CLEAN AGENT FIRE EXTINGUISHING SYSTEMS

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1.0 SCOPE

This data sheet provides general information on clean agent fire extinguishing systems including guidelines for their design, installation, testing and maintenance. FM Global Property Loss Prevention Data Sheet 4-0, *Special Protection Systems,* also applies to clean agent fire extinguishing systems. See Appendix C for a listing and description, including physical properties data, for the specific clean agent extinguishants covered by this document which presently includes halocarbons and inert gases.

More detailed explanatory information on clean agent fire extinguishing systems including toxicity data and safety considerations, fire test data, fire testing protocols and enclosure integrity testing procedures is provided in NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems, 2000 Edition* and ISO 14520-1:2000, *Gaseous fire-extinguishing systems: Physical properties and system design:* Part 1: *General requirements* (other Parts covering specific agents are included under Section 4.0 REFERENCES).

Clean agent fire extinguishing systems are currently recognized for total flooding applications only. Clean agents are primarily suited for such applications given their physical properties, particularly the inert gas clean agents which are stored as compressed gases. Also, there are no established local application design criteria for clean agent extinguishing systems as exists for carbon dioxide extinguishing systems which were established through extensive testing. Carbon dioxide extinguishing systems are covered by FM Global Loss Prevention Data Sheet 4-11N.

1.1 Changes

October 2015. Interim Revision. Added references to tables in NFPA 201, *Standard on Clean Agent Fire Extinguishing Systems*, that provide the quantity of clean agent needed to archieve design concentration (Section 2.1.3.2 and Appendix C).

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Equipment and Processes

2.1.1 Plans and Specifications

2.1.1.1 Let contracts for new installations or changes in existing systems subject to FM Global's acceptance of plans, materials, and the completed installation.

2.1.1.2 Submit final plans and calculations of new or modified systems to FM Global for review and acceptance before installation is started.

2.1.1.3 Provide final plans to scale or fully dimensioned, with sufficient detail to define clearly both the hazard and proposed system. Clearly indicate the location and sizes of piping and nozzles and their supports together with the location of the extinguishing agent supply, fire-detecting units and all auxiliary equipment. Show dampers, doors and other features in any way related to the protection of the hazard. Submit a wiring diagram if fire detection or system operations are electric. Use Approved components for the application identified by part or model number.

2.1.1.4 Prepare new drawings and calculations representing the ″as-built″ installation if the final installation varies from the previously submitted ″final″ drawings and calculations.

2.1.2 Approval of Installations (Acceptance Testing)

2.1.2.1 Verify that the clean agent fire extinguishing system has been installed in accordance with the Approved/recognized applicable system manufacturer's installation guidelines. Check that all fittings and connections necessary for the actuation of the system, particularly for pilot cylinders and interconnected storage containers or multiple banks of storage containers, have been properly arranged, secured and tightened by the system installer.

2.1.2.2 Conduct an enclosure integrity procedure (i.e., door fan test) of the protected occupancy in accordance with Appendix C of NFPA 2001. An enclosure integrity procedure in accordance with Annex E of ISO 14520 is an acceptable alternative.

The enclosure integrity procedure outlines a method to equate enclosure leakage as determined by a door fan test procedure to worst-case clean agent leakage from the protected enclosure. The calculation method provided within the procedure makes it possible to conservatively predict/estimate the hold time for a desired

clean agent concentration at a specified height within the enclosure using the applicable design concentration/ agent quantity required per the guidelines of 2.1.3.

Request the contractor/installer provide certification of their training by the door fan test equipment manufacturer enabling them to properly conduct an enclosure integrity procedure in accordance with Appendix C of NFPA 2001 or Annex E of ISO 14520.

For inert gas clean agent system protected enclosures, the ELA (equivalent leakage area) determined from the door fan test may be considered as part of the recommended venting to prevent enclosure overpressurization per the system manufacturer's design guidelines.

2.1.2.3 Conduct complete system component functional tests in accordance with the applicable system manufacturer's design, installation, operation and maintenance manual.

