SIEMENS

# Cerberus® FM200

# Dry extinguishing system

## System description

Fire Safety

Siemens Building Technologies

# Cerberus®FM200 - fastest acting due to high pressure technology

## 1 Introduction

*FM200*™ (HFC 227ea, Heptafluoropropane $C_3F_7H$) is world-wide exclusively produced by Great Lakes Chemicals, USA, and is patented for its applications as a fire extinguishing agent in most industrial and emerging countries. Due to the special molecular structure containing neither bromine nor chlorine, *FM200™ it has zero* ozone depletion potential and therefore no destructive effect on the stratospheric ozone layer. The chemical structure of *FM200*™ is illustrated in *Fig. 1*.

```
        F       H       F
        I       I       I
F   -   C   -   C   -   C   -   F
        I       I       I
        F       F       F
```

Fig. 1 Chemical Structure of FM200™

*FM200*™ is part of the chemical group of halonfluorocarbons (HFC) which are often declared as clean agents in literature. All HFCs show similar chemical and extinguishing behaviour to Halon 1301 in having zero ODP.

Among the group of halonfluorocarbons, *FM200*™ is an outstanding medium for the following reasons (see *Tab. 1*):

- small extinguishing concentration
- no ozone depletion potential (ODP)
- small global warming potential (GWP)
- very short atmospheric stability (ALT)

| Agent [Brand name] | Extinguishing concentration [Vol%] cup burner (n-Heptane) | ODP | GWP | Atmospheric lifetime [years] | NOAEL [Vol%] | LOAEL [Vol%] |
|---|---|---|---|---|---|---|
| Halon 1301 | 2.9 to 3.9 | 16 | | > 110 | 5 | |
| ***FM200™*** | ***6.6*** | ***0*** | ***2900*** | ***31 to 42*** | ***9.0*** | ***10.5*** |
| Fe-13 | 12 - 13 | 0 | 9000 | 280 | 50 | |
| CEA 410 | 5 to 5.9 | 0 | 5500 | 2600 | 9.7 | 10.5 |

Tab. 1 Halonfluorocarbons HFCs

NOAEL: No Observed Adverse Effect Level
LOAEL: Lowest Observed Adverse Effect Level

# 2 Extinguishing effect

In general, the extinguishing effect is based on the physical property, that the conflagration is progressively cooled down by the supply of the extinguishing agent to a critical temperature of 500°C, which then leads to the extinguishing of the conflagration.

While the evaporation of water lowers the temperature of the flame, inert gases dilute the oxygen in the air so that it cannot support combustion. The foam forms a barrier between the combustible and the oxygen making it impossible for them to combine. Powders act basically in the same way.

Releasing *FM200™* into a room is not accompanied by a significant lasting fall in temperature and because of the small design concentrations the reduction of the oxygen concentration is very low. The action of *FM200™* is chemical and works by inhibiting oxidation reactions which are produced between the combustible and the oxygen. In addition the flame is cooled due to the absorption of heat by *FM200™*.

Since the molecular size of *FM200™* is very large, it is split into smaller molecules because of thermal instability at temperatures above 400°C which are reached close to the flame. One mole of *FM200™* will lead to the formation of 8 moles of gas of smaller molecular size (see *Fig. 2*).

Due to this increase of gas volume close to the flame - the volume of one mole of ideal gas is defined as 22.414 l and is independent of the gas itself - the probability of molecular collision between the flame and oxygen is limited. Therefore the transport of oxygen to the flame is reduced leading to a reduction in energy of the combustion reaction and therefore to the extinguishing of the fire by continuously cooling the flame.

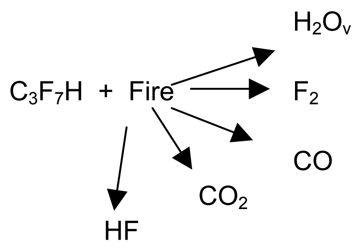


Fig. 2 Thermal decomposition of FM200™ in the reaction zone

The local replacement of oxygen at the flame is forming the basis for the very fast acting of FM200 as an extinguishing agent.

The extinguishing effect of FM200™ results mainly from the local displacement of oxygen in the reaction zone; the cooling effect of FM200™ due to its capacity to absorb heat is only secondary

It must be mentioned that the extinguishing effect of *FM200™* will only take place if *FM200™* is present in the reaction zone as a gas and the required extinguishing or design concentration is reached in the reaction zone. Otherwise it is not possible to replace enough oxygen at the flame and to extinguish the fire.

