



THE ROLE OF HYDROFLUOROCARBONS IN GLOBAL FIRE PROTECTION: AN UPDATE

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ABSTRACT

From their introduction in the early 1990s to present day, hydrofluorocarbon (HFC) clean extinguishing agents have retained their status as the most widely employed halon replacements, protecting billions of dollars worth of assets worldwide. This update to the original paper from 2009 compares the properties of HFC-based clean agents with those of inert gas and perfluoroketone clean agents, including fire suppression performance and efficiency, and environmental, toxicological, and physical properties. HFC clean agents provide the best overall combination of properties desired in a clean agent, and, as a result, remain the most widely used clean agents for the protection of critical assets.

INTRODUCTION

This paper reviews the development of replacements for the widely employed fire extinguishing agents Halon 1301 and Halon 1211. For more than 30 years, Halon 1301 and Halon 1211 served as ideal clean fire extinguishing agents. Due to their unique combination of properties, halon systems provided protection of valuable and sensitive assets for a wide range of applications, including the protection of computer rooms, control rooms, electronic data processing facilities, museums, military installations and equipment, and oil and gas industry applications. However, because of their implication in the destruction of stratospheric ozone, the production and use of halons has been severely restricted since the early 1990s. As a result, intensive research efforts were undertaken in the industrial,

academic, and governmental sectors with the goal of developing halon replacements. This paper reviews these efforts, and details the development and properties of HFC clean agents, the most widely employed halon replacements worldwide.

HISTORIC[1]

Halogenated compounds have been employed as fire extinguishing agents since the early 1900s, when hand-held extinguishers containing carbon tetrachloride (CCl_4) were first introduced. In the late 1920s, methyl bromide (CH_3Br) was found to be more effective than carbon tetrachloride, and was widely used as a fire extinguishing agent by the British in the late 1930s for aircraft protection and by the German military during World War II in aircraft and marine applications. Fire extinguishing systems employing bromochloromethane (CH_2BrCl) were also developed in the late 1930s and were utilized by the German Luftwaffe. Bromochloromethane was evaluated by the United States military during the late 1930s to the late 1940s and was eventually employed by the U.S. Air Force for fire protection.

Although extremely effective as fire extinguishing agents, the relatively high toxicities of methyl bromide and bromochloromethane prompted the U.S. Army to initiate a research program to develop an extinguishing agent that retained the high effectiveness of these agents, but was less toxic. Army-sponsored research at Purdue University in the late 1940s evaluated over sixty candidate agents, most of

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which were halogenated hydrocarbons, for both fire extinguishing effectiveness and toxicity. As a result of these studies, four agents were selected for further evaluation: bromotrifluoromethane (CF_3Br , Halon 1301), bromochlorodifluoromethane (CF_2BrCl , Halon 1211), dibromodifluoromethane (CF_2Br_2 , Halon 1202), and 1,2-dibromotetrafluoroethane ($\text{BrCF}_2\text{CF}_2\text{Br}$, Halon 2402). Further testing and development led to the widespread use of Halon 1301 in total flooding and small portable applications, and the use of Halon 1211 in streaming applications (hand-held and wheeled portables, and local applications).

Halons 1301 and 1211 are characterized by high fire suppression efficiency, low chemical reactivity, low toxicity, low electrical conductivity, long-term storage stability, and do not leave a residue following extinguishment. Because these agents produce no corrosive or abrasive residues upon discharge, they are ideally suited for the protection of areas containing sensitive or valuable assets – such as libraries and museums – where the use of water, foam, or solid extinguishing agents could cause secondary damage equal to or exceeding that caused by direct fire damage. Because they are electrically non-conducting, they can be employed to protect electrical and electronic equipment, and their low toxicity allows use in areas where the egress of personnel may be undesirable or impossible.

The unique properties of halons allowed them to serve as near ideal fire suppression agents during the past 30 years. However, due to their implication in the destruction of stratospheric ozone, the Montreal Protocol of 1987 identified Halon 1301 and Halon 1211 as two of a number of halogenated agents requiring limitations of use and production. An amendment to the original Montreal Protocol resulted in halting the production of Halon 1301 and Halon 1211 on January 1, 1994.

