greater the amount of liquefied FM-200™, the higher the expansion ratio and the longer the discharge time. However, it seems that the volume of the LWC-aqueous solution did not affect greatly the discharge time and the expansion ratio.

As a result, the optimum point for the high expansion ratio was found from this experiment. When using the 18 vol-% LWC-aqueous solution of 1.0 L, and 0.6kg of liquefied FM-200™ in the container, the expansion ratio of the FM-200™ gas-filled AFFF was maximum (62:1). The volume of the foam was 62 L and the average discharge time of the foam was 80.4 seconds. The inside pressure of the fire extinguishing agent container was 9 kg/cm^2. The container had the inside volume of 2.0 L. Two siphon tubes were installed in the container.

Most importantly, the maximum expansion ratio, 62:1, of the FM-200™ gas-filled AFFF was higher than the maximum expansion ratio, 44:1, of the halon 1301 gas-filled AFFF. This was true even though the amount of the liquefied FM-200™ used was less than the amount of the halon 1301 used. In addition, the heat of vaporization of the liquefied FM-200™ is higher than the heat of vaporization of the liquefied halon 1301. It can be presumed that when discharging, the boundary layer between liquefied FM-200™ and the LWC-aqueous solution in the container was dissipated. This was accomplished by using two siphon tubes, so that FM-200™ gas could be mixed effectively with the LWC-aqueous solution when the liquefied FM-200™ vaporized.

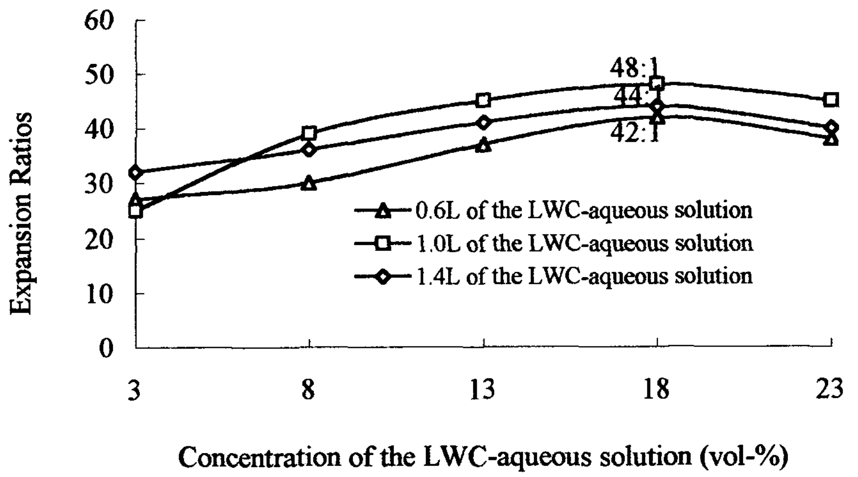


Figure 4. Expansion ratios of the FM-200™ gas-filled AFFF depend on the variations of the concentration and volume of the LWC-aqueous solution.

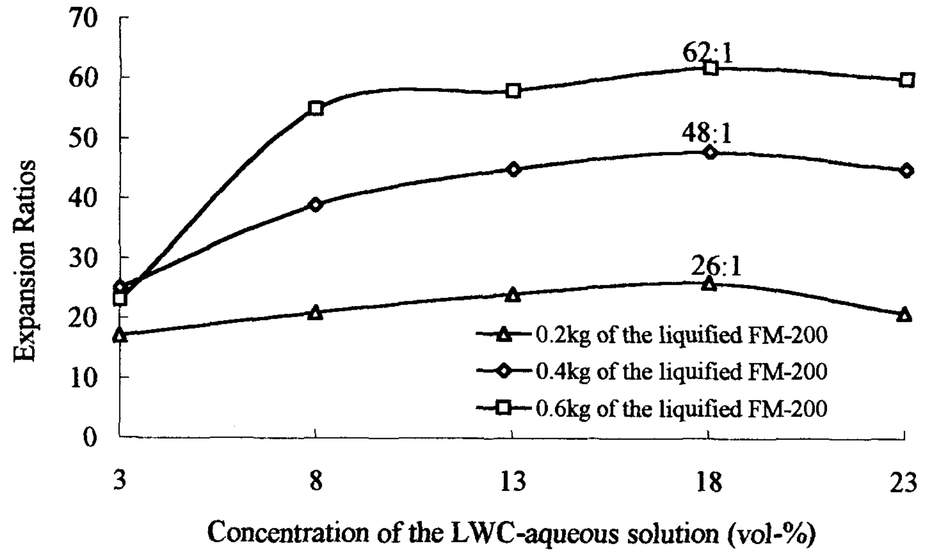


Figure 5. Expansion ratios of the FM-200™ gas-filled AFFF depend on the variations of the concentration of the LWC-aqueous solution and the amount of liquefied FM-200™.

