

# **TOTAL FLOODING GAS PROTECTION SYSTEM WITH FM-200**

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## **ABSTRACT**

The objectives of this project are to study how the total flooding gas protection system with the FM-200 clean agent is used in Hong Kong. The performance of the systems is evaluated with relevant properties of the clean agent described. It is followed by introducing the installation application on buildings in Hong Kong. A cost analysis on installation is presented. Testing and commissioning of the systems installation are briefly described. Full-scale burning test on evaluating the fire extinguishment performance on upgrading the existing BTM installations with FM-200 agent is proposed.

## **1. INTRODUCTION**

The clean agent Fire Master 200 (FM-200), heptafluoropropane is widely used as a substitute for Halon. Halon 1301 (BTM) is an effective fire suppressant and has been widely used in total flooding gas protection system. The physical and chemical properties of FM-200 are not the same as BTM. The extinguishing performance of FM-200 appears to be not so quick as BTM.

FM-200 is a trade name. The chemical is 1,1,1,2,3,3,3-heptafluoropropane or HFC-227ea, liquefied compressed gas. This compound consisting of carbon, fluorine and hydrogen is used to suppress a fire or explosion hazard. The halogen element of fluorine substitute of hydrogen atom influences the properties. Fluorine imparts stability to the compound, reduces toxicity, lowers the boiling point and increases the thermal stability [1].

The objectives of this research project are:

- System evaluation on clean agent of FM-200
- Installation application on buildings in Hong Kong
- Cost analysis on installation
- Design guide
- Testing criteria

A good design on developing uniform distribution of FM-200 clean agent, and improvement in existing building FM-200 system will be proposed.

## **2. METHODOLOGY**

### **2.1 Recognized System**

Major components of the FM-200 system including cylinders, piping, nozzles and detectors were studied and reviewed. Relevant experimental results appeared in the literature were also

reviewed and analyzed. The application of the system in Hong Kong was surveyed from two suppliers. Schedule of Rates for term contracts for building works was used to estimate the cost of FM-200 system.

### **2.2 Field Study**

A telecommunication plant room QT103 at The Hong Kong Polytechnic University with the FM-200 system was studied. Firstly, system drawing was obtained and design quantity was calculated. The number of bottle and agent weight was checked. The components of the system including smoke detector, gas nozzle, gas cylinder, lock-off unit, alarm bells, yodalarm and panel were all the same as in the system drawing.

### **2.3 Interview with Engineers**

Special software was used in system design. The pipe size, piping arrangement and nozzle location were able to be designed by the software. Different companies have their own software.

### **2.4 Laboratory Test**

Evaluation of the fire extinguishment performance on the improved existing BTM installation system filling with FM-200 agent in full-scale experiment is proposed to do.

## **3. SYSTEM EVALUATION ON CLEAN AGENT OF FM-200**

### **3.1 Agent Quantity**

Because of different cup burner experimental results are taken by various investigators, the minimum flame extinguishing concentrations which conform to UL standard [4] are unlike from different investigators. The design extinguishing concentration ranges are from 7.0 % to 7.5 % in

class A fire and the range has included a safety factor of 1.2% [2,3].

### **3.2 Agent Discharge Time**

The maximum discharge time permitted for FM-200 clean agent system is 10 s. This discharge time is taken to be the point where all liquid agent has cleared the nozzle. There are four objectives of 10 s discharge time limitation [8]:

- a. Provide high flow rates through nozzles to ensure adequate mixing of agent with air inside the enclosure
- b. Provide sufficient velocity through pipes to ensure homogeneous flow of liquid and vapour.
- c. Limit the formation of agent thermal decomposition products. The longer time of fire exposed to FM-200 agent, the more thermal decomposition product of HF.
- d. Minimize direct and indirect fire damage particularly in fast-developed fire scenarios. The fast fire extinguishment would reduce the damage level of computer server or furniture.