HALON REPLACEMENTS

The ideal halon replacement, in addition to possessing the desirable characteristics of halons, is also required to have a much lessened environmental impact. The ideal halon replacement would, therefore, be characterized by the following properties:

- Clean (no residues)
- High fire extinguishment efficiency on a mass basis
- Low chemical reactivity
- Long-term storage stability
- Noncorrosive to metals
- High material compatibility (metals, plastics)
- Not reactive in the human body
- Electrically non-conducting
- Low toxicity
- Zero ozone depletion potential (ODP)
- Zero global warming potential (GWP)
- Reasonable manufacturing cost

It should be noted that, to date, no halon replacement agent has been developed that meets all of the above requirements for an ideal replacement agent. Initial efforts seeking to develop viable halon replacements included the investigation of several classes of compounds later eliminated as halon replacement candidates[1]. Hydrobromofluorocarbons (HBFCs) and brominated olefins proved to be very effective fire extinguishing agents, but were eliminated from further consideration due to their non-zero ODPs and relatively high toxicity. Perfluorocarbons (PFCs) are toxicologically inert and effective fire extinguishing agents, but have been banned in fire extinguishing applications due to their extremely high atmospheric lifetimes and permanent effect on global warming. Iodine-containing compounds, especially iodotrifluoromethane, CF_3I , are extremely efficient fire extinguishing agents, but are also characterized by high toxicity, non-zero ODP and prohibitive manufacturing costs.

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Four classes of compounds were ultimately commercialized as halon replacements: hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), inert gases, and a perfluorinated ketone (see Table 1). Due to their non-zero ODPs and contribution to stratospheric ozone depletion, HCFC agents are subject to the provisions of the Montreal Protocol and are either already banned or subject to phaseout, depending upon local regulations.

CLEANLINESS

A key characteristic of halon agents was their “clean” nature – following fire extinguishment, no corrosive or abrasive residues are left on assets or equipment. Traditional extinguishing agents, such as water, foam, and dry powder, leave a residue following extinguishment. In many cases, secondary damage due to the extinguishing agent can exceed the damage to assets and equipment caused by the

fire itself; for example, in the case of libraries or museums, where books, papers, and other sensitive assets are subject to damage caused by these non-clean agents.

A further advantage of leaving no residues behind is that there is no need for cleanup following clean agent use. This allows for business continuity, i.e., no interruption of the services a business supplies following clean agent system discharge. The financial impact of service disruptions can be significant, particularly in telecommunications facilities and data processing centers. Table 2 shows the estimated downtime impact per hour for various industries. The average cost per minute of downtime in data centers is \$7908[2], and downtime impacts for companies relying entirely on telecommunications technology, such as online brokerages or e-commerce sites, can often reach \$1 million per hour or more.

Table 1: Commercially Available Halon Replacements

	Designation	Chemical Formula	Trade Name	Manufacturer
HFCs	HFC-227ea	CF ₃ CHFCF ₃	FM-200®	DuPont
	HFC-125	CF ₃ CF ₂ H	FE-25™	DuPont
	HFC-23	CF ₃ H	FE-13™	DuPont
	HFC-236fa*	CF ₃ CH ₂ CF ₃	FE-36™	DuPont
HCFCs**	HCFC Blend A	CF ₂ HCl (82%) CF ₃ CHCl ₂ (4.75%) CF ₃ CHFCI (9.5%) d-limonene (3.75%)	NAF-S-III	Safety Hi-Tech
	HCFC Blend B*	CF ₃ CHCl ₂ , CF ₄ , Ar	Halotron I	American Pacific
Inert Gases	IG-541	N ₂ (52%) Ar (40%) CO ₂ (8%)	Inergen®	Ansul
	IG-55	N ₂ (50%), Ar (50%)	Argonite®	Ginge-Kerr
	IG-01	Ar	Argotec	Minimax
	IG-100	N ₂	NN100	Koatsu
Perfluorinated Ketones	FK-5-1-12	CF ₃ CF ₂ C(O)CF(CF ₃) ₂	Novec™ 1230	3M

*Streaming applications (Halon 1211 replacements)

**Subject to phaseout under the Montreal Protocol

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Table 2: Downtime Impact per Hour for Various Industries [3]

Industry	Cost per Hour
Brokerage Service	\$6,480,000
Energy	\$2,800,000
Telecommunications	\$2,000,000
Manufacturing	\$1,600,000
Retail	\$1,100,000
Health Care	\$636,000
Media	\$90,000

CLEAN AGENTS: EFFICIENCY AND COST-EFFECTIVENESS

Comparison of Inert Gas and Halocarbon-Based Clean Agents.

