

POWDERED AEROSOLS PERFORMANCE IN VARIOUS  
FIRE PROTECTION APPLICATIONS

by

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ABSTRACT

Powdered Aerosols technology has introduced into the fire protection market new concepts for total flooding fire extinguishment. The phaseout of the Halon 1301 combined with the limitations of the new emerging halocarbon substitutes (on the weight/volume requirements) has created a real need for an agent with total flood extinguishing capabilities that is also economic on a weight/volume basis and cost effective.

Such an application is the car parking towers that are increasing in numbers, especially in crowded built urban areas in large cities such as Tokyo, Hong-Kong etc., where the land is expensive and limited.

According to national fire protection requirements, the car parking towers are presently protected by Halon 1301 Automatic systems, that include several dozens of cylinders, a lot of piping and nozzles combined with a fire detection system. The large Halon 1301 cylinders are located in a specific building adjoining the car-parking tower, thus occupying expensive land that otherwise can be profitable.

The most attractive fire suppression solution for such an application is the powdered aerosol system, that requires no pressurized cylinders, no piping and nozzles, and can be introduced into the car-parking tower without the need for the adjoining storage building

Such a system is described in the present paper, including the engineering considerations for fire detection and suppression within one combined unit, the aerosol discharge in situ, its flow pattern and filling capability, extinguishing and inertization evaluation as well as cost effectiveness.

## INTRODUCTION

Powdered Aerosol A (SFE) is a new type of 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.

This highly efficient aerosol contains upto 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 SFE aerosol achieves superior extinguishing power, approximately 3 times that of Halon (on a weight ratio).

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 heterogeneous 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 according to the fire protection application.

## ENGINEERING CONSIDERATIONS

In order to design an effective powdered aerosol extinguishing system, several chemical and physical features of the aerosol technology must be addressed:

1. The aerosol is created in an exothermic chemical reaction generating large amounts of heat (temperatures in the combustion zone upto 2000°K).
2. The same combustion process generates visible flames, the flame front advances with the aerosol stream.
3. The aerosol dispersion pattern is influenced by its discharge force (rate of combustion), atmospheric (wind airflow) conditions, fire size and turbulence, volume configuration.
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 cover within the discharge system prior to their exit, the nozzle orifice size and configuration.

The tasks associated with the engineering of a fire protection system based on aerosol technology included:

- a. Cooling the aerosol products via chemical and physical means using heat absorbing chemicals and metal heat conductors.  
The heat absorbing chemicals tested included:  
water, water + additives, dry powders, gelled mixtures. The heat absorbing chemicals were introduced in the systems walls as well as in the aerosol stream path.
- b. Arresting the flame front from the SFE combustion zone, via several metal flame arrestors designed so as to create a very long path for the aerosol products to release heat.
- c. Discharge of the SFE aerosol in a stream form and directing this stream toward the fire source.
- d. The acceleration of the aerosol stream was obtained chemically (using different formulations) rather than physically via pressurized systems. The pressure within the SFE combustion chamber was kept at atmospheric pressure.

These engineering considerations served as the basis for the development of two prototype systems for aerosol delivery:

1. Deployable units (hand grenades or cannon launched units that contain SFE solid charges from 50 gr upto **250** gr. These units are designed to extinguish fires in closed volumes from  $1 \text{ m}^3$  upto  $5 \text{ m}^3$  per unit. Several such units deployed simultaneously can cover large volumes, such as control rooms, electrical cabinets, elevators, cable tunnels, etc..
2. Modular units that contain SFE solid charges from 2kg upto 6kg per unit. These units can contain an autonomous fire detection sub-system (either heat or smoke) or can be connected to external optical flame detection. Automatic fire protection systems containing from 12 such units, each with 3kg SFE, and upto to 38 units were designed for several applications described in this paper.

## **APPLICATIONS**

The unique features of Powder Aerosol technology (SFE/EMAA agents) render it as a promising tool for existing traditional fire protection applications, as well as for novel approaches to fire protection.

The key characteristics that influence the design of application are:

- a. Similar to a gaseous agent, SFE can flow around barriers and obstacles, behaving as a gas in its basic transport properties. It can be introduced into ductwork and be delivered to an area via forced convection.
- b. SFE/EMAA has excellent fire suppression characteristics, similar to dry chemicals, both of which are **6** times as effective as Halon 1301 per unit mass and upto 10 times as effective as the forecasted replacements for Halon 1301 such as perfluorobutane and HFC-23.