### **3.3 Discharge Nozzle**

The nozzle design and minimum nozzle pressure are critical in ensuring agent distribution. The performance of the nozzle is evaluated by full-scale approval testing. The maximum nozzle coverage area is established by extinguishing tests in a plenum at the minimum height 0.5 m at the maximum nozzle coverage area 100 m<sup>2</sup> [8]. Manufacturers have their specific nozzle design that satisfies UL standard. The maximum agent quantity to be discharged from one nozzle is between 25 kg - 100 kg in 10 s. In general, the maximum nozzle heights are 4 to 5 m, nozzles area coverage 9 to 10 m<sup>2</sup>, and minimum nozzle pressures between 3 to 6 bar.

### **3.4 Piping Network**

A sufficient uniform quantity of FM-200 agent is discharged into the enclosure. It is not accurate to design pipe sizing by hand involved two-phase flow since the characteristics that differentiate two-phase pipe flow from incompressible fluid pipe flow are the existence of gas and liquid phases simultaneously in the pipe network. Coupled with the relatively short flow times results in significant challenges to correctly predicting the flow [8]. Manufacturer of FM-200 suppression system makes software available to its distributors to perform the flow calculations necessary to size the system piping and discharge nozzles. A computational fluid dynamics program was used to

predict the fluid flow characteristics in FM-200 [10].

Every attempt should be made to keep the system in reasonable balance. A balanced piping system is defined as a system in which the actual linear pipe, equivalent pipe length from the containers to each nozzle is equal and the design flow rate at each nozzle is equal.

### **3.5 Detection System**

Photoelectric smoke detector is selected to install by contractors [9]. The principle of the photoelectric smoke detector is obscuration and scattering visible dense smoke particles. Light scattering type detectors make use of the scattering property of smoke. Smoke causes deflection of light beam to the photocell, resulting in electric current flow to actuate the alarm. It is a fast response on smouldering fires and thus life safety is the primary consideration. It performs well in high airflow areas [11].

## **4. INSTALLATION APPLICATION ON BUILDINGS IN HONG KONG**

There are more than one-fifth of FM-200 system installation projects in computer rooms. The average FM-200 agent weight is 141.4 kg. FM-200 is especially appropriate for protecting information technology facilities because it is electrically non-conductive, non-corrosive and leaves no residue when discharged. Since it is discharged as a gaseous vapor, it rapidly penetrates enclosures to get to the source of the fire, reaching areas that water or dry chemical agents cannot [11]. Consequently, FM-200 extinguishing systems are widely used in the computer rooms. Moreover, the installation of FM-200 fire extinguishing system seems to be a brandname to raise the image and confidence in the market. It plays an important role in promoting web hosting of server facility.

Other large project sizes are found in the commercial field. It included data centre in banks and telecommunication facilities. Those companies are willing to pay more money to reduce the risk of damage in case of fire and to ensure their business keep running. Otherwise, the service disruption would significantly decrease the stock value.

FM-200 extinguishing system should be installed for all gaseous extinguishing systems because personnel safety is a priority consideration in the government buildings [7]. To compensate a loss of life by an accident in case of fire is much expensive than the installation of the system.

The design extinguishing concentration is 7 % in the above three rooms, that means the FM-200 weight of protective volume is  $0.5458 \text{ kgm}^{-3}$ . The volume of Room A is  $32 \text{ m}^3$  that requires 18 kg FM-200 agent. The volume of Room B is  $77 \text{ m}^3$  that requires 42 kg FM-200 agent. The volume of Room C is  $142 \text{ m}^3$  that requires 78 kg FM-200 agent.

The maximum discharge rate of the nozzle is  $2.5 \text{ kgs}^{-1}$ . The nozzle discharges 25 kg agent in 10 s. Therefore, a nozzle is sufficient for Room A demanding 18 kg. The number of nozzles required

in Room B and Room C are found by the same method. Each nozzle coverage area is within  $100 \text{ m}^2$ . In Room C, the ceiling height is 6.2 m that exceeds the nozzle coverage maximum height. For that reason, an additional discharge nozzle is provided for the false ceiling void.