Clean agents can be separated into two classes based on their mechanism of extinguishment: inert gas agents (IGs) and halogenated agents (HFCs, HCFCs, and perfluoroketones). Inert gas agents extinguish fire via oxygen dilution, reducing the concentration of oxygen in an enclosure to the level where the combustion reaction rate is slowed to the point where the reaction can no longer sustain itself. The halogenated agents extinguish fire primarily via the removal of heat, i.e., the flame temperature is reduced to a temperature below that required for the maintenance of combustion. On a volumetric basis, heat removal is a much more efficient method of fire extinguishment compared to oxygen dilution. As a result, the extinguishing concentrations for the halogenated agents typically range from about 4-12% by volume, compared to the inert gas agents whose extinguishing concentrations range from approximately 40-70% by volume. Table 3 compares the efficiency of the HFC agent FM-200® with the inert gas Inergen®.

Table 3. Agent Quantity Required for Protection of a 100 m³ Enclosure

Agent	Class A Hazard		Class C Hazard	
	Agent required, % v/v	Agent required, kg	Agent required, % v/v	Agent required, kg
FM-200®	6.7	52.3	7.0	54.8
Inergen®	34.2	59.2	38.5	68.8

The higher volumetric requirements of inert gas agents, along with the differing physical properties of inert gases compared to halocarbon agents, has a significant impact on system design and cost. Inert gas agents cannot be compressed to the liquid state and, therefore, must be stored as high pressure gases. This, in turn, necessitates the use of high pressure storage cylinders and high pressure piping for inert gas systems, adding significant cost to inert gas suppression systems. The low volumetric efficiency of inert gas agents and their inability to be stored as liquids leads to the requirement of a large number of cylinders compared to other halon replacement systems. This, in turn, leads to the requirement for additional storage space and increased system footprint, adding further to the cost of systems.

In contrast to inert gas agents, halogenated agents can be stored as liquids, allowing for a much larger mass of agent to be stored in the same volume compared to inert gases. This significantly reduces the number of system cylinders required with these systems compared to inert gas systems. In addition, with the exception of FE-13™ (HFC-23), halocarbon agents can be stored in standard low pressure cylinders and employ standard piping. Due to the requirements of high pressure piping and containers, and the large number of storage containers associated with inert gas systems, system costs increase with system size much more rapidly for inert gas systems compared to halogenated systems.

HDD Damage. In addition to the substantial weight and volume penalties associated with inert gas agents, the high nozzle pressures employed with inert gas systems result in high sound levels during system discharge. Inert gas discharges are very loud (high dB levels) and very lengthy (60-120 sec) compared to the quieter and shorter (<10 sec) halocarbon system discharges, and acoustical damage to hard disk drives (HDDs) during inert gas discharges is well documented[4-6].

In contrast, with more than 20 years of in-field use, there is not a single documented report of acoustic damage to HDDs during a halocarbon clean agent discharge.

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Comparison of HFC and Perfluoroketone Clean Agents.

Novec™ 1230, unlike all other clean agents, is a high boiling liquid. As a result, it is characterized by increased risk of liquid discharge, low mass efficiency, and reduced nozzle area coverages compared to gaseous HFC clean agents such as FM-200®. Table 4 indicates the quantity of agent required for the protection of a 100 m³ IT facility and demonstrates that for the protection of an identical hazard, 25% more Novec™ 1230 by mass is required compared to FM-200®.

Table 4. Clean Agent Requirements: IT/Telco Facility Protection

Agent	Class C Design Conc., % v/v	kg Agent Required to Protect 100 m ³	Mass Efficiency
FM-200®	7.0	55	1.00
Novec™ 1230	4.7	69	1.25

per NFPA 2001 (2015)

Due to its high boiling point, uniform distribution of Novec™ 1230 throughout an enclosure is more difficult to achieve compared to the case of low boiling agents such as FM-200®; this is reflected in the relatively low nozzle area coverages provided by Novec™ 1230 systems. Table 5 compares the nozzle area coverages for one system manufacturer's product line and shows almost three times the nozzle area coverage is achievable with a gaseous HFC such as FM-200®.

Table 5. Clean Agent Nozzle Coverage Areas

Agent	Maximum Nozzle Coverage, length x width	Maximum Nozzle Coverage Area, m ²	Area Coverage Efficiency
FM-200®	19.5 m x 19.5 m	380	2.7
Novec™ 1230	11.9 m x 11.9 m	142	1.0

Decreased nozzle area coverage increases system cost due to the requirement of additional nozzles and piping; more complex system design further adds to the overall system cost. Table 6 compares the case of a 38 m x 38 m x 3 m IT facility. In addition to requiring 25% more Novec™ 1230 by mass, four times the number of nozzles are required for protection with Novec™ 1230.

Table 6. System Design Example: 38 m x 38 m x 3 m IT Facility

Agent	Design Conc., % v/v	kg Agent Required	Nozzles Required
FM-200®	7.0	2375	4
Novec™ 1230	4.7	2972	16

per NFPA 2001 (2015)

HALON REPLACEMENTS: CHEMICAL REACTIVITY

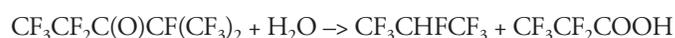
Halon 1301 and Halon 1211 are characterized by very low chemical reactivity, a property critical to the efficacy and safety of halon replacements. Chemical reactivity affects five major aspects of halon replacement systems:

- System performance
- Agent handling
- Safety in use/human exposure implications
- Agent cleanliness
- Environmental impact

Halons, HFCs, HCFCs, and inert gas agents are all characterized by very low chemical reactivity. In contrast, perfluoroketones exhibit very high chemical reactivity.

Chemical Reactivity and System Performance. Clean agent systems are often in place for 10 to 20 years and must remain leak-free throughout this period. Chemical reactions producing even small amounts of acidic or corrosive products are very undesirable, as even small amounts of such products can potentially lead to corrosion and eventual leakage of the extinguishing agent, compromising the effectiveness and safety of the extinguishing system.

Halons, HFCs, HCFCs, and inert gases do not react with water or with common industrial solvents. Perfluoroketones, however, are very chemically reactive and undergo reactions with many commonly encountered chemicals, such as water, alcohols, and amines. The reaction of the perfluoroketone Novec™ 1230 with water is well-documented[7-10]. Reaction of Novec™ 1230 with water produces 1,1,1,2,3,3,3-Heptafluoropropane (HFC-227ea, CF₃CHF₂CF₃) and Perfluoropropionic acid (F-Propionic acid, CF₃CF₂COOH):



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The reaction of Novec™ 1230 with water has two major implications with regard to system effectiveness. First, system effectiveness can be affected by the loss of extinguishing agent resulting from a chemical reaction; any amount of agent undergoing chemical reaction is not available for extinguishment. Indeed, Novec™ 1230 design manuals advise that “contact with water or solvents, either polar or hydrocarbon, could render Novec™ 1230 ineffective” and indicate that during transfer operations “a drier is required because humid air may cause the agent to convert to acid”[7].

Secondly, the production of corrosive compounds due to chemical reaction can lead to corrosion of the system cylinders and leakage of agent. As indicated above, the reaction of Novec™ 1230 with water produces F-Propionic acid[7-10]. F-Propionic acid is a highly toxic and corrosive acid[11]. It belongs to the class of perfluorocarboxylic acids (PFCAs), which are among the strongest acids known. F-Propionic acid attacks steel to produce the corresponding iron salt; the formation of this salt in Novec™ 1230 cylinders exhibiting signs of corrosion has been verified[12]. F-Propionic acid is also toxic, and is reported to cause eye and skin burns, damage to the digestive tract, and gastrointestinal burns[11]. PFCAs as a class are known tumor promoters, causing damage to the liver[13].

Chemical Reactivity and Agent Handling. Halons, HFCs, HCFCs, and inert gases do not react with water, and no special procedures are required when handling these agents to avoid the introduction of water. Perfluoroketones such as Novec™ 1230, in contrast, are known to undergo reaction with water and require special procedures during handling to avoid the introduction of moist air into the product. As a result, Novec™ 1230 design manuals prescribe special handling procedures, such as the use of vent driers and nitrogen purges to prevent contact of perfluoroketone with moist air[7, 9].

Chemical Reactivity and Safety in Use. The ideal halon replacement does not react within the human body, i.e., the ideal halon replacement is not metabolized. HFC and inert gas clean agents are not metabolized within the human body and do not react with water. Perfluoroketones, in contrast, undergo reaction with water, and

Novec™ 1230 is hydrolyzed when it crosses the lung-air interface to produce HFC-227ea and F-Propionic acid[8].

