The Relationship Between Particulate Aerosol Cooling Process and Its Effectiveness As A Fire Extinguishing Agent

by

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Abstract

The powdered aerosol technology has gained a lot of interest as a viable alternative to Halon fire protection. In the past years we have seen several approaches to producing the powdered aerosols either chemically (by combustion methods) or physically (by evaporation methods). The solid dry powder particles entering the fire zone act chemically and physically in the combustion process to slow it down and eventually stop it by extinguishing the open flames. We have observed that the temperature of the powdered aerosol as it enters the fire area is an important factor in the extinguishing process. According to recent studies, the "hot" aerosol particles are more active, fill the protected volume for longer time periods, extinguish the flames faster at lower concentrations in air. Cooling the aerosol particles to the environment temperature, requires more material for some extinguishing fire scenarios, longer extinguishing time periods, in addition to obvious obscuration and clean-up problems.

The present paper presents recent test data and some interesting conclusions regarding this fire extinguishing technology.

Introduction

Powdered Aerosol A (SFE) is a chemical extinguishing agent consisting of extremely small solid particles ($\leq 1\mu$) that are created in a chemical oxidation reduction reaction, and released in the aerosol form.[1]

This highly efficient aerosol contains up to 40% solid particles and 60% gaseous molecules, has the flow characteristics of gas, and being lighter than air, is persistent and suspended in the air for long periods of time.

Because of the high volume expansion and small particle size, the aerosol achieves superior extinguishing power, approximately 3 times that of Halon 1301 (on a weight ratio).[2]

SFE acts on the fire in more than one way. It combines the heat absorption capability of *dry* powder extinguishing agents with the chemical interfering capability such as performed by Halon extinguishing agents. SFE aerosol creates active species, solid particles, that act either by hetrogeneous chemical reactions on the particles surface or by homogeneous chemical reactions in the gaseous phase with the fire chain precursors (OH, H) preventing their recombination and thus stopping the combustion process.

The **SFE** aerosol can be delivered to a fire either directly, created in the combustion area itself or indirectly piped in from external generators. Various modular systems have been designed[(3)] according to the fire protection applications and the following engineering considerations:

1. The powdered aerosol is created in an exothermic chemical reaction, generating large amounts of heat. This heat can be absorbed via chemical or physical means before the aerosol is discharged into the protected volume. The temperature of the discharged aerosol was found to be an important factor related to its extinguishing effectiveness.

2. The combustion process of the **SFE** solid material generates visible flames and the flame front advances with the aerosol stream. Arresting the flame front while at the same time allowing free flow conditions for the **aerosol** stream is an important factor in system design.

3. The aerosol dispersion pattern is influenced by its discharge force (rate of combustion and gas generator outlet design), atmospheric conditions (air ventilation, wind airflow), fire size and turbulence **as** well as protected volume configuration (barriers or obstacles, hidden places, ducts, etc.).

4. The aerosol discharge force is dependent on the chemical ingredients of the SFE raw material, its surface area available for combustion, the pressure build-up of the gaseous products and the distance they travel within **the** discharge system **prior** to their exit, the nozzle orifice size and outlet configuration.

Test Program

We have observed that the temperature of the powdered aerosol as it is discharged into the protected volume is an important factor in the extinguishing effectiveness of these agents.

The present test program **was** designed to evaluate the relationship between the aerosol discharge temperature (following its discharge from various generators) and its capacity to extinguish a preselected fire scenario.

Several types of generators were developed inorder to discharge aerosol at various temperatures ranging from ambient up to 350°C. The raw SFE material when burned freely generates temperatures from 800°C up to 1600°C depending on formulation, configuration and size.
Table 1 summarizes the aerosol temperatures (**as** ΔT°C over the ambient) obtained when the aerosol was discharged from various generators. Their ability to cool down the aerosol stream is a function of their internal combustion chamber design, free flow of aerosol stream

and cooling medium within the generator. The temperatures were measured at a distance of 10 cm downstream from generator's outlet.

For the present test program *two* types of generators were selected: pipe generator (see table 1, tests 3 & 4) and modular type I (see table 1, test **5)** **as** well **as** additions of free burning **SFE** tablets (activated without any generating device).

The tests were performed in a 60m^3 test chamber with the following dimensions:
Length 4m x width 3.3m x height 4.3m.

The fire scenario was the same in all the tests:
2 n-heptane pools (Ift x Ift) were located in the center of the test chamber at lower (0.6m) and upper (1.2m) positions.

The flames were monitored by optical UV/IR detectors and the aerosol temperature was monitored by heat detectors located at a distance of 10cm from the generator's outlet (node).

The powdered aerosol was discharged into the test chamber by one or several (combinations) of the following modes:

1. From "pipe generators" that have dimensions height 1.8m, diameter of 0.3m and contain several kg of SFE casted in solid containers with a diameter of ϕ180mm.

   This type of generator, when located vertically, discharges the aerosol at 1.8m height, from its upper outlet. However. this generator can be located horizontally or at an angle of 15°C or 30" from the floor, thus generating the aerosol stream at lower heights (0.3-0.5m).