Utilizing photoelectric smoke detectors connected in a cross-zoned mode of operation combines sensitivity and reliability. This arrangement prevents a false signal by an individual detector from discharging the entire system [1].

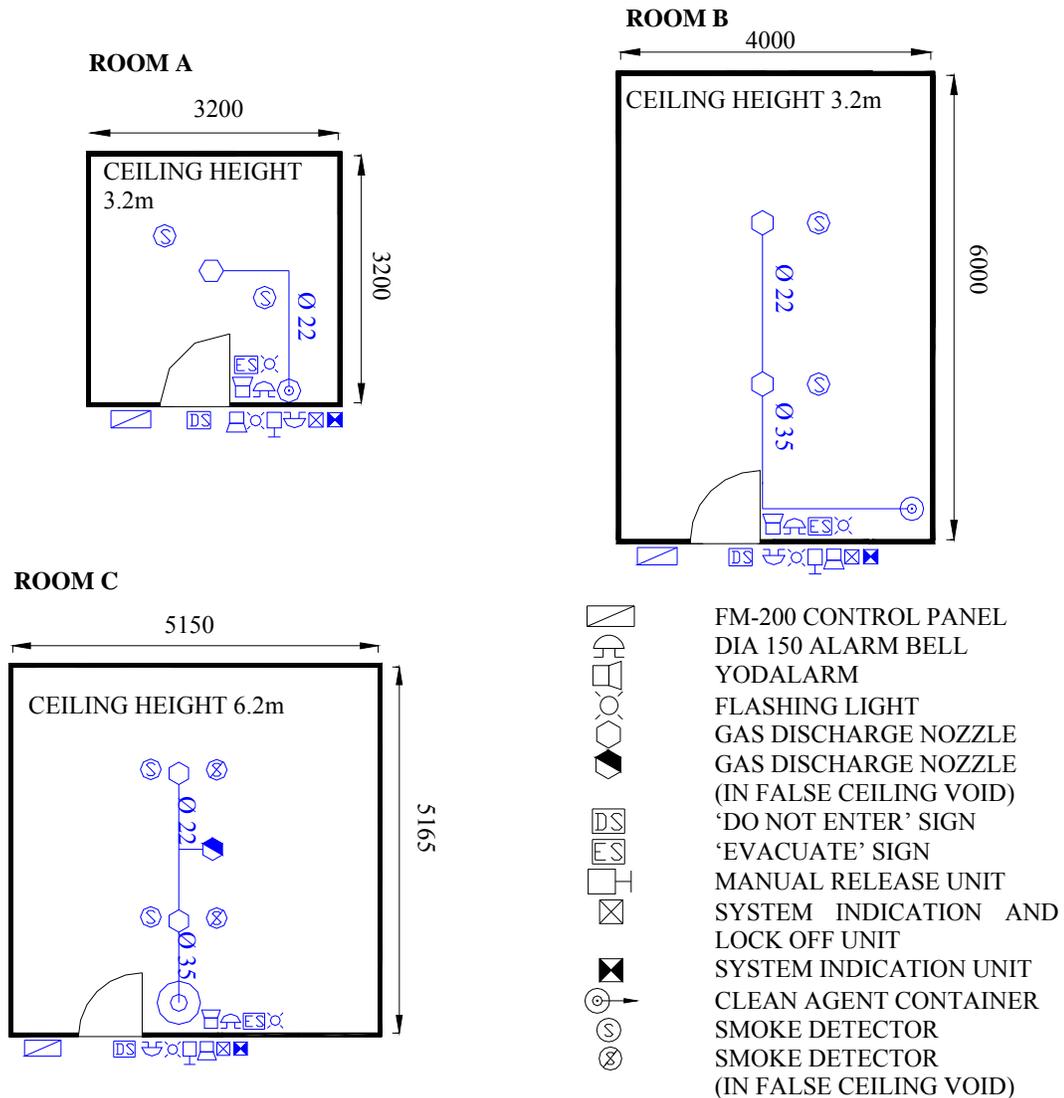


Fig. 1: Three typical rooms with FM-200 fire suppression systems installed

## 5. COST ANALYSIS

Key data on the FM-200 system are shown in Table 1.