# 3 Performance of *FM200™*

*FM200™ is* excellent for extinguishing fires involving different combustibles such as solids or electronic equipment (class A).

*FM200™* is the chemical alternative which as regards performance is closest to Halon 1301 requiring less than twice the weight and storage space of Halon 1301 showing the major advantages listed below:

- very fast extinguishing of the fire before equipment is severely damaged
- chemically inert and therefore no influence on the installed equipment
- clean; no residue after discharge
- harmless; personnel can remain in the protected volume during discharge
- no electronic conductivity
- low extinguishing concentration similar to Halon 1301
- stored pressurized liquid resulting in few bottles and little hardware
- *no thermal shock to the installed equipment; the temperature of FM200™ at the nozzle is above zero Celsius ensuring no damage to electronic equipment*
- *zero ozone depletion potential (ODP)*

The performance of FM200™ as a fire extinguishing agent is mainly determined by reaching the exact extinguishing concentration as fast as possible requiring the fulfilment of the following key criteria:

- quick release of FM200™ into the extinguishing sector, fast and total evaporation of liquid FM200™ in the extinguishing sector and
- proper and quick homogenisation of FM200™ in the extinguishing sector

It is of great importance that no leakage occurs during and after discharge of *FM200™*. If the protected volume does not have complete air-tightness

- the extinguishing concentration will not be reached and
- according to international regulations or standards the design concentration cannot be maintained for 10 minutes after discharge which leads to increased likelihood of re-ignition.

To be sure about the tightness of the room a fan door test can be provided.

Furthermore, the resulting overpressure in the protected volume must be taken into account and if necessary, overpressure relief valves must be provided if necessary which is usually needed only for special applications. If pressure relief valves are requested the leakage of *FM200™* during depressurization must not be ignored.

The limits for using *FM200™* are the same as for Halon 1301 or inert gases.

Compared to water or inert gases, chemical alternatives to Halon 1301 generally generate decomposition by-products during fire extinguishing. Since *FM200™* contains one hydrogen and seven fluorine atoms, hydrogen fluoride (HF) is formed during decomposition of *FM200™* in the reaction zone.

It is very important that HF is only produced during the extinguishing process when FM200 is in direct contact with the flame, a phenomenon that also occurs with all other chemical alternatives to Halon 1301.

It is of the utmost importance that the fire is extinguished in a very short time (30s after start of discharge at the latest).

The prime objective must be to reduce the period of contact between the flame and *FM200™,* which is the same as reducing the extinguishing time.

This is one of the major requirement of the *Cerberus®FM200™* extinguishing system to ensure that the resulting HF concentrations are neglectible and far below the levels that are critical for personnel and installed equipment.

The design of the Cerberus®FM200™ automatic fire extinguishing system is an innovative solution for reducing the risk to personnel and installed equipment by using a high pressure system and by complying with engineering and installation guidelines

# 4 The SBT FIS high pressure philosophy

The Siemens Building Technologies Division Fire Safety (hereinafter called *SBT FIS* ) high pressure philosophy defines a clear pressure criteria at the nozzle stating that

**the minimum pressure of the extinguishing agent at the nozzle is 10 bar**

leading to full compliance with the three key criteria.

Furthermore, *SBT FIS* uses a 42 bar storage pressure which ensures on the one hand that the pressure criteria at the nozzle are complied with and on the other hand that flexibility is increased for the realisation of complex pipe networks.

Reduced storage pressure leads to a decrease in pressure difference between the nozzle and bottle. Due to the lower working pressure, the diameter of the pipes increases, leading to an increase in the pressure drop in the pipe network caused by enhanced entrainment of the nitrogen out of the liquid *FM200™*. To compensate for this increased pressure drop, more nitrogen is necessary. For this reason the filling factor of a low pressure system is decreased compared to a high pressure system and therefore additional bottles must be used leading to an increase in the total installation costs.

The *SBT FIS* high pressure criteria minimises the time until *FM200™* is fully evaporated and properly distributed in the protected volume leading to

- an earlier start to extinguishing,
- a reduction of the fire size,
- fast extinguishing
- a significant reduction of the HF concentration to a neglectible level during fire extinguishing and no injury to the personnel or damage to installed equipment in the protected volume

# 5 Physical background

Due to the thermodynamic characteristics of *FM200™* nitrogen is dissolved in the liquid *FM200™* after the bottles are filled which entrains out of the liquid during discharge of *FM200™* leading to the formation of a complex two-phase / two-component flow through the piping.