- c. SFE/EMAA initiation is independent of oxygen supply and can therefore be effective under or within a liquid or at altitudes where oxygen concentrations are low.
- d. Initiation of SFE/EMAA can be via electrical ignition or self-ignition due to interaction with the fire.
- e. The delivery rate of SFE/EMAA is a function of its composition, form (solid, powder, gel,) and the delivery system. The aerosol is generated via combustion of the SFE material and variations in the active component, oxidizer, and reducer dramatically affect the combustion rate, perhaps upto 2 orders of magnitude in difference.
- f. SFE/EMAA does not require piping, pressure cylinders, or valves. A device for containing the solid material is all that is normally required. Pressure testing, weighting, pressure/leak detection, and other maintenance and testing of cylinder/pipes/nozzles/valves is not required.

The fire protection market segments that can be addressed by the SFE powdered aerosol include (but are not limited to):

A. Industrial Applications

Fire protection (including detection and suppression) for industrial areas such as: warehouse and storage facilities, boiler rooms, transformers/engine rooms, control rooms, underfloor and over-ceiling closed (unventilated) areas, elevator shafts, cables/electrical equipment tunnels, electrical cabinets and "Safe" storerooms.

A new emerging application is the car parking tower (lifts) that are unmaned and pose a serious fire hazard.

Additional industrial applications include: paint shops, garages, technical support areas in aircraft hangars, chemicals (flammable) storage areas (closed) etc..

B. Automotive / Transportation Application

Fire protection for automotive industry is a must (because of the flammable fuels and interior materials) however almost none of the large numbers of public transportation vehicles (autobuses, trains, taxis, etc..) have automatic fire detection and extinguishing capability.

The new emerging technology of modular aerosol producing units that can be introduced (including automatic fire detection) into the engine compartments of the various vehicles promises additional safety to these potential hazardous means of transportation.

Similar units can be introduced into commercial aircraft dry-bays, cargo compartments and lavatories, engine nacelles, etc., to prevent fire spread and inertization of the protected volume for long period of time (45 minutes and more).

Modular aerosol producing units can be installed also in large engine rooms of ships and marine containers, as well as in small to medium engine rooms of pleasure boats, coast-guard patrol ships, yachts, etc...

### C. Military Applications

Fire protection for the military includes the airforce, ground and naval forces with their specific equipment. Engine and crew compartments of armoured vehicles, cargo bays, engine nacelles and dry bays for military aircraft as well as engine rooms and auxiliary equipment areas in naval ships are protected today by the phasing out Halons 1301 and 1211. Various alternatives are considered and tested for these applications, the aerosol being one of them.

Since the SFE material has been approved by the EPA for the non-occupied spaces and pending for occupied ones, it still needs to be evaluated for the traditional "Halon" users applications.

### D. New Applications

Remote sensing of fires is a growing trend in the fire protection market, and as such can create a real need of remote fire extinguishing, especially where the entrance is limited or obstructed. The use of deployable (throwable) fire extinguishing modular units, either manually or cannon-launched, is an appealing application.

Two recent applications have been evaluated for fire protection by SFE powdered aerosol technology.

1. Control rooms containing electrical cabinets, that require automatic fire detection and suppression.

Nuclear power electrical installations have a large number of such control rooms that are extremely important for the continuous operation of the facility.

An SFE powdered aerosol system has been designed for such an installation to protect a control room with a volume of approximately 400 m<sup>3</sup>.

The system included 12 SFE generators, each containing 3kg SFE and an autonomous heat detection sub-system. The generators were connected via activation boxes to an automatic fire detection system that includes both optical flame detectors (Sharpey IR<sup>3</sup>) and smoke detectors.

Preliminary tests of the prototype system were conducted in a 60 m<sup>3</sup> test chamber using two SFE generators each containing 3kg SFE. Recent test results are reported herein. Fig. 1 shows the schematic installation.

2. Car Parking Towers (and car parking cubicles) require automatic fire detection and suppression. Presently the parking tower is protected with Halon 1301 fire extinguishing system, that has been phased out and is forbidden in future installations. In addition, the present fire protection installation comprises a large amount of big pressurized cylinders (stored in a highly expensive area) and a lot of pipelines and discharge nozzles. This system aside from being cumbersome and expensive must now be changed to contain an acceptable Halon Alternative that is environment friendly with zero ODP and no GWP, non toxic, competitive on weight and volume basis.

The new emerging powdered aerosol (SFE) technology offers a cost effective solution for this protection scenario.

An SFE powdered aerosol system was designed for a car parking tower that has a volume of 1414 m<sup>3</sup> and is divided in 9 floors. The cars are introduced into the parking tower via two lifts so as to contain max. 4 cars per floor. The fire hazard being caused by fuel spills from the cars that may create vapours migrating to hot areas (engine, exhausts, electrical sparks, etc..) require that the car platforms be directly protected by discharge of the extinguishing agent.

The extinguishing agent (SFE) is discharged automatically when a fire is detected via a smoke/heat/optical detection system.

The entire system includes a total of 38 SFE generators, each containing 3-4 kg of solid SFE located 4 units per each floor + 2 units on the ground. Each generator includes a heat detection device to be connected to the central control, and serve as an emergency fire detection system.

In order to obtain homogeneous total flooding of the entire volume (once a fire is detected), the activation of the generators is simultaneous. The location of the generators is according to the free space on each floor (under the hinges of the wall columns).

Fig 2. describes such an installation, Fig 3. describes the wiring connections of the SFE fire protection system.

#### TEST PROGRAM

The present test program was designed to evaluate the powdered aerosol A (SFE) performance on Class A (wood crib) and Class B (n-heptane fuel pool) fires using the modular units specifically designed for the total flood applications described in this paper.

The extinguishing effectiveness as well as the inerting capabilities of the aerosol technology were tested.

The tests were performed in a 60m<sup>3</sup> test chamber with the following dimensions: length 4m x width 3.3m x height 4.3m.

2 SFE generators each containing upto 3kg SFE (2 x 1.5kg casted charges) were located on the floor (near the walls). The fire sources were located in the center of the test chamber as follows:

- a. Wood-crib (1ft x 1ft) located on the floor was ignited (using n-heptane) and burned for 5 minutes. (open windows and hatch) prior to SFE activation.
- b. 2 n-heptane pools (1ft x 1ft) were located at lower (0.6m) and upper (1.2m) positions in the test chamber center.

The fire sources were monitored by optical UV/IR detectors (for flame occurrence) and heat detectors (in the wood crib center and at mid-chamber position).

The n-heptane pools once extinguished were tested for reignition using electrical matches and a torch. Attempts to reignite the pools were conducted during the inertization tests. Various concentrations of SFE (50 gr/m<sup>3</sup>, 80gr/m<sup>3</sup> 100gr/m<sup>3</sup>) were tested to determine effectiveness and inertization periods.

## **TEST RESULTS**

The test results are summarized in table 1.

## **NOTES**

- a. Tests 1-4 were performed on class B (n-heptane) fires. The flames were monitored by optical detectors.
- b. Tests 5-8 were performed on two fire sources: wood crib and n-heptane pools, that were both ignited simultaneously in test chamber. The extinguishment was observed via optical detectors (for flames) and visual observation upon door opening.
- c. Tests 9-12 were performed only on Class A fire (wood crib). The open flames on the wood pile were registered by optical flame detectors and the heat generated by the wood pile was monitored in its center. Glowing ambers were monitored visually and total extinguishment was tested by spraying n-heptane on the wood.