### 5.1 Fixed Cost and Variable Cost of System

System installation cost is divided into fixed cost and variable cost. Fixed cost includes container assembly, local manual actuator, 24V solenoid actuator, pressure switch, supervisory pressure switch, door caution plate, instruction plate, alarm bell, banshee sounder, warning light box, auto/manual mode select and status unit and control panel. Variable cost includes agent, discharge nozzle, smoke detector, conduit wiring and system pipework.

### 5.2 Estimation on System Installation Cost

A precise cost estimation of the system installation is fixed cost plus variable cost. The fixed cost is about \$51,000.00, it does not affect by the system complexity or protective compartment volume. Variable cost can be estimated by the room volume, the number of nozzles or protective area because variable cost consists of agent quantity and nozzles. The agent quantity and nozzles are proportional to room volume and protective area. In items 17, 19 and 23, the range of the total cost is large and it is not easy to estimate the system installation cost.

For an example, a 200 m<sup>3</sup> room is 7 % design concentration of FM-200 by volume. The fixed cost is about \$51,000.00, a variable cost per protective volume is around \$200.00 per m<sup>3</sup>. The estimated installation cost is  $[51000 + (200 \times 200)] = \$91,000.00$ .

**Table 1: Summary of key data on the FM-200 system**

	Parameter	Room A	Room B	Room C	
1	Design room temperature	°C	22	22	22
2	Design concentration	%	7	7	7
3	FM-200 weight requirement of hazard volume	kg/m <sup>3</sup>	0.5458	0.5458	0.5458
4	Protective area	m <sup>2</sup>	10	24	26.6
5	Protective height	m	3.2	3.2	6.2
6	Protective volume	m <sup>3</sup>	32	77	142
7	Total FM-200 weight require	kg	18	42	78
8	FM-200 cylinder required	nos	1	1	1
9	FM-200 maximum discharge time	sec	10	10	10
10	Nozzle required	nos	1	2	3
11	FM-200 agent cylinder	kg	26	58	85
12	FM-200 nozzle 360 deg	nos	1	2	3
13	Smoke detector	set	2	2	4
14	Variable cost of items 11, 12, 13	HK\$	7,136	15,742	23,284
15	Fixed cost	HK\$	50,391	50,391	50,391
16	Total installation cost	HK\$	57,527	66,133	73,675
17	Total cost / room volume	HK\$/m <sup>3</sup>	1,798	859	519
18	Variable cost / room volume	HK\$/m <sup>3</sup>	223	204	164
19	Total cost / nozzle	HK\$/nos	57,527	33,067	24,558
20	Variable cost / nozzle	HK\$/nos	7,136	7,871	7,761
21	Variable cost / total cost x 100%	%	12	24	32
22	Variable cost / fixed cost x 100%	%	14	31	46
23	Total cost / protective area	HK\$/m <sup>2</sup>	5,753	2,756	2,770
24	Variable cost / protective area	HK\$/m <sup>2</sup>	714	656	875

### 5.3 Suggestion on System Cost

#### 5.3.1 Design concentration

The agent is about 50 % of the total system installation cost. Therefore, the agent affects the total cost significantly. Reducing the agent would decrease the system cost. The agent design concentration by volume is 7 %. The actual fire suppression is 5.8 %. A safety factor of 1.2 % is added in the installation system. For a small computer room or server room, the piping arrangement is simple. The number of nozzles is 1 or 2 with less tee joint and elbow. The safety factor could be reduced without reducing the extinguishing performance. However, the lower extinguishing concentration should be tested with a fire load to acquire the actual extinguishing agent by full-scale experiment.

#### 5.3.2 Monopoly and price discrimination

The FM-200 fire extinguishing agent is patented by the Great Lakes Chemical Corporation and its exclusive fire suppression system manufacturer partners. It is a kind of monopoly in economic view. The company is granting monopoly right enjoying monopoly status. There is only one supplier in the market for FM-200 agent. The supplier is said to have a monopoly over the supply of the agent. The supplier acquired the monopoly status due to the agent supplier produce is unique that other suppliers are unable to produce.