A two-phase (gas / liquid mixture) discharge of *FM200™* can be seen at the nozzle whereas the largest amount of *FM200™* is released as liquid into the protected volume. Only a small amount is released as gas due to changes to the thermodynamic equilibrium during discharge.

For this reason the nozzle design and the pressure at the nozzle is a very important factor. Because of the gas jet of nitrogen and *FM200™* at the nozzle, liquid *FM200™* is distributed as small droplets.

It is a fact that an increase of pressure at a nozzle leads to the formation of smaller droplets. Furthermore, it can be proven thermodynamically that a nozzle pressure of 10 bar ensures the formation of *FM200™* droplets which are evaporated faster than droplets which are distributed at a pressure at the nozzle of 4 bar.

If the pressure at the nozzle is low, liquid *FM200™* is distributed as large droplets leading to incomplete evaporation. For this reason these droplets do not fully evaporate before coming into contact with the ground floor or installed equipment leading to the formation of a liquid film which must evaporate under non-ideal thermodynamic conditions (no turbulent heat transfer). Therefore the time needed until *FM200™* is properly distributed and the design concentration is reached in the protected volume will increase.

Furthermore, the increased momentum of the jet of nitrogen leads to an increase in the diffusion layer of the jet of gas in the protected volume which is called turbulent free jet (see *Fig. 3*). The turbulence of the jet of gas is increased on the one hand by the pressure criteria at the nozzle and on the other hand by the large amount of entraining nitrogen which is dissolved in the liquid *FM200™*.

High turbulence of the jet of gas leads to a larger entrainment of air. The entrained air is responsible for the energy transport which evaporates the *FM200™* droplets produced (see *Fig. 3*). Therefore *FM200™* is perfectly homogenised after discharge due to the fact that the maximum distance of a *FM200™* droplet can be transported is below 1,5m while the minimum distance of a low pressure droplet is 4-5m.

For this reason *SBT FIS* provides a minimum pressure at the nozzle of 10 bar assuring a perfect fulfilment of the three key criterias.

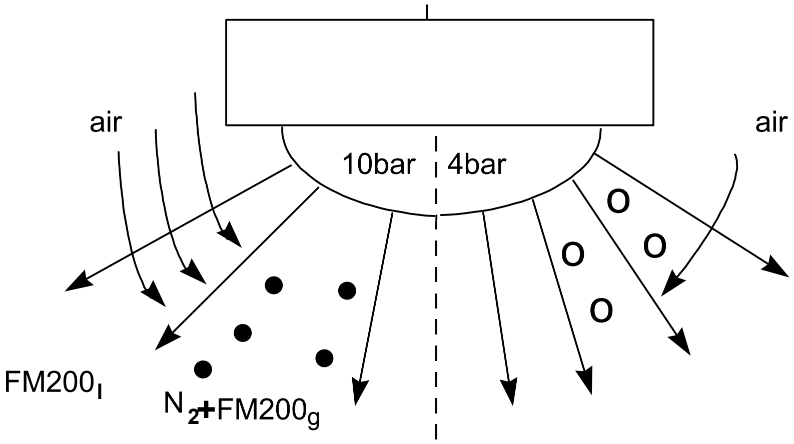


Fig. 3 Low and high pressure at the nozzle

The table *Tab. 2* shows a summary of the consequences of high or low pressure at the nozzle.

| **Criteria** | **High Pressure (> 10 bar)** | **Low Pressure (< 5 bar)** |
|---|---|---|
| *FM200*™ droplet size | Small (< 750 μm) | Large (> 1000 μm) |
| Droplet transport distance | < 1.5 m | > 4 to5 m |
| Total evaporation | During discharge | Delayed after discharge |
| Perfect homogenization | During discharge | Delayed after discharge |
| Design concentration | Continuously built up during discharge and reached after release of *FM200*™ into the protected volume | Reached after delay after *FM200*™ is fully evaporated and homogenised in the protected volume |
| Concentration of toxic decomposition products | Negligible after Extinguishing | Might affect personnel or installed equipment |

Tab. 2 Consequences of high or low pressure at the nozzle

Finally, a special nozzle design is supporting the homogenization of *FM200*™ in the extinguishing sector. Due to the spherical design of the high pressure nozzle *FM200*™ is discharged in an angle of 50° to the nozzle axis leading to a wide jet conic surface area perfectly designed for a large entrainment of air into the gas jet.

The maximum distance between to nozzles is determined by the jet working distance in order to guarantee that there is an interaction between two neighboured spray surface areas leading to a perfect mixing effect.

If perfect homogenisation is required as a key target too large nozzle areas are not making sense from a technical point of view.

# 6 The advantage of a high pressure system for engineering

While nitrogen located at the top of the FM200™ bottle is mainly used to fill the pipe network with FM200™, the dissolved nitrogen which entrains during discharge out of liquid FM200™ is responsible for maintaining a certain working pressure in the pipe network to guarantee the distribution of FM200™ at the nozzle.

According to Henry's Law the solubility of nitrogen in liquid FM200™ is in proportion to pressure. Therefore at 25 bar, 10g of nitrogen are dissolved in one kg of liquid FM200™ while at 42 bar, 17g per kg are dissolved.

It is obvious that the high pressure philosophy of SBT FIS gives rise to increased availability of propellant compared to a low pressure system. Apart from less dissolved nitrogen, more propellant is stored above the liquid level of FM200™ in the bottle because of increased gas density.

i Irrespective of the size of the system, the centralised high pressure system can always be realised with higher filling factors than a corresponding low pressure system which can be proven with our calculation software.

If an FM200™ system cannot be realized with maximum filling factors, the ratio between the volume of FM200™ stored per bottle decreases leading to an increase in the hardware required and to an increase in system costs.

For this reason the high pressure system has a cost advantage over the FM200™ low pressure systems.

While a high pressure system can be realized with average filling factors of 0.9, the filling factor for a centralised low pressure systems is only 0.6.

# 7 Replacement of Halon 1301 as a special application

The replacement of Halon 1301 by *FM200*™ has become one of the most important applications for *FM200*™. Among the group of HFCs, *FM200*™ is today the chemical alternative whose performance is closest to Halon 1301 requiring less than twice the weight and storage space of Halon 1301. Most of the installed Halon 1301 systems are low pressure systems.

High pressure systems have another advantage over low pressure systems. Due to increased working pressure, smaller pipe diameters are needed. Therefore in most cases the existing Halon 1301 pipe network can be used for the *FM200*™ system though more *FM200*™ is needed for Halon replacement. The pipe dimensions of such a system are big enough to compensate for the increased mass flux of *FM200*™. The only part of the piping that must be changed are the nozzles which have a different design to those for Halon 1301. In special cases even the existing Halon bottles can be re-used and only the valves and a few additional bottles must be added.

If the Halon system to be replaced is a high pressure system, only some additional pipes and new nozzles need be added to the existing pipe network.

# 8 Approvals

- VdS Schadenverhütung GmbH system approval
- Hong Kong FSD
- LPC component listing pending
- national approvals in Europe and Asia/Pacific

# 9 Appendix: Corporate guidelines for the design concentration

**Standard applications**

Standard applications are room protection for class A and B fires and fires of plastic and electronic equipment (electronic risks). As long as no special national guidelines are available, the Product Line Extinguishing & ASD at FIS-HQ recommends as a corporate policy to install and design the Cerberus®FM200 systems according to ISO 14520. The ISO meeting in 2002 agreed on the following values to be integrated into the first revision of ISO 14520 standard:

| **Fire class / risk** | Class A [Vol.% FM200] | Electronic Risks [Vol.% FM200] | Class B (n-heptane) [Vol.% FM200] |
|---|---|---|---|
| Design Concentration | 7.5 | 8.5 | 9.0 |

The new NFPA 2001 standard on clean agent fire extinguishing systems gives the following new design concentrations for nitrogen and argon:

| **Fire class / risk** | Class A [Vol.% FM200] | Electronic Risks [Vol.% FM200] | Class B (n-heptane) [Vol.% FM200] |
|---|---|---|---|
| Design Concentration | 7.0 | 7.0 | 9.0 |

Deep seated fires are regarded as class A fires (both, ISO and NFPA standard). However, it is strongly recommended to use FM200 for class A fires and electronic and other risks if deep seated fires or remaining hot surfaces can be excluded.

Siemens Building Technologies AG
Alte Landstr. 411
CH-8708 Männedorf
Tel. +41 1 - 922 6111
Fax +41 1 - 922 6450
www.sibt.com