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HALOCARBON AND INERT GAS (CLEAN AGENT) FIRE EXTINGUISHING SYSTEMS

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1.0 SCOPE

This data sheet provides general information on inert gas and halocarbon (i.e., clean agent) fire extinguishing systems, including guidelines for their design, installation, testing, and maintenance. Information on clean agent systems is also located in Data Sheet 4-0, *Special Protection Systems*.

The guidance in this data sheet is limited to total flooding applications only. Halocarbon and inert gas agents are primarily suited for such applications given their physical properties, particularly the inert gas clean agents that are stored as compressed gases. Carbon dioxide extinguishing systems are covered in Data Sheet 4-11N, *Carbon Dioxide Extinguishing Systems*.

1.1 Changes

April 2025. Interim revision. Significant changes include the following:

A. Revised Section 2.2.2, Minimum Design Concentrations for Table 2.2.2.1-1 to include:

1. IG-541 minimum design concentration for Class B fires, based upon the cup-burner test value specified in NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2025 Edition.

2. IG-01 minimum design concentration for Class C greater than 480 volts, based upon FM Approvals testing

3. IG-100 minimum design concentration for Class C greater than 480 volts, based upon FM Approvals testing

B. Revised Section 2.3.4, Nozzles, to update the terminology “silencers” to be FM Approved discharge nozzle for “acoustically sensitive environments” and included associated design parameters. This terminology is consistent with Data Sheet 5-32, *Data Centers and Related Facilities* and FM Approval Class Number 5600, *Examination Standard for Clean Agent Extinguishing Systems*.

1.2 Hazards

Halocarbon and inert gas (i.e., clean agent) fire extinguishing systems are recommended for the protection of critical, high-valued electronic/electrical equipment occupancies such as electronic data processing facilities/computer rooms, control rooms, telephone central office/switch room facilities and switchgear rooms.

Where a clean agent system is recommended for the protection of a hazard or occupancy, it will be listed in the applicable occupancy specific data sheet. A summary of appropriate applications for clean agent systems is provided in Data Sheet 4-0, *Special Protection Systems*.

Halocarbon and inert gas fire protection systems are recognized for total flooding applