A Design of Fire Master 200 Total Flooding Fire Extinguishing Systems for Moderated Hazards of Computer and Electronics Rooms in Integrated Processing Plant Under Global Environment.

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Abstract:

FM-200 total flooding fire extinguishing system has been designed for a specified premises of computer and electronics room. FM-200 (heptafluoropropane, CF3CHFCF3) is a colorless odorless gas, low in toxicity, electrically non-conductive, leaves no residue, and is an extremely effective fire suppression agent and approved by Factory Mutual Research Global. FM-200 extinguishes a fire by a combination of chemical and physical mechanisms without affecting the available oxygen and it is one of the most suitable replacement of Halon 1301 (Bromo trifluoromethane) to avoid Ozone depletion . A typical computer cum electronics room with sizes 15m X10m X4m has been considered for the specified design. One extinguisher unit can be used to protect one hazard only. System has been designed with the following parameters/units:
(i) Class A type Hazard with plastic materials typically found in electrical and electronics instruments in Computer rooms (ii) FM 200 cylinders in liquefied condition each with 85kgs of clean agent is super pressurized with dry nitrogen to 150 psig at 70ºF. (iii) Minimum design concentration 7.48% by volume (iv) Specific volume superheated agent 2.115 ft³/Ib (v) Discharge time of 10secs (vi) Ambient temperature ranges from 0ºF to 130ºF. (vi) Nozzle each having coverage area of 10m² with proper spacing(vii) Soft annealed copper pipes conforming to ASME B-31.1and Power Piping requirements of NFPA – 2001. (viii) Brass made pipe fittings with pressure rating 1000 psig (ix) Fire detecting addressable sensors with response indicators, automatic actuation, main fire control panel , repeater panel, manual call point, alarm and control systems in accordance to NFPA-72A and NFPA-72E. (x) One manual control for activation located within 1.5m above the floor (xi) the detection tubing is temperature sensitive and acts as a continuous linear thermal detector that ruptures at designated temperature. Due to such rupturing, the cylinder valve is actuated allowing clean agent FM-200 fluid to flow through the distributing piping discharging extinguishing agent through nozzles in the hazard areas.(xi) Other instrumentation ,control and accessories.
Design of the systems with maximum concentration anticipated, location and number of FM-200 cylinders and its capacities, locations and quantities of nozzles, layout of piping and fittings, automatic detection and actuation systems, testing and bill of materials have been made generally in accordance to NFPA-2001 and NFPA-12A wherever applicable. The system can also be suitable for electrical and electronics room, telecommunication areas, data processing areas, UPS units, Flammable chemical storage cabinets etc and also capable for extinguishing Class A, Class B, and Class C type fires.

Key words: National Fire Protection Association**,** heptafluoropropane, Bromo trifluoromethane, Sensors, actuation, design concentration.

Introduction:

Halogenated extinguishing agents are hydrocarbons in which one or more hydrogen atoms have been replaced by atoms from the halogen series like fluorine, bromine, chlorine or iodine. FM-200 is clean and leaves no residue, thereby minimizing after fire clean up, along with keeping expensive downtime to a minimum. Most materials such as steel, aluminum, stainless steel, brass, as well as plastics, rubber and electronic components are not affected by exposure to FM-200. This agent is also environmentally friendly, having an ozone depletion potential (ODP) of 0.00.

Table-1: Physical Properties of FM-200
Chemical Name: Heptafluoropropane (CF3CHFCF3**)**

Properties	**value**	**Properties**	**value**	**Properties**	**value**
Molecular Weight	170.0	Critical Volume (ft3/Ibm)	0.0258	Viscosity, Liquid (Ib/ft hr) @ 77ºF	0.433
Freezing Point (ºF)	- 204	Specific Heat, Liquid (BTU/Ib-ºF) @ 77ºF	0.282	Ozone Depletion Potential	Nil
Critical Temperature (ºF)	214	Heat of Vaporization (BTU/Ib) at Boiling Point	56.7	Specific Heat, Vapor (BTU/Lb-ºF) @ constant pressure (1 Atm.) @ 77ºF	0.185
Critical Pressure (psia)	422	Thermal Conductivity (BTU/h ftºF) of Liquid @ 77ºF	0.040	Boiling Pont (ºF) @ 14.7psia	1.9

CONDITIONS OF FIRE OCCURRENCES.