Chemical Reactivity and Cleanliness. Chemical reactivity is also undesirable, due to potential implications related to the cleanliness of the extinguishing system. Chemical reaction of the extinguishing agent with enclosure contents runs counter to the purpose of a “clean” extinguishing system. Halons, HFCs, and inert gas agents are chemically unreactive and, hence, do not pose a threat to protected assets. Due to their high chemical reactivity, perfluoroketones can undergo reaction with certain materials. Figure 1 shows the results of the discharge of Novec™ 1230 in an enclosure lined with U-PVC/acrylic cladding, where one can see the staining of the cladding due to chemical reaction; identical exposure to HFC or inert gas agents does not produce any effects on the cladding.



Figure 1. Novec™ 1230 Discharge onto U-PVC/ Acrylic Cladding

ENVIRONMENTAL IMPACT OF THE HFC-BASED CLEAN AGENTS: THE SCIENTIFIC FACTS

No other issue related to clean agents is more misunderstood or misrepresented than the environmental impact of HFC clean agents. Factual information regarding their environmental impact is available from numerous sources, and, as discussed below, recent international regulatory decisions regarding HFC-based clean agents confirm their negligible environmental impact and long-term sustainability.

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Ozone Depletion. Because HFCs do not contain chlorine or bromine, they do not contribute to the destruction of stratospheric ozone. As a result, HFCs are not subject to the provisions of the Montreal Protocol, which pertains only to ozone depleting substances (ODSs).

Global Warming. The impact on global warming/climate change of HFCs in fire protection is often misunderstood and misrepresented. A key misconception is that the emissions of HFCs in fire protection applications have a significant impact on climate change, due to the GWP values of the agents.

It is important to understand that the impact of a gas on climate change is a function of both the GWP of the gas and the amount of gas emitted. For example, carbon dioxide (CO₂) has one of the lowest GWP values of all GHGs (GWP=1), yet emissions of CO₂ account for approximately 85% of the impact of all GHG emissions – due to the massive amounts of CO₂ released into the

atmosphere from numerous sources, including energy production, automobile use, and the CO₂ emitted when humans exhale. **Clearly, the GWP value by itself cannot be employed to evaluate the environmental sustainability of a particular compound.** Emissions of HFCs from fire suppression applications are extremely low; hence, the impact of these emissions on climate change is negligible.

Factual information related to the environmental impact of HFCs in fire protection is available from several independent sources including the U.S. EPA and the European Environment Agency (EEA), and indicate that the contribution to global warming of HFCs in fire protection is negligible[14, 15]. For example, in the U.S., the impact on global warming of HFCs in fire protection represents 0.015% of the impact of all greenhouse gases on global warming. For the EU-15 countries, the impact on global warming of HFCs in fire protection represents 0.05% of the impact of all greenhouse gases on global warming. Figure 2 summarizes the U.S. EPA and EEA data.