2.1.2.4 Discharge test inert gas agent systems for final acceptance by FM Global. The design concentration should be achieved and maintained above the highest combustibles/equipment within the hazard enclosure per the guidelines of 2.1.3. Establish adequacy of venting for the hazard enclosure also.

2.1.2.5 Pneumatically test open-ended piping in a closed circuit for a period of 10 minutes at 40 psig (276 kPa). At the end of 10 minutes, the pressure drop should not exceed 20% of the test pressure. Hydrostatically test any closed-section piping to a minimum of 1.5 times the maximum working pressure for two minutes.

Note: Conduct pneumatic testing of open-ended piping prior to any planned clean agent fire extinguishing system discharge test.

2.1.2.6 Conduct a flow test using nitrogen or an inert gas on the piping network to verify that flow is continuous and that the piping and nozzles are unobstructed (i.e., a puff test). Refer to Recommendation 2.1.3.9.4 also to best assure this unobstructed flow condition.

Note: This puff test need not be conducted if the clean agent fire extinguishing system is discharge tested.

2.1.3 Installation and Design

2.1.3.1 System Design Concentrations

2.1.3.1.1 The minimum design concentration for a Class A surface fire hazard shall be the extinguishing concentration as determined by test during the system Approval evaluation times a safety factor of 1.2. Concentrations in the FM Approval Guide listings and Table 1 are the Design Concentrations, inclusive of this safety factor. Minimum design concentrations for Class C hazards shall be at least that for Class A surface fire hazards.

A 7% FM-200 (HFC-227ea) design concentration held for 10 minute is acceptable to FM Global for typical electrical/electronic equipment areas having little or no ordinary combustibles present.

A 12-14% oxygen concentration (approximately 33-43% inert gas concentration) held for 10 minutes is acceptable to FM Global for typical electrical/electronic equipment areas having little or no ordinary combustibles present.

An 18% FE-13 (HFC-23) design concentration held for 10 minutes is acceptable to FM Global for typical electrical/electronic equipment areas having little or no ordinary combustibles present.

2.1.3.1.2 The minimum design concentration for a Class B fuel (flammable liquid hazard) shall be the extinguishing concentration as determined by the cup burner test method per Appendix B of NFPA 2001 or Annex B of ISO 14520 times a safety factor of 1.3. Concentrations in the FM Approval Guide listings and Table 1 are the Design Concentrations, inclusive of this safety factor.

Have the clean agent system manufacturer provide the appropriate minimum design concentration verifying that the cup burner value used is in accordance with either of the above referenced test methods.

Table 1. Minimum Design Concentrations

Agent	*Class A Minimu Design Concentration, %*	*Class B Minimu Design Concentration, %*
FK-5-1-12	4.2	5.9
HFC-125	8.0	11.3
HFC-227ea	6.25 - 7.0	8.7
IG-541	34.2	42.0
IG-55	37.9	39.1

Note: Class B values are for n-Heptane.

2.1.3.2 Clean Agent Quantities

2.1.3.2.1 Determine the amount of halocarbon clean agent needed to achieve the design concentration using the following equation:

$$W = \frac{V}{S}\left(\frac{C}{100 - C}\right)$$

where:

W = weight of halocarbon clean agent [lb (kg)]

V = net volume of hazard, calculated as the gross volume minus the volume of fixed structures impervious to clean agent vapor [ft^3 (m^3)]

s = specific volume of the superheated halocarbon clean agent at 1 atmosphere and the temperature, *t [ft^3/lb (m^3/kg)]*

C = halocarbon clean agent design concentration [volume percent]

t = minimum anticipated temperature of the protected volume [^oF (^oC)]

Note: This equation includes an allowance for the normal leakage from a ″tight″ enclosure due to agent expansion.

Refer to Table A.5.5.1(a) though Table A.5.5.1(r) (NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2015 Edition) that also provide the weight of halocarbon clean agent needed per unit volume of enclosure to achieve the total flooding design concentration based on the above equation. These tables may be used for the applicable halocarbon clean agent rather than the referenced equation. Multiply the appropriate weight factor from the applicable table by the net enclosure volume to determine the required quantity of halocarbon clean agent.