Initiations of fire requires three parameters in the adequate proportions to be satisfied simultaneously. These parameters are (i) Combustible materials/fuel ii) Oxygen iii) ignition . combustible materials/fuel are generally available in the hazards which when combined with other two parameters at required proportions /level initiates fire and it spreads on satisfaction of these parameters. Therefore , satisfaction of these three parameters in required proportions makes a closed triangle known as " **Fire Triangle** " whose three sides represents fuel , oxygen and ignition at it's proportionate level .

Clean Agent FM 200.[A substitute of Halon 1301]

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.Fluorine imparts stability to the compound, reduces toxicity, lowers the boiling point and increases the thermal stability.

Principles of Extinguishment of fire.

Traditionally, there were three distinct elements assumed for combustion: heat, fuel and oxygen known as " Fire-Triangle". Typical fire extinguishing involves removing fuel from fire, limiting oxygen to fire (Smothering) or removing heat (Quenching). FM-200 does not extinguish the fire in any of these methods. Instead of these, it breaks up the uninhibited chain reaction of the combustion process. When exposed to temperatures of 1300ºF (700oC) FM-200 will form products of decomposition (halogen acids). Test results have shown that when the agent is rapidly discharged, causing rapid extinguishment of flames, the amount of decomposition products formed is minimal. Hepta fluoro propane atoms act y removing the active chemical species involved in the flame chain reaction.

Agent Discharge Time

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

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.

Table- 2: Types of Fire

Type	Class of Fire	Type	Class of Fire
A	Fires in ordinary combustibles (wood, vegetable fibers paper and the like)	D	. Fires in Reactive Chemicals, active metals and the like
B	Fires in flammable liquids, paints, grease, solvents and the like	E	Fires in electrical equipments
C	Fires in gaseous substances under pressure		

Premises Suitable for fire-protection by FM-200 agents Heptafluoropropane includes, but are not to be limited, to protect the following premises:
(i)Electrical and electronic installations (ii) Computer, Control, UPS units, Switchgear rooms, telephone exchange rooms.(iii) Telecommunication areas.(iv) Data Processing areas and cabinets. (v) High Value risks [Museums, archives and libraries, banks) (vi) Pump rooms (vi)Flammable Chemicals storage cabinets (vii) Generator Enclosures (viii) Transformer Cabinets (ix) CNC & VMC Machining centers (x) Military Installation (xi) Other special risks.

Heptafluoropropane should not be used where the following materials may be present.
(i)Pyrotechnic chemicals containing their own oxygen supply.(ii) Reactive metals such as lithium, sodium, potassium, magnesium, titanium, zirconium, uranium and plutonium. (iii)Metal hydrides. (iv) Chemicals capable of undergoing auto thermal decomposition, such as certain organic peroxides and hydrazine.

Fill Density
Each FM-200 storage cylinder has been designed for a maximum fill density ranges from 70I**b/ft³ to** 75I**b/ft³** and super- pressurized with nitrogen to 150 psig +10, -0 psig at 70ºF (10.4 bars gage + 0.7, -0 bars gage at 21ºC). Adherence to the limits on fill density and pressurization levels will prevent excessively high pressures from occurring if the storage cylinder is exposed to elevated temperature.

Factors generally needed to be considered in selecting the Heptafluoropropane [FM 200] as fire extinguishing agent and also in designing the total flooding systems.

i) FM-200 is included in NFPA-2001, under the generic name HFC-227ea, and is an approved agent for use in occupied areas as a Total Flooding medium.

ii)Type of hazards involved observing the type of materials stored, understanding the processes and activities involved in the premises. Details regarding false floor, false ceiling, ventilation and air conditioning, closable and unclosable openings, dampers in the ventilation duct, etc.

(iii) Generally, photoelectric and optical detectors are used in two wire circuits in loop configurations. But depending on the type of combustible and environmental conditions, alternative types of detectors like ionization type smoke and photoelectric smoke detectors can be used in a close loop circuits. This will enable the confirmed fire signal on receipts of activations by the Fire Control Panel from both type of detectors separately from the same location of premises. Closed loop and ring circuits prevents the affect of faults in one detector and also in one circuit over another and hence ensure the fail safe conditions in the protection systems.

iv) A means of emergency release of the system resulting from a single manual operation needs to be provided. At least, one manual control of activation shall be located at a maximum radial distance of 15m and 1.5m above the floor.

v) Standby cylinders with 100% provisions are provided incase of single risk. However, in very large plants where many FM-200 protected areas are spread over a vast area, one centralized reserve cylinder storage taking care the various sizes of containers.

vi) Cylinder Nitrogen Recharge Adapter is connected to a tubing, and the other end of the tubing is attached to the ball valve, located on top of the cylinder valve, during the charging procedure.
vii) The thickness of the pipes shall be calculated in accordance with ANSI B31.1: Power Piping Code. The internal pressure for this calculations shall be the maximum storage pressure at maximum storage temperature, but in no cases shall be less than the followings:

(a) for 360 psig charging pressure, an internal pressure of 620 psig (130ºF)
(b) for 600 psig charging pressure, an internal pressure of 1000 psig (130ºF).

viii) **Piping Network**

A sufficient uniform quantity of FM-200 agent is discharged into the hazard areas. Fluid flow is involved two-phase flow and 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. A computational fluid dynamics program has been used to predict the fluid flow characteristics in FM-200 . Every attempt should be made to keep the system in generally balanced. A balanced piping system is defined as a system in which the actual linear pipe, equivalent pipe length from the cylinder to each nozzle is equal and the design flow rate at each nozzle is equal.

ix) Nozzle discharge is in a 360º pattern. Made from brass with female NPT pipe threads. Each nozzle is to be installed at the top of the hazard enclosure facing down in a pendant position, and centered in the area to be protected by that particular nozzle The discharge nozzle made from anti-corrosive metal consists of the orifice and associated horn, shield or baffle. The type of nozzles selected, its quantities, and spacing shall be such that the design concentration will be established in all parts of the hazard enclosure and such that the discharge will not unduly splash flammable liquids or create dust clouds that might extend the fire, create an explosion or otherwise adversely affects the contents or integrity of the enclosure.
xiii) The agent discharge shall be substantially completed in a nominal 10 seconds to reach 95% of the minimum design concentration.
x) Pressure Switch.
A pressure switch is provided as a standard part of the cylinder valve assembly and is connected directly into the pressurized portion of the cylinder valve. This pressure switch is used to monitor unit pressure, unit actuation and or to energize or de-energize electrically operated equipment.. This switch is connected at the end of the line heat detector tubing to provide additional electrical functions as may be required. All units use a pressure switch coupled with some device to alert personnel.

Table-3: Design Parameters and Results for Automatic FM-200 [Clean agent] total flooding systems.

Sl. No.	Design Parameters	Value/Unit	Sl. No.	Design Parameters	Value/Unit
i)	Size of the premises with RCC ceiling and false floor and false ceiling.	15X10X4m [49.2' X32.5' X13.1']	xx)	Nozzle Size	Nominal Orifice: 15mm.
ii)	Type of fire hazards	Moderated	xxi)	Coverage area of each nozzle(m^2)	9-10
iii)	Class of Fire	A and B.	xxii)	Minimum nozzle pressure (bar(g))	3-6
iv)	Type of installations	Total Flooding	xxiii)	Total nos. of nozzles in the entire protected area.	15 nos.
v)	Type of extinguishing agent	FM-200((heptafluoropropane, (CF3CHFCF3)	xxiv)	Operating pressure of the system	10.50KG/cm^2 (150 psig).