TABLE 1 - TEST RESULTS

TEST NO.	AMOUNT OF SFB (KG) & FORMULATION	FIRE SOURCE & EXTING.			INERT. TIME (min)	REIGNITION TIME (min)	VISUAL REMARKS	GENERAL REMARKS
		CLASS A (wood)	CLASS B (n-heptane)					
			upper	lower				
1	6 kg Form. A. stoich	—	36 sec.	42 sec.	10	10	Total extinguishment	
2	4.5 Form. A. stoich	—	40 sec.	no exting	—	—	The lower pool was not extinguished	
3	4.5 kg 3kg Form. A + 1.5 kg Form. C	—	35 sec.	48 sec.	18	18	Total extinguishment	
4	6 kg Form. A (non-stoich)	—	55 sec.	16 sec.	—	—	Total extinguishment	OT in test chamber. 72°C max. during test.
5	6.0 kg Form. A stoich	+	30 sec.	40 sec.	—	—	Wood crib open flames extinguished glowing charred wood.	Inertization not tested.
6	4.5 kg Form. A stoich	+	41 sec.	31 sec.	—	—	Wood crib open flames extinguished glowing charred wood.	Inertization not tested.
7	6.0 kg Form. A stoich	+	35 sec.	38 sec.	—	—	Wood crib extinguished. Reignited outside.	Open test chamber window. No inertization tests.
8	6.0 kg Form. "D"	+	17	42	—	—	Wood crib extinguished (totally)	Open test chamber window. No. inertization tests.
9	3.0 Kg Form. A. stoich	+	—	—	14 door opened	No No re-ignition of wood-crib	No flames after 17 sec. glowing charred wood.	Only Class A fire test heat detector insert into wood-crib.
10	4.5 kg Form. A. stoich	+	—	—	14 door opened	—	No flames after 17 sec. Wood crib totally extinguished.	Only Class A fire test heat detector insert into wood-crib.
11	6.0 kg Form. A. stoich	+	—	—	16 door opened	—	No flames after 8 sec. Wood crib totally extinguished.	Only Class A fire test heat detector insert into wood-crib.
12	6.0 kg Form. A. stoich	+	—	—	15 door opened	No No re-ignition	No flames after 13 sec.	Reignition trials with n-heptane sprayed on hot wood-crib.



## TEST RESULTS INTERPRETATION AND CONCLUSIONS

The present series of tests evaluated the enhanced performance of SFE Formulation A Stoichiometric and its effectiveness on Class A (wood crib) and class B fires, as well as its discharge from the specifically designed generators.

The combustion of Class A material takes place in two phases: in the vapor phase over the solid surface that is visible in "open flames" and can be monitored by optical flame detectors and on the solid surface where glowing ambers take in oxygen and smoldering combustion can be monitored by heat sensors (or smoke sensors).

We inserted heat detectors inside the wood-crib and an optical flame detector at 30 cm distance from the surface flames on the wood crib.