2.1.3.2.2 Determine the amount of inert gas clean agent needed to achieve the design concentration using the following equation multiplying X by the net enclosure volume:

$$X = 2.303\left(\frac{V_s}{S}\right)\log_{10}\left(\frac{100}{100 - C}\right)$$

where:

X = volume of inert gas added at standard conditions of 14.7 psia, 70^oF (1.013 bars, 21^oC) per volume of hazard space [ft^3/ft^3 (m^3/m^3)]

V_s = specific volume of inert gas clean agent at 70^oF (21^oC) and 14.7 psia (1.013 bar)

s = specific volume of inert gas clean agent at 1 atmosphere and temperature, t [ft^3/lb (m^3/kg)]

t = minimum anticipated temperature of the protected volume [^oF (^oC)]

C = inert gas design concentration [volume percent]

Note: This equation includes an allowance for agent leakage from a ″tight″ enclosure.

Refer to Table A.5.5.2.(a) through Table A.5.5.2(h) in NFPA 2001 that provide the volume factor, X, (i.e., the volume of inert gas clean agent needed per unit volume of enclosure) to achieve the total flooding design concentration based on the above equation. These tables may be used for the applicable inert gas clean agent instead of the above referenced equation. Multiply the appropriate volume factor for the applicable inert gas clean agent by the net enclosure volume to determine the required total volume of inert gas.

2.1.3.3 System Discharge Time

2.1.3.3.1 Design halocarbon clean agent systems to achieve 95% of the minimum design concentration for flame extinguishment based on a 20% safety factor within a discharge time of 10 seconds.

2.1.3.3.2 Design inert gas agent systems to achieve 95% of the minimum design concentration for flame extinguishment based on a 20% safety factor within a discharge time of 60 seconds.

Note: The applicable system discharge time period limitation is considered during the FM Approvals evaluation of any clean agent fire extinguishing system. That is, the Approved/recognized physical system/equipment arrangement limitations for pre-engineered systems is based on meeting these recommended discharge times. For engineered systems, the Approved/recognized flow calculation program is constrained to satisfy these discharge time limitations or an error message will be given for the proposed system arrangement necessitating redesign. Pre-engineered and engineered systems are further defined/described in Appendix A.

2.1.3.4 Duration of Protection

2.1.3.4.1 Maintain the agent design concentration within the protected enclosure for a minimum of 10 minutes or longer where necessary to assure effective emergency response by trained personnel.

2.1.3.5 Detection and Actuation

2.1.3.5.1 Provide automatic detection and actuation for clean agent systems using Approved fire detection devices suitable for the protected hazard or occupancy. Refer to Data Sheet 5-48, *Automatic Fire Detectors*, and the appropriate FM Global occupancy data sheet, as applicable, for guidance on detector(s)/detection system(s) selection and arrangement.

2.1.3.5.2 Provide a power supply for electrical detection and release devices independent of the power supply for the hazard area. Where this is not practical, use pneumatic or mechanical devices or provide an emergency minimum 24-hour standby capacity, battery-powered supply with automatic switchover if the primary supply fails.

Where a clean agent fire extinguishing system is the sole or recommended protection for valuable and important occupancies, provide an alternate power supply for any electrically operated detection and actuation system. An emergency battery-powered supply, with automatic switchover if the primary supply fails, as required for an Approved control panel is an acceptable alternate power supply. Locate the electrical power supply so it is not exposed by the protected area.

2.1.3.5.3 Locate and protect wiring, cables and tubing to avoid mechanical damage. Install wiring and cables in conduit. Also locate tubing in vulnerable locations in conduit or equivalent. Conduit is not needed for short lengths of cables or tubing near detectors and controls. Do not install wiring or tubing used as detectors in conduit.

2.1.3.5.4 Where manual bypass switches are provided to prevent accidental discharge of a a clean agent fire extinguishing system especially during testing or servicing of the system; provide ‘‘keyed lock-out’’ devices located at the control panel. Arrange these devices so they do not disable the alarm circuit. Establish and follow written impairment procedures. Preferably, leave the key(s) under the control of a responsible management or fire protection person.

2.1.3.5.5 Provide a readily accessible normal manual and emergency manual means of operation, preferably mechanical, for clean agent fire extinguishing systems.