vi)	Design concentration for Class A type fire hazards(%by volume)	7.48	xxv)	Maxim. And Minim. ambient temperature anticipated.	55ºC and -18ºC (130ºF and 0ºF)
vii)	Minm. Safety Factor	1.3	xxvi)	Design Room Temperature	22ºC
viii)	Specific vapour volume at room temperature of 40ºF (ft^3/Ib)	2.0678	xxvii)	Openings and Ventilation:	Provision must be made to provide mechanisms to close all openings in hazard enclosures and shut-off ventilation at the time of discharge.
ix)	Maximum fill density	70 Ib/ft^3	xxviii)	Volume of the hazards to be protected.	600m^3(21,188 ft^3)
x)	FM-200 weight requirement per unit volume of protected space(Ib/ ft^3)	0.0391.	xxix)	Amount of FM 200 agent contained in each cylinder with maximum storage pressure 1000 psig at 130ºF (Maximum operating temperature)	85kgs.
xi)	Qty of FM-200 agent required to provide the proper design concentration at the minimum anticipated temperature in the hazards	828 Ibs.(376 Kgs)	xxx)	Nos. of such Cylinders:	5 nos(working) +5 nos(Standby).
xii)	Actual concentration(**C** maxim) to be achieved in the protected space at maximum anticipated ambient temperature (%by volume)	8.84	xxxi)	Size and total length of Distribution pipes conforming to ANSI B 31.1.	DN25 & 45m Sch.40
xiii)	Depth of beam/Joist	200mm	xxxii)	Size and length of main supply/feed pipe conforming to ANSI B 31.1.	DN50 &5m Sch.40
xiv)	Electrical Cables	Armoured.	xxxiii)	Nos. of Photo-electric type smoke detectors(PSD). [Addressable]	9
xv)	Spacing of beam(centre to centre line)	3m	xxxiv)	Provision of continuous linear thermal detector and its rating.	Yes and ruptures at 212°F
xvi)	Ceiling type	Combustible	xxxv)	Main Fire- Control Panel conforming to	NFPA 72: National Fire Alarm and Signaling Code, 2016 Edition
xvii)	Minim. Horizontal distance from the nozzle vertical axis to the centre line of the beam	2m	xxxvi)	Manual Call Point	Provided near entrance and exit.
xviii)	Maximum height of nozzle deflector above bottom of beam:	+260mm	xxxvii)	Response Indicator.	Provided.
xix)	Minim. Horizontal distance from the nozzle vertical axis to the side wall/beam/Joist.	2m	xxxviii)	Backup power	100% provision

Materials and Methods:

Automatic detection has been made with the devices/sensors capable of detecting and indicating heat, flame, smoke, combustible vapours or any abnormal conditions in the hazard such as process trouble that is likely to occur fire. More than one type of detectors have been provided to have confirmed alarm before automatic actuation of the extinguishing agent from storage cylinders. The detection

tubing is temperature sensitive and acts as a continuous linear thermal detector that ruptures at designated temperature.

Photoelectric smoke detector has been is selected to install in the premises. 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.

Addressable detectors and LHS cables have been installed in closed loop circuits and connected with the main fire alarm panel in such a way that fault in any detector or any part of the LHS cable will not in any way affect the remaining parts of the circuits and panel. Cable fault will also e detected with initiation of audio-visual alarm in the fire control panel. Provisions have also been made to connect the main fire control panel with the nearest fire brigade station and also with a number of repeater panels at designated locations in case of larger sizes of hazard arrears. When tubing ruptures, the cylinder valve is actuated allowing extinguishing agent to flow through the piping network distributing the agent through nozzles in the hazard areas.

Results:

Once installed, the Automatic Unit becomes a self-contained, self-actuating unit that requires an external source of power or electricity with 100% back-up power provision. The unit utilizes unique flexible tubing that is attached to the top of the cylinder valve. This tubing is pressurized with dry nitrogen to maintain the cylinder valve in the closed position. This tubing is temperature sensitive, and acts as a continuous linear thermal detector that ruptures at approximately 212ºF (100ºC). Once the detector tubing is ruptured, the cylinder valve automatically opens, allowing the FM-200 agent to flow through the discharge tubing, distributing the extinguishing agent through the nozzle(s) into the protected area. Upon actuation, the pressure switch can be used to indicate discharge, shutdown ventilation, close all openings, shut-off electrical power, etc. as may be required.

Conclusions:

FM-200 , a clean agent (CF3CHFCF3) is widely used in total flooding gas protection systems to replace halon as it is safe , efficient and environmental friendly. System evaluation including agent and pressure loss with different components is considered. All design parameters and bill of quantities for the specified systems have been furnished and evaluated. Closed loop Piping network in gas discharge nozzles for minimum pressure loss and also closed loop circuit diagram for detectors have been considered for proper balancing and higher reliability. Actual fire extinguishing concentration of 8.48 can be achieved with in 10 sec upon actuations of the discharge of the clean agent from the storage cylinders. The clean agent extinguishing system should be installed for all gaseous extinguishing systems because personal safety is a priority consideration in industrial, commercial, and also domestic premises. To compensate a loss of life by an accident in case of fire is much expensive than the installation of the systems.

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