To maximize the net gain of the monopoly, the supplier is to produce up to the quantity where the marginal cost of production equal the marginal revenue. The increase in revenues beyond what should have gained by the supplier by producing up to Q is monopoly rent [13].

From Fig. 2, if the marginal cost remains the same, with the large increase in quantity from  $Q_{OLD}$  to

$Q_{NEW}$ , the price reduces from  $P_{OLD}$  to  $P_{NEW}$ . In addition, the new monopoly rent area is larger than the old monopoly rent area, that means the supplier can earn more than before with the higher price. Therefore, if more clean agent is produced, the selling price can be lowered because of the huge demand for clean agent in the market.

Price discrimination is a feature of monopoly markets [5]. Price discrimination exists when sales of identical clean agent are transacted at different prices from a single vendor. Small-size computer companies want to install FM-200 system on server rooms. However, the installation cost is very expensive in such small server room area. Moreover, these small-size companies might not have sufficient capital to build the best fire suppression FM-200 system. Therefore, the lower price of clean agent should be sold to the small-size companies to attract a large number of those companies.

### 5.4 Cost on Container Space

A container engaging space of a room is also a cost. The container size between 6.5 liters - 25.5 liters is 222 mm in diameter [9]. The protected volume is up to 25.5 (liter) / 0.5458 (kg/m<sup>3</sup>) = 46.7 m<sup>3</sup>. The container area is [(0.222/2)<sup>2</sup> x π] = 0.039 m<sup>2</sup>. The container size between 52 liters and 180 liters is 406 mm in diameter. The protected volume is up to 180 (liter) / 0.5458 (kg/m<sup>3</sup>) = 330 m<sup>3</sup>. The container area is [(0.406/2)<sup>2</sup> x π] = 0.129 m<sup>2</sup>.

The land is very expensive in Hong Kong. The rental price in commercial buildings is about \$5000 per feet, that is equal to \$53,800.00 per meter. For a 222 mm diameter cylinder, the container space value is 0.039 m<sup>2</sup> x \$53,800.00 = \$2,082.00, while for a 406 mm diameter cylinder, the container space value is 0.129 m<sup>2</sup> x \$53,800.00 = \$6,940.20.