   The approximate temperature of the aerosol at its outlet (measured at 10cm distance from the exhaust) is 160°C over the ambient (AT = 160°C).

2. From modular generators type I that have dimensions 550mm x 460mm x 175mm and contain *2* SFE - charges each 1.5kg casted in solid rectangular containers (160 x 90 x 80mm).

   This type of generator, located on the floor of the test chamber (near its wall) resembles an "air condition" unit and discharges the aerosol at a height of approximately 0.5m, and at average temperatures of max. 375°C (AT over ambient).

3. From free burning tablets, each containing 500gr with diameter ϕ = 80mm and height 64mm located on a metal tray on the test chamber floor.

Table 1 - SFE Aerosol Discharge Temperatures

	Type of Generator	S i of SFE Charge	Weight of SFE (kg)	Combustion Time (Sec)	Temperature AT ("C) at 10cm from outlet
1.	---------	Tablet "A" ϕ = 50 mm h = 43 mm	0.15	24	1375
2.	---------	Tablet "C" ϕ = 50 mm h = 47 mm	0.15	27	1250
3.	Pipe Generator	ϕ = 180 mm h = 90 mm	4.0	48	155
4.	Pipe Generator	ϕ = 180 mm h = 72 mm	3.0	40	165
5.	Modular Type I	Rectangular Type l = 160 mm W = 90 mm h = 80 mm	3.0 (2x 1.5 kg)	63	237-375
6.	Modular Type II	ϕ = 140 mm h = 60 mm	3.0	40	330-250
7.	Modular Type III	ϕ = 140 mm h = 60 mm	2.0	60	125

Table 2 - Extinguishing Effectiveness

Test No.	Amount of SFE (kg) and formulation	Type & Number of Generators	Extinguishing Time (Sec.)		Remarks
			Lower Pool	Upper Pool	
1.	A - 5.0	1 - Pipe	No	48	Vertical
2.	A - 5.5	1 -Pipe	No	50	Vertical
3.	C - 3.5	1 - Pipe	No	115	Vertical
4.	C - 6.0	2 - Pipe	No	82	Vertical
5.	C - 6.5	2 - Pipe	No	72	Vertical
6.	C - 6.0	2 - Pipe	No	76	Vertical
7.	C - 6.5	2 - Pipe + 2 x 0.5kg tablets	48	58	Vertical 5.5kg.+ 1.0kg tablets
8.	C - 6.0	2 - Pipe + 2 x 0.5 kg tablets	80	50	Vertical 5.0kg + 1.0kg tablets
9.	C - 6.0	2 - Pipe	No	47	outlet angles.
10.	C - 6.0	1 - Pipe 1 - Modular type I.	76	48	Two different generators, each contain 3kg SFE.
11.	C - 6.0	2 Modular type I.	62	53	Each gen 3 kg (2 x 1.5 kg) located on the floor.
12.	C - 6.0	2 Modular type I.	58	29	1 generator at 2m height.
13.	C - 6.0	2 Modular Type I.	No	42	Both generators located at 2 m height.
14.	C - 7.0	2 Modular Type I + 2 x 0.5 kg tablets	35	37	The tablets were on the floor.

Test Results

The test results are summarized in table 1 - SFE aerosol discharge temperatures and in Table 2 - Extinguishing effectiveness. Additional tests were performed at Hatsuta (Japan)[4] test facilities in test chambers of $8m^3$, $50m^3$, $100m^3$ using various designs of aerosol generators and various application concentrations of SFE powdered aerosol.

The major findings in the Hatsuta tests are as follows:

a) Low level fire pans required longer extinguishing times.
b) Increasing aerosol concentration does not necessarily increase effectiveness. For certain fire scenarios increasing the aerosol application (nominal) up to $250gr/m^3$ has not accelerated the extinguishing process obtained with $100gr/m^3$
c) The design of the generator's internal combustion chamber is critical in the actual aerosol discharge rate and its effectiveness as a tire suppressant.
d) Corrosion tests performed on steel, aluminium, copper and tin test strips showed no evidence of corrosion.
e) The gas analysis of the aerosol, especially the CO content was strongly influenced by SFE - solid chemical formulation and by generator design.

Conclusions

The extinguishing effectiveness of the powdered aerosol was found to be dependent on several design factors:

1. Chemical composition of raw materials.
2. Generator design, especially the internal combustion chamber and the pathway the aerosol travels within the generator.
3. The aerosol temperature at the generator's outlet.
4. The protected volume configuration and location of generators.

The present test program has shown that using two types of generators, discharging the aerosol at different temperatures (approx. 160°C and 300°C at lOcm distance from generator's outlet) increases the aerosol fire extinguishing effectiveness. Also, tests where additional hot aerosol sources were added, exhibited by far better extinguishing times (shorter) than totally cooled aerosol application.

Although the present test program was limited so far to two generator designs, and a more detailed test program is required to further establish the optimal design parameters, we can conclude that a mixture of "hot" and "cold" generating devices located at various positions in the protected volume is the preferred solution.

References

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