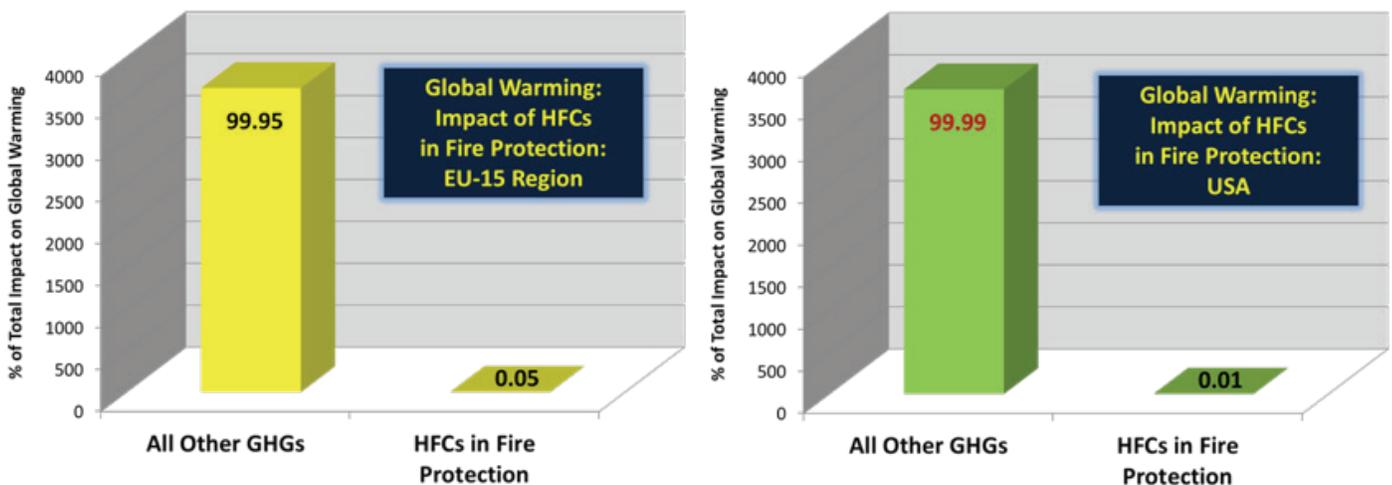


Figure 2. Impact of HFCs in Fire Protection on Global Warming

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Two recent major regulatory decisions in the USA and Europe have established the sustainability of HFCs in fire protection.

On July 9, 2014, the U.S. EPA announced proposed rules that would change the status under the Significant New Alternatives Policy (SNAP) Program of certain HFCs in mobile, stationary, foam, and aerosol applications. Consistent with its science-based pragmatic approach of controlling HFC use by application, the U.S. EPA is proposing no SNAP changes to any HFCs when used in a fire protection application. This means HFC-based clean agents continue to be sustainable fire protection solutions. In addition, no alternatives are currently available that match the overall combination of proven performance, safety in use, and cost-effectiveness offered by HFC clean agents.

On May 20, 2014, the European “F-Gas II Regulation” (Regulation [EU] No. 517/2014) was published. Consistent with the U.S. EPA proposed ruling, the EU F-Gas II Regulation also recognizes the value and sustainability of HFC clean agent fire protection technologies. Because HFCs in fire protection have a negligible impact on global warming, restricting HFC use in fire protection applications would not provide any significant reduction in global warming. For this reason, the F-Gas II Regulation does not call for specific restrictions on HFCs most widely employed in fire protection (HFC-227ea, HFC-125, HFC-236fa). For a detailed review of the EU F-Gas II Regulation and its impact on HFC clean agents, see Reference 16.

The recent regulatory decisions of the U.S. EPA and the EEA are based on sound science – recognizing the value, importance, and non-emissivity of HFC clean agents in fire protection. As regulators outside of the USA or the EU are empowered with the facts, they too are likely to reach similar conclusions: the environmental impact of HFCs in fire protection is negligible, and HFCs in fire protection will remain sustainable fire protection choices for the foreseeable future.

CLEAN AGENTS: TOXICOLOGY

Inert gas toxicity is due primarily to asphyxiation (low oxygen level) at elevated inert gas concentrations, i.e., at inert gas concentrations exceeding approximately 43% v/v. The toxicological properties of FM-200® and Novec™ 1230 are compared in Table 7, which shows that FM-200® exhibits lower toxicity based on several toxicological standards. FM-200® is characterized by extremely low acute and chronic toxicity, and has been approved by the U.S. Food and Drug Administration for use as a propellant in metered dose inhalers. In this application, FM-200® is used to propel a medicament down the patient’s throat and directly into their lungs.

Table 7. Clean Agents: Overall Comparison

	FM-200®	Novec™ 1230
4h LC ₅₀ , ppm	>800,000	>10,000
CS NOAEL	9.0 %	10.0 %
CS LOAEL	10.5 %	> 10.0 %
PBPK safe exposure level	10.5 %	Not available
28 day inhalation	NOAEL > 10.5%	LOAEL = 0.0997% ^a
AEL (allowable exposure level)	1000 ppm	150 ppm
Metabolism	-	F-Propionic acid

FM-200® exhibits lower toxicity in: 4h LC₅₀, CS LOAEL, PBPK, 28 day inhalation, AEL and metabolism tests

^a Peroxisome proliferation in liver; Increased lung and liver weights

The above discussions have compared the properties of commercially available halon replacements with respect to five critical characteristics: fire extinguishment efficiency, cleanliness, chemical reactivity, environmental properties, and toxicological properties.

Table 8 provides a summary comparison of halon replacements in terms of the desired properties of an ideal halon replacement. As seen from Table 8, no agent satisfies all of the requirements of an ideal halon replacement; however, one can see from the table that HFCs represent the best overall combination of the desired properties. Halons and HCFCs both meet a large portion of the

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desired requirements, but are (in the case of halons), or will be (in the case of HCFCs), phased out due to their non-zero ODPs. Table 8 shows that the agent class offering the second best combination of desired properties are inert gases. As discussed in the next section, this is exactly how the clean agent market has developed worldwide – HFCs are the most widely employed halon replacements, followed by inert gas agents.

HALON REPLACEMENTS: MARKET AND APPLICATIONS

Figure 3 shows the breakdown of the global clean agent market by agent type. HFC systems dominate the global clean agent market, accounting for approximately 70% of all installed clean agent systems; inert gas systems account for approximately 20% of the total market, and other agents represent approximately 10% of the total installed clean agent systems.

Table 8: Overall Comparison of Halon Replacements

Ideal Halon Replacement	Halon 1301	HFCs	HCFCs	Inert Gases	F-ketones
Zero ODP		✓		✓	✓
High weight efficiency	✓	✓	✓		
Cleanliness	✓	✓	✓	✓	
Low Chemical Reactivity	✓	✓	✓	✓	
Electrically Non-conducting	✓	✓	✓	✓	✓
Low Toxicity		✓		✓	
Low metabolism	✓	✓	✓	✓	
Low Agent Cost	✓	✓	✓	✓	
Low System Cost	✓	✓	✓		
Ease of Gasification	✓	✓	✓	✓	
Low Storage volume	✓	✓	✓		✓
Low No. Cylinders	✓	✓	✓		✓
Low System footprint	✓	✓	✓		✓
Low Cylinder pressure rating	✓	✓	✓		✓
Low Manifold pressure rating	✓	✓	✓		✓
Slow Stratification	✓	✓	✓	✓	
Low Enclosure pressures	✓	✓	✓		✓
Zero GWP				✓	

Worldwide Clean Agent Market Number of Installed Systems

HFCs are the most widely employed
Halon 1301 alternatives

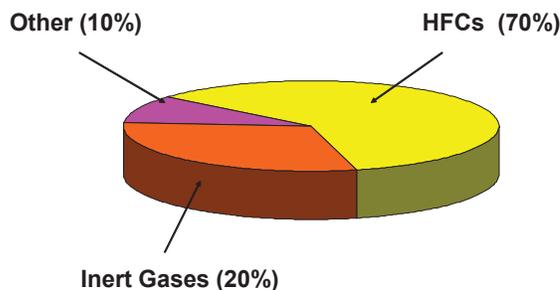


Figure 3. Worldwide Clean Agent Market

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Applications of HFC clean agents include the classic Halon 1301 applications: telecommunication facilities, computer rooms, data centers, museums, libraries, hospitals, medical facilities and equipment, clean rooms, engine compartments, engine nacelles, petrochemical facilities, grain elevators, oil rig platforms, floating roof tanks, and aircraft.

Table 9 lists a number of facilities worldwide that employ HFC clean agent systems, and Figure 4 lists a selection of the numerous industry leaders that employ HFC clean agent systems. As seen from these tables, HFC clean agents have wide acceptance on a global basis.

Table 9. Select Applications of HFC Clean Agents

American Museum of Natural History
Smithsonian Institute
Library of Congress
Eiffel Tower
Alexandria Library, Egypt
National Museum of Prehistory, Taiwan
Field Museum, Chicago
Aristoles University Rare Book Collection, Greece
Royal Thai Silk Museum, Thailand
North American DEW Line Radar Installation
Dusseldorf Airport
San Francisco Airport
U.S. EPA Supercomputing Center
Caesar's Palace, Las Vegas
Harrah's Casino
MGM Casino
Cox Communications
F/A-18 E/F Aircraft
Abrams Tank
U.S. Navy Ground and Naval Vessels
Madrid Int'l Airport
Charles DeGaulle Airport
Newark Int'l Airport
New Bangkok Int'l Airport



Figure 4. Industry Leader Acceptance of HFC Clean Agents

CONCLUSION

HFC clean agents provide the best overall combination of properties desirable in a clean agent replacement for halons: high effectiveness, cleanliness, low chemical reactivity, low toxicity, negligible environmental impact, and competitive system cost. As a result, HFCs are the most widely employed halon replacements worldwide, and these systems currently protect billions of dollars worth of assets in more than 70 countries. HFC clean agent technology is a mature technology, having provided protection of valuable assets for over 20 years with an excellent performance and safety record.

The recent regulatory decisions of the U.S. EPA and the EEA acknowledge the negligible impact of HFCs in fire protection on global warming and confirm that HFC-based clean agents will remain sustainable fire protection choices for the foreseeable future.



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