Figure 6 shows the variations of the inside pressure of the extinguisher depending on variation of the inside temperature of the dry oven. From this experiment, it was observed that when the liquefied FM-200™ was mixed with the LWC-aqueous solution in the extinguisher, the inside pressure of the extinguisher was almost unaffected by high temperature. However, when only the liquefied FM-200™ was used in the extinguisher, the inside pressure of the extinguisher was increased greatly. It was presumed that when the liquefied FM-200™ was mixed with the LWC-aqueous solution in the extinguisher, there was almost no variation of the vapor pressure of the FM-200™ depending on the variations of temperature.

The FM-200™ gas-filled AFFF was found to have a higher expansion ratio and quicker discharge time than NAF-SIII™ gas-filled AFFF. In addition, FM-200™ is environmentally safer. Consequently, the FM-200™ gas filled AFFF extinguisher can be installed in the engine compartment of automobiles.

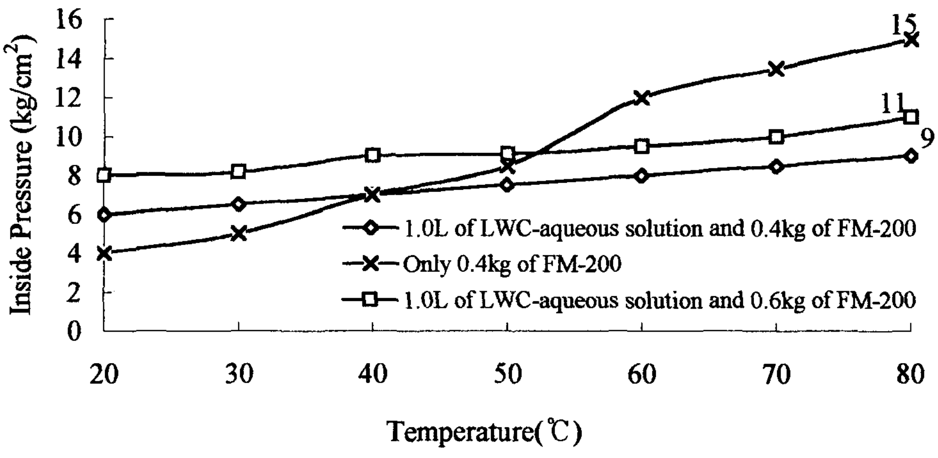


Figure 6. Variations of the inside pressure of the extinguisher depend on the variations of temperature.

In the experiments for testing the fire extinguishing ability of the fire extinguisher, the fire was extinguished by covering the surface of burning gasoline with the FM-200™ gas-filled AFFF. The gasoline did not reignite. But when only the LWC-aqueous solution 1.0 L was used, it failed to extinguish the fire. From this experiment, it can be stated that the FM-200™ gas-filled AFFF fire extinguisher has the fire extinguishing efficiency of FM-200 ™ and the AFFF at the same time.

CONCLUSION

Initially, the desired performance and qualities of a gas-filled AFFF fire extinguisher for the engine compartment of automobiles were:

- high fire extinguishing capability
- high expansion ratio
- minimum size and weight.
- low inside pressure
- operation in the temperature range of -20 to +70 °C

For this, the 1,1,1,2,3,3,3-heptaflouropropane (HFC-227ea, FM-200™) gas-filled AFFF fire extinguisher was devised. It appears that this extinguisher has the fire extinguishing efficiency of HFC-227ea (FM-200™) and AFFF at the same time.

First and foremost, the expansion ratio of the FM-200™ gas-filled AFFF is 62:1. Therefore, it is certain that the foam generated fills quickly the engine compartment of automobiles. This extinguisher has the fire extinguishing ability of a B-4 unit of Class B fire.

Second, this extinguisher can be installed in the engine compartment of automobiles because the inside pressure of the extinguisher is almost unaffected by variations of the temperature of the engine compartments, even though the method of operation of this fire extinguisher is self-expelling. The inside volume of this fire extinguisher is 2.0 L. The 18 vol-% LWC-aqueous solution 1.0 L and 0.6 kg of liquefied FM-200™ are used as fire extinguishing agents in this extinguisher.

Third, the FM-200™ has zero of ODP value, so it is assumed that this fire extinguisher is environmentally safe.

Hence, if this 1,1,1,2,3,3,3-heptaflouropropane (HFC-227ea, FM-200™) gas-filled AFFF extinguisher is applied to automatic fire suppression system for the engine compartment of automobiles, it will be possible to make the system more effective and environmentally safe.

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