2.1.3.6 Operating Devices

2.1.3.6.1 Locate, install or suitably protect all operating devices so that they are not subject to mechanical, chemical, or other damage that would render them inoperative. Operating devices include all clean agent releasing devices or valves, discharge controls and equipment shutdowns/interlocks necessary for successful performance of the system.

Exception: Power interlocks, although preferred to minimize the potential for sustained ignition and agent decomposition (in the case of halocarbon clean agents), are not required for critical electronic equipment areas (e.g., computer rooms, process control rooms, telecommunication offices, etc.) where this will cause operating problems.

Abort switches though generally not recommended are acceptable to FM Global. Where provided, use abort switches that requires constant manual pressure to cause abort and located them within the protected area near the means of egress from the protected area. Where activation of more than one detector is necessary for system actuation, arrange the abort switch to prevent discharge only if operated before the second detector activates. In addition, operation of an abort switch should not recycle any time delays.

2.1.3.6.2 Identify all controls as to function, area controlled, and operating instructions.

2.1.3.7 Alarms and Supervisory Devices

2.1.3.7.1 Provide a pre-discharge alarm and time delay sufficient to allow personnel evacuation prior to discharge. Limit the time delay to 30 seconds maximum after the appropriate detection signal(s) for system actuation have been received.

System discharge can be startling and avoiding unnecessary exposure to extinguishants is desirable even when the design concentration is below the No Observed Adverse Effects Level (NOAEL).

2.1.3.7.2 When a clean agent system is is the sole or recommended protection for an important occupancy or equipment, supervise the detection devices and circuits through an Approved proprietary system or central station. Provide trouble alarms and discharge alarms distinctive from each other, to sound at a constantly attended location.

2.1.3.8 Supply of Extinguishing Agent

2.1.3.8.1 Provide an in-service supply of extinguishing agent adequate for at least the largest single hazard or group of hazards to be protected simultaneously.

2.1.3.8.2 Provide a reserve supply equivalent to the required in-service supply unless available from an outside source within 24 hours. Reserve supplies are necessary to permit prompt restoration of the system after a discharge, to minimize interruption of the process and the interval of impaired protection.

2.1.3.8.3 Where two or more hazards are protected by a single supply through selector valves, connect the reserve supply to the distribution piping. Provide a switchover arrangement to permit actuation by the normal means (e.g., a manually actuated main/reserve switch at the control panel).

2.1.3.8.4 Provide a connected reserve where the clean agent system is the sole protection for valuable and important occupancies unless protection can be fully restored within 24 hours, occupancies are constantly attended and written impairment procedures have been established.

2.1.3.8.5 Preferably locate agent storage containers outside the hazard area to minimize fire exposure and provide ready accessibility for actuation, inspection and maintenance. Storage containers may be located within the hazard area for low frequency/fire severity areas (e.g., computer or control rooms) provided the wiring from the control panel to the storage containers is mineral-insulated metal-sheathed cable, Type MI or at least 212°F (100°C) rated in conduit.

2.1.3.8.6 Locate or arrange agent storage containers such that storage temperatures are maintained within the system manufacturer's listed limits.

2.1.3.9 Piping

2.1.3.9.1 Provide system piping of noncombustible material having physical and chemical characteristics such that its integrity under stress can be predicted with reliability. Calculate the required piping wall thickness

in accordance with ASME B31.1, *Power Piping Code*, or other relevant national standard. Use a pressure for this calculation not less than the greater of either of the following values:

a) The normal charging pressure in the agent container at 70°F (21°C), or

b) Eighty percent of the maximum pressure in the agent container at the maximum storage temperature of not less than 130°F (54°C) using the equipment manufacturer's maximum allowable fill density, if applicable.

Exception: Flexible pipe, tubing or hose which is part of an Approved system.

2.1.3.9.2 Do not use cast iron pipe, steel pipe conforming to ASTM A-120, *Specification for Seamless Carbon Steel Pipe for High Temperature Service*, or nonmetallic pipe.

2.1.3.9.3 Provide special corrosion-resistant materials or coatings for piping located in corrosive environments. At a minimum, use galvanized piping, inside and out, where exposed to varying atmospheric conditions.

2.1.3.9.4 Avoid obstructions in piping from foreign materials or faulty fabrication. Ream and clean piping before assembly. After assembly, blow out the entire system before nozzles or discharge devices are installed.

2.1.3.10 Nozzles

2.1.3.10.1 Install nozzles within the hazard enclosure in compliance with their Approval limitations for the specific manufacturer's clean agent fire extinguishing system.

2.1.3.11 Piping Supports (Hangers)

2.1.3.11.1 Install pipe hangars in accordance with good piping practice. Space hangars in accordance with Table 2. Install a hangar between fittings when the fittings are more than 2 ft (0.6 m) apart. Install a hangar a maximum of 1 ft (0.3 m) from any nozzle located to prevent the nozzle from moving vertically.

Table 2. Recommended Hanger Spacing

Pipe Size in. NPT	*Maximum Spacing between Hangers ft(m)*
¼	4 (1.3)
½	6 (2.0)
¾	8 (2.6)
1	12 (3.9)
1-¼	12 (3.9)
1-½ and larger	15 (4.9)

2.1.4 Inspection, Testing, Maintenance and Training

2.1.4.1 Inspection and Testing

2.1.4.1.1 Conduct weekly system inspections to see that nozzles are clear and in proper position, that all operating controls are properly set, and that system components have not been damaged.

2.1.4.1.2 At least semiannually, check the agent quantity and pressure of clean agent containers. Refill or replace halocarbon clean agent containers if they show a loss in agent quantity of more than 5% or loss in pressure (adjusted for temperature) of more than 10%. Refill or replace inert gas clean agent containers if they show a loss in pressure (adjusted for temperature) of more than 5%.

2.1.4.1.3 At least annually, thoroughly inspect and test clean agent systems for proper operation exclusive of a discharge test. Inspect and test all actuating and operating devices in accordance with the system manufacturer's recommendations as outlined in the appropriate system design, installation, operation and maintenance manual. Regular service contracts with the system manufacturer's authorized representative are advised.

2.1.4.1.4 At least annually, thoroughly inspect the clean agent system protected enclosure determine if penetrations or other changes have occurred that could adversely affect agent leakage or change the volume

of the hazard or both. Correct any conditions discovered during the inspection that could result in inability to maintain the clean agent concentration. If uncertainty still exists with regard to the enclosure integrity, conduct an enclosure integrity test of the enclosure.

Note: It's recommended that a log/record be kept of all changes made to or within the protected enclosure to facilitate the inspection and maintenance of the enclosure integrity.

2.1.4.2 Maintenance

2.1.4.2.1 Maintain clean agent systems in operating condition at all times and restore to service promptly after any impairment or operation. Report any impairments to the local FM Global office so that appropriate precautionary guidance may be obtained. Follow procedures based on the use of the FM Global *Red Tag Permit System*.

2.1.4.2.2 Seal any penetrations made through the clean agent system protected enclosure immediately.

2.1.4.3 Training

2.1.4.3.1 Provide periodic training of plant personnel who may be called upon to inspect, test, maintain or actuate clean agent systems.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

Satisfactory performance of a clean agent fire extinguishing system can best be assured by following the loss prevention recommendations within this document.

4.0 REFERENCES

4.1 FM Global

Data Sheet 4-0, *Special Protection Systems.*
Data Sheet 4-11N, *Carbon Dioxide Extinguishing Systems.*
Data Sheet 5-48, *Automatic Fire Detectors.*

F&EC Engineering Form EMV 2332, *Contractor's Application for Acceptance of Gaseous Extinguishing System Installations*, 1/2000.

FM Global *Red Tag Permit System*.

4.2 NFPA Standards

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2000 Edition.