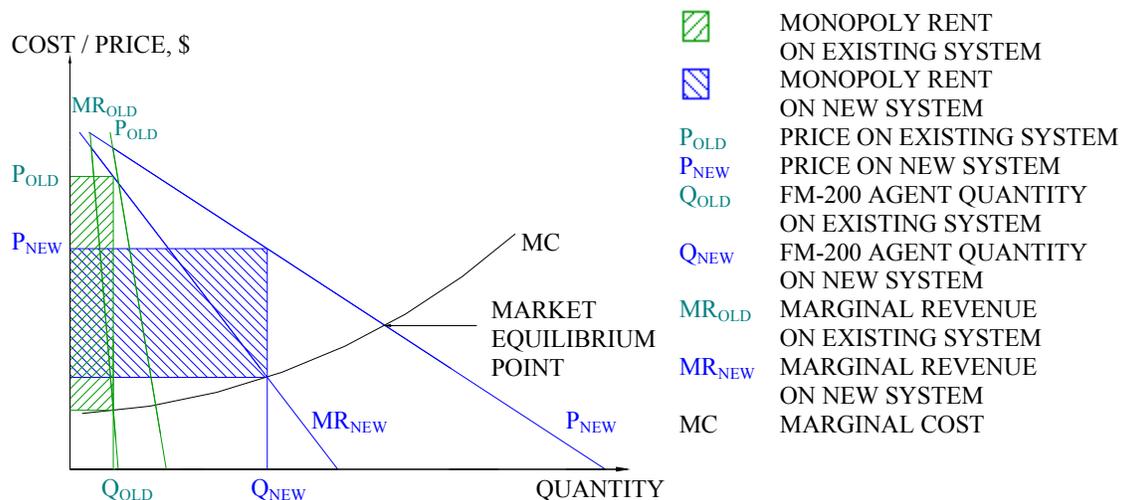


Fig. 2: The graph of reduce clean agent price

## 6. TESTING AND COMMISSIONING

### 6.1 NFPA 2001

Clean agent quantity and pressure shall be checked semi-annually. Annually, all systems shall be thoroughly inspected and tested for proper operation. All system hose visual examination and enclosure inspection shall be processed. Every five years, cylinders continuously in service shall undergo external visual inspection and all hose shall be tested [6].

### 6.2 Manufacturer

It contains not only test and commissioning in NFPA 2001 requirement, but also requests visual inspection on all system components monthly. All system components cover detectors, piping, nozzles, auxiliary components, storage rack, cylinder, cylinder valves, cylinder straps and outlet fittings. Cylinder pressure should be noted [2].

### 6.3 Hong Kong Fire Services Department (FSD)

FM-200 system are required by FSD to be tested, inspected and maintained quarterly [7]. All electrical components, automatic or manual release mechanism, pipes and fittings, valves, nozzles, cylinders, warning system and operating instructions, time delay and lock-off devices, the coincident unit and ancillary function are to be tested.

## 7. PROPOSED SYSTEM EVALUATION TEST

The aim of the proposed experiment is to evaluate the fire extinguishment performance on the improved existing BTM installation system filling with FM-200 agent in full-scale experiment. Halons have been phased out of production and many halon systems have not been replaced in Hong Kong. However, it is hard to remove the whole existing halon systems since some large plants such as transformers, telecommunications facilities are difficult to take out.

### 7.1 Experiment Procedures

#### 7.1.1 Preparation

A full-scale test compartment volume is measured. A BTM system including pipe size, nozzle numbers, and nozzle location is designed. FM-200 cylinders are connected to the BTM system. Finally, smoke detectors are checked with heptanes placed in a fuel pan.

#### 7.1.2 During test processes

FM-200 cylinder weight, piping pressure and piping temperature are measured. An electric heating igniter is used to set off a fire. The compartment door is kept open before discharging agent from the nozzle and the time  $T_i$  is taken when agent is released from the nozzle. The door is closed when agent is released from the nozzle and the time  $T_e$  is taken when the fire is put out. The existing BTM system filling with FM-200 is supposed to take longer than 10 s to put out the fire. FM-200 system is redesigned and compare with the existing BTM system, then some additional piping and FM-200 type nozzles are estimated. The steps are to be repeated until the fire extinguishing time is within 10 s.

#### 7.1.3 Confirm system design

An electric heating igniter on the fuel pan is placed after the fire has extinguished for 5 mins and activated for 30 s to determine whether re-ignition would occur [12]. The door is opened for 30 s after 4 mins to simulate an actual fire situation where personnel may enter the fire compartment to check the condition inside. Second re-ignition is attempted. In that situation, the agent may leak out through the open door, resulting in reduced agent concentration, which may permit re-ignition of the fires. The reading of FM-200 cylinder weight, piping pressure and piping temperature are taken during the test processes. The full-scale test is terminated at 10 mins. Finally, the graphs of cylinder weight loss against time, pipe pressure against time and pipe temperature against time are plotted.

## 8. CONCLUSION

FM-200 agent is widely used in total flooding gas protection systems to replace halons as they are safe, efficient and environmental friendly. System evaluation including agent and system components are considered. The most favorable installation application is in computer rooms in Hong Kong. Cost analysis and suggestion on the system installation are conducted. A fixed cost of HK\$51,000.00 adding a variable cost of HK\$200 per  $m^3$  is good for cost estimation on the system. Testing and commissioning are required by the Authority such as FSD and others such as NFPA and the manufacturers. A full-scale experiment on evaluating the fire extinguishment performance on the improved testing BTM installation system filling with FM-200 agent is proposed. Those are presented to give a general view to the professionals.

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