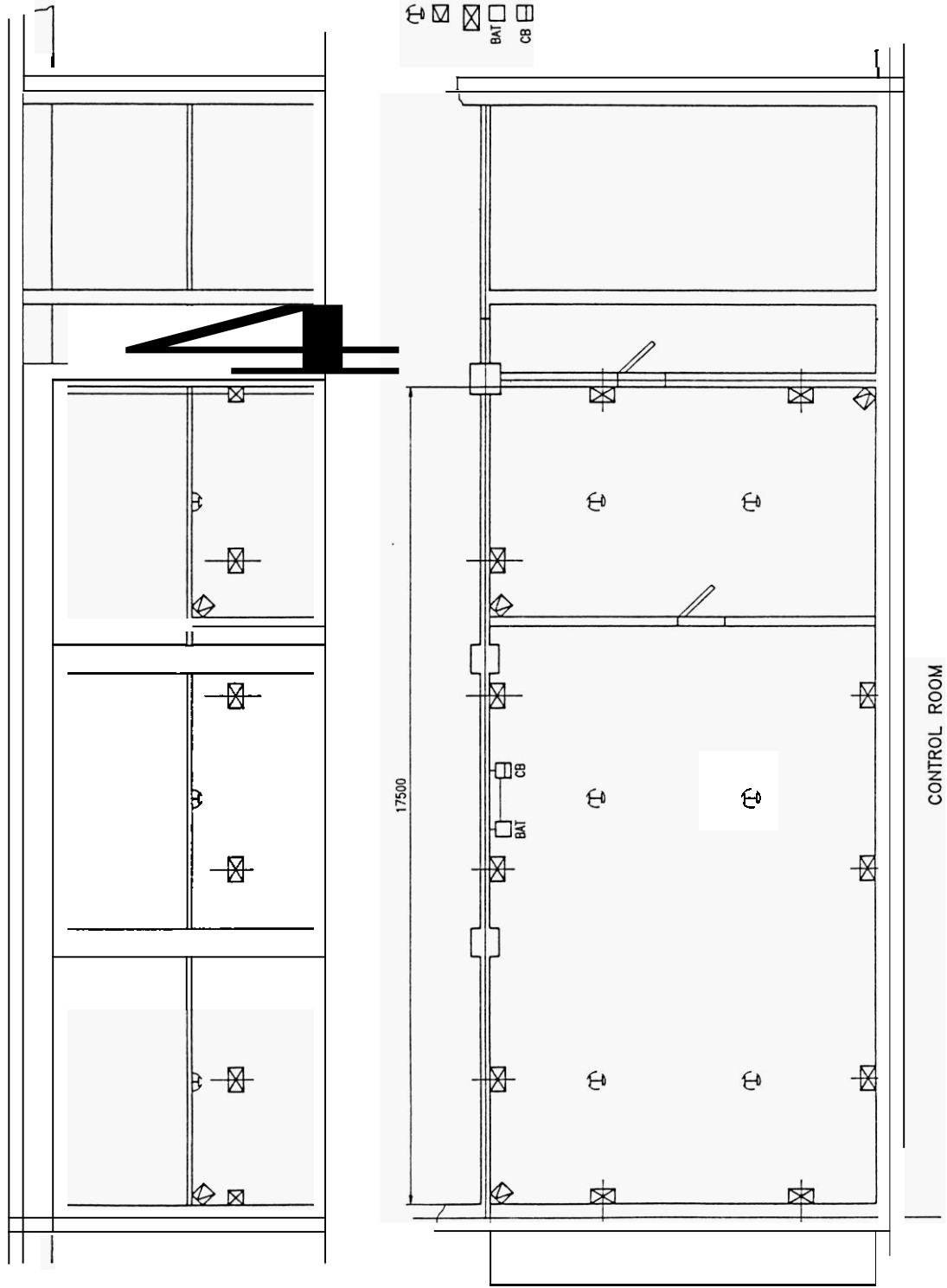
Although in some tests (5-7) the wood crib was observed to be visually extinguished (no open flames) the charred wood had glowing (red) ambers. Inside the test chamber filled with aerosol there was no reignition (open flames) on the wood crib, however when exposed to the open atmosphere (outside the test chamber) the wood pile reignited (and when the wood pieces were turned they ignited in open flames).