4.3 Others

ISO 14520-1:2000, *Gaseous fire-extinguishing systems – Physical properties and system design:*

- Part 1 General requirements.
- Part 2: CF_3I extinguishant.
- Part 3: FC-2-1-8 extinguishant.
- Part 4: FC-3-1-10 extinguishant.
- Part 6: HCFC Blend A extinguishant.
- Part 7: HCFC 124 extinguishant.
- Part 8: HFC 125 extinguishant.
- Part 9: HFC 227ea extinguishant.
- Part 10: HFC 23 extinguishant.
- Part 11: HFC 236fa extinguishant.
- Part 12: IG-01 extinguishant
- Part 13: IG-100 extinguishant.
- Part 14: IG-55 extinguishant.
- Part 15: IG-541 extinguishant.

ANSI B31.1, *Power Piping Code.*

ASTM A-120, *Specification for Seamless Carbon Steel Pipe for High Temperature Service.*

Fire Safety Technology web site (www.firesafetytech.com)

Fire Suppression Systems Association web site (www.fssa.net)

Infiltec Inc. web site (www.infiltec.com)

Retrotec Inc. web site (www.retrotec.com)

APPENDIX A GLOSSARY OF TERMS

Approved: References to ‘‘Approved’’ in this data sheet means the product and services have satisfied the criteria for FM Approval. Refer to the *Approval Guide*, a publication of FM Approvals, for a complete listing of products and services that are FM Approved.

Clean Agent: Electrically nonconducting, volatile or gaseous fire extinguishant that does not leave a residue upon evaporation.

Engineered System: A system requiring individual calculation and design to determine the flow rates, nozzle pressures, pipe size, area or volume protected by each nozzle, quantity of agent, and the number and type of nozzles and their placement in a specific system.

An engineered system is a designed/flow-calculated system which normally involves the use of a proprietary flow calculation program. The flow calculation program is evaluated/verified through testing as part of the FM Approval process for each fire equipment manufacturer’s system. Typically, an engineered system allows for unbalanced piping arrangements, commonly up to 90-10 or 10-90 flow splits.

Fill Density: Mass of agent per unit of container volume, lb/ft^3 (kg/m^3).

Halocarbon Agent: An agent that contains as primary components one or more organic compounds containing one or more of the elements flourine, chlorine, bromine, or iodine.

Inert Gas Agent: An agent that contains as primary components one or more of the gases helium, neon, argon, or nitrogen. Inert gas agents that are blends of gases can also contain carbon dioxide as a secondary component.

Lowest Observed Adverse Effect Level (LOAEL): The lowest agent concentration at which an adverse physiological or toxicological effect has been observed.

No Observed Adverse Effect Level (NOAEL): The highest agent concentration at which no adverse physiological or toxicological effect has been observed.

Pre-engineered System: A system having predetermined flow rates, nozzle pressures and quantities of agent. These systems have the specific pipe size, maximum and minimum pipe lengths, flexible hose specifications, number of fittings, and number and types of nozzles prescribed by a testing laboratory such as FM Approvals.

A pre-engineered system simply means the system is limited to very specific combinations of pipe sizes and lengths including the total number of tees (flow splits), elbows and nozzles and does not involve flow calculations. Typically, pre-engineered systems are restricted to balanced piping configurations (i.e., 50-50 flow splits).

Safety Factor: A multiplier of the agent flame extinguishing or inerting concentration to determine the agent minimum design concentration.

APPENDIX B DOCUMENT REVISION HISTORY

October 2015. Interim Revision. Added references to tables in NFPA 201, *Standard on Clean Agent Fire Extinguishing Systems*, that provide the quantity of clean agent needed to archieve design concentration (Section 2.1.3.2 and Appendix C).

September 2010. Minor editorial changes were made for this revision.

May 2010. Added information to Section 2.1.3.1, System Design Concentrations.

January 2002. First published.

APPENDIX C ADDITIONAL INFORMATION

C.1 General

Clean agents are gaseous fire extinguishing agents which leave no residue. Clean agents are frequently referred to as halon alternatives since they are primarily intended for applications previously covered by the halons which are no longer produced, particularly Halon 1301 and Halon 1211. Clean agent fire extinguishing systems covered by this document use total flooding clean agents primarily intended for applications previously covered by Halon 1301 systems. Clean agents referred to as streaming agents are primarily intended for applications previously covered by Halon 1211, particularly its use within portable extinguishers.