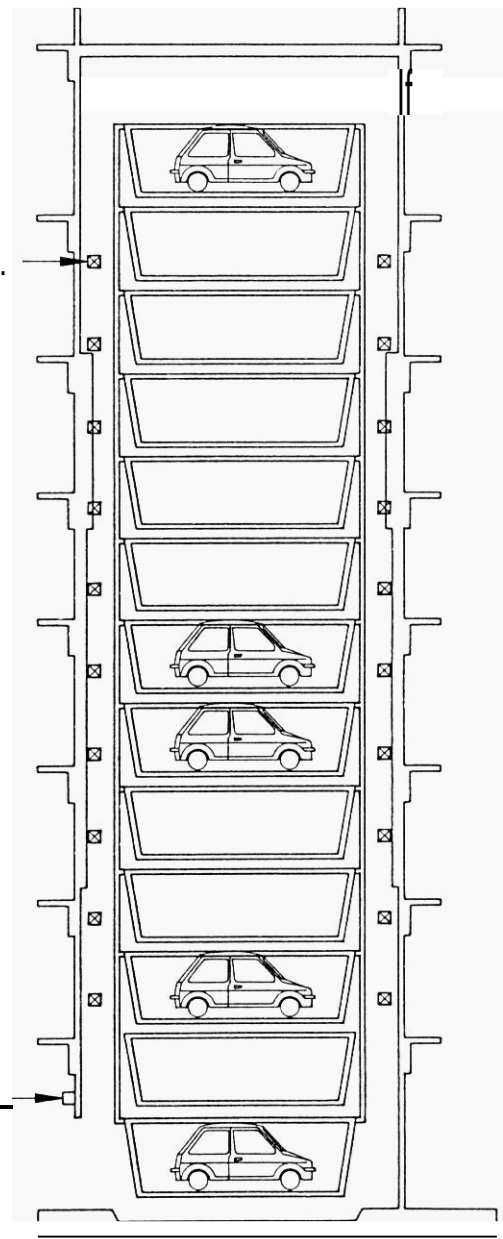
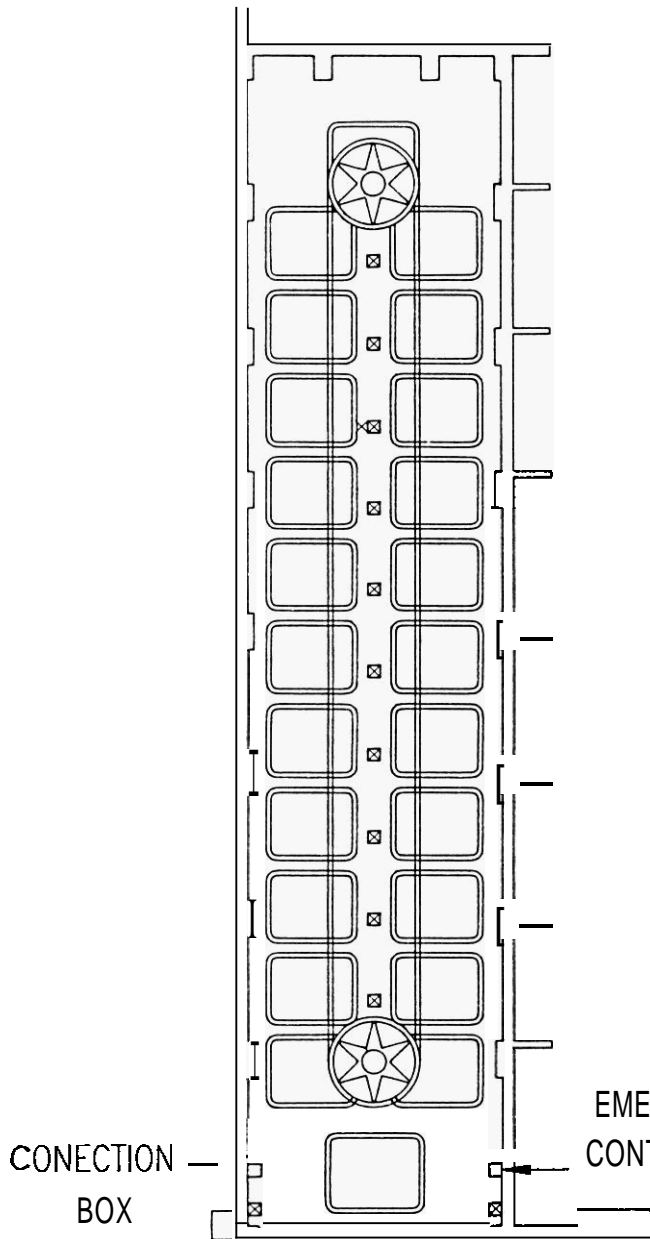
When using formulation "D" (which produced a dark aerosol) the wood crib was totally extinguished (not reignited even outside the test chamber). Same effect was obtained with formulation "A" Stoichiometric at a concentration of  $100 \text{ gr/m}^3$  (6kg SFE for  $60 \text{ m}^3$  test chamber). In test no. 12 the wood-crib fire was totally extinguished and even spraying n-heptane on the wood pile during the inerting time and after the exposure to the atmosphere did not cause reignition.

The combination of SFE Formulations A and C (test no. 3) provided longer inerting times.

The unique fire protection system using powdered aerosol as the extinguishing and inerting agent proved to be efficient on class A and class B fires as well as cost effective and simple for installation. The system does not require pressurized cylinders or pipelines, hence its installation is simple, rugged non-expensive containers that generate the aerosol and can be installed on the walls (like air conditioners) or on the floor (next to the walls). The aerosol discharged from the generators is cooled down to ambient temperatures at 0.5 m distance from the generator's exhaust, creates no pressure heat or toxic hazard upon contact with equipment. The SFE aerosol has been determined as non-toxic at extinguishing concentrations of  $50\text{-}100 \text{ gr/m}^3$  and upto  $240 \text{ gr/m}^3$  no fatalities were observed among test animals. A detailed toxicity evaluation will be presented by the scientists of the Naval Medical Research Institute (Toxicology department).

To conclude, the new emerging technology of powdered aerosols generated via chemical oxidation reduction reactions promise some unique fire protection applications that so far were protected by Halons or were not protected at all because of cumbersome existing systems. The simplicity, high extinguishing effectiveness (on weight, volume and cost bases), non toxicity and environment friendly qualities render the powdered aerosol technology as a most promising **fire** protection tool.





CAR - PARKING TOWER

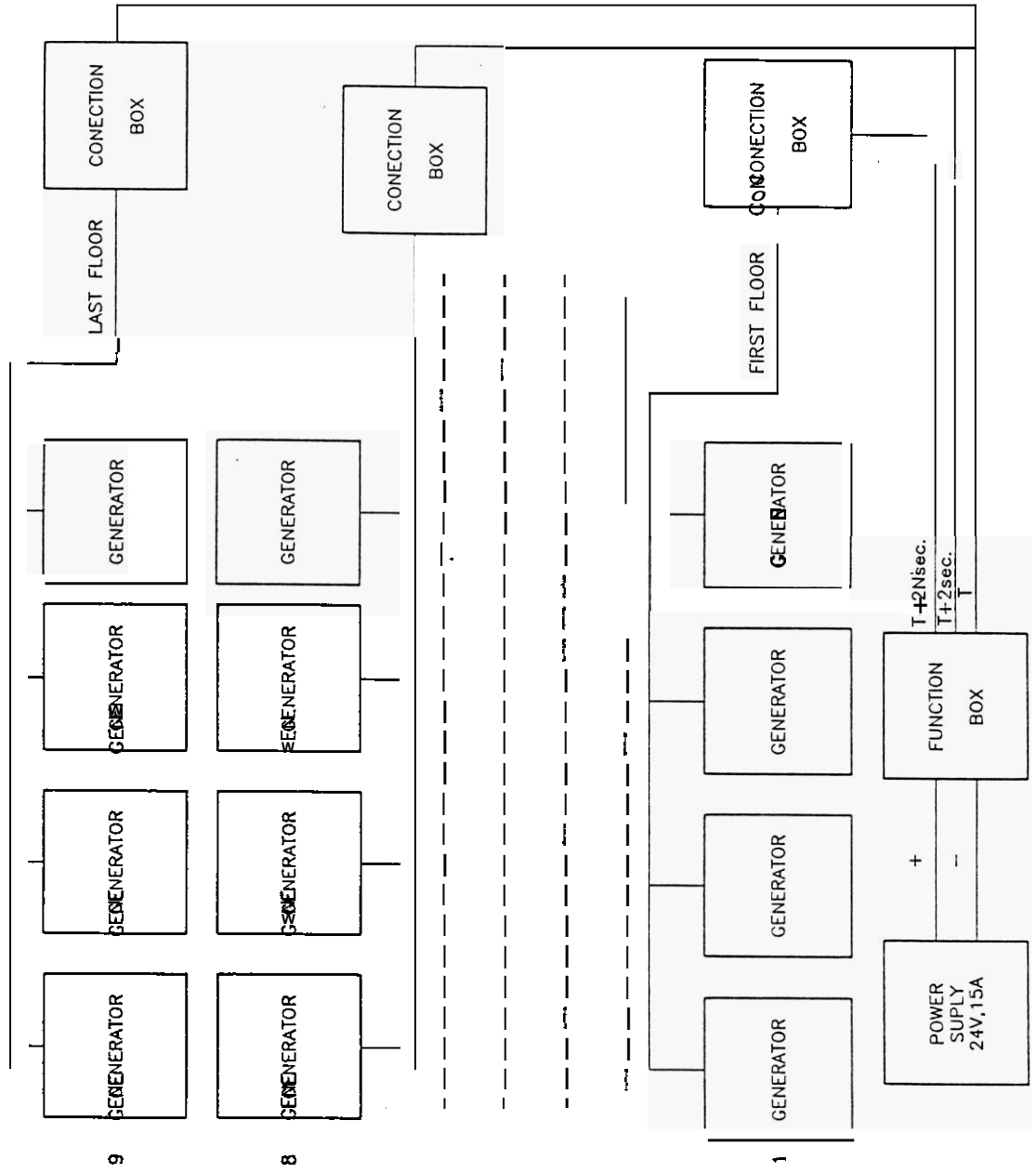


FIG. 3 : WIRING CONNECTIONS