Clean agent fire extinguishing systems are either liquefied halocarbon gas or inert gas types for total flooding application only. See Table 3 for a list of currently recognized clean agents within NFPA 2001 all of which are also addressed within ISO 14520. The clean agents recognized within NFPA 2001 have been evaluated and accepted as total flooding halon alternative agents by the U.S. Environmental Protection Agency under their Significant New Alternatives Policy (SNAP) program.

Table 3. Currently Recognized Clean Agents within NFPA 2001/ISO 14520

Agent/Extinguishant	*Chemical Name*	*Trade Name*
Halocarbons		
FC-2-1-8	Perfluoropropane	CEA-308
FC-3-1-10	Perfluorobutane	CEA-410
FIC-13I1	Trifluoroiodomethane	Triodide
HCFC Blend A		
HCFC-123	Dichlorotrifluoroethane (4.75)	NAF S-III
HCFC-22	Chlorodifluoromethane (82)	
HCFC-124	Chlorotetrafluoroethane (9.5)	
	Isopropenyl-1-methylcyclohexene (3.75)	
HCFC-124	Chlorotetrafluoroethane	FE-241
HFC-23	Trifluoromethane	FE-13
HFC-125	Pentafluoroethane	FE-25
HFC-227ea	Heptafluoropropane	FM-200, FE-227
HFC-236fa	Hexafluoropropane	FE-36
Inert Gases		
IG-01	Argon	Argotec
IG-100	Nitrogen	
IG-55	Nitrogen (50), Argon (50)	Argonite
IG-541	Nitrogen (52), Argon (42), Carbon Dioxide (8)	Inergen

HCFC Blend A constituents are listed in percent by weight.
Inert gas constituents are listed in percent by volume.

Personnel Safety

Halocarbon clean agents are potentially cardiotoxic while inert gas clean agents can present phsiological effects associated with a hypoxic (i.e., low oxygen) atmosphere. The experimentally determined No Observed Adverse Effects Level (NOAEL) and Lowest Observed Adverse Effects Level (LOAEL) values, which are defined in Appendix A, are given in Table 4 for the halocarbon agents. The corresponding NOAEL and LOAEL values for the inert gas agents have been set at 12% oxygen (43% inert gas concentration) and 10% oxygen (52% inert gas concentration) respectively. Inert gas mixture concentrations (e.g., Inergen) can only be determined indirectly by measuring the oxygen concentration within an enclosure.

The clean agent system design extinguishing concentration ideally should be less than the NOAEL for the specific clean agent for occupiable areas. However, system design concentrations in accordance with Section 1-6 of the the 2000 Edition of NFPA 2001, if acceptable to the governing health and safety authority, are acceptable to FM Global.

Table 4. Reported NOAEL/LOAEL Values for Halocarbon Agents

Agent/Extinguishant	*NOAEL ()*	*LOAEL ()*
FC-2-1-8	30	>30
FC-3-1-10	40	>40
FIC-13I1	0.2	0.4
HCFC Blend A	10	>10
HCFC-124	1.0	2.5
HFC-23	50	>50
HFC-125	7.5	10
HFC-227ea	9.0	10.5
HFC-236fa	10	15

Refer to Table A.1.4.1(a) through Table A.1.4.1(d) in NFPA 2001, *Standard on Clean Agent Fire Extinguishing Sytems,* for physical properties data for the halocarbon and inert gas type clean agents.

APPENDIX D BIBLIOGRAPHY

Gaseous Fire Extinguishing Systems using Inert Agents: Guidance for Insurers, LPR 9, Loss Prevention Council, 1998.

Gaseous Fire Extinguishing Systems using Halocarbon Agents: Guidance for Insurers, LPR 10, Loss Prevention Council, 1998.

Gaseous Fire Protection Systems - *Guidance for the Use of Insurers, System Suppliers and their Mutual Clients on the Specification, Installation and On-going Maintenance of Gaseous Fixed Fire Extinguishing Systems,* LPR 16, Loss Prevention Council, 2000.

*"Direct Halon Replacement Agents and Systems",*Fire Protection Handbook, 18th Edition, National Fire Protection Association, Quincy, MA, 1997.

National Fire Protection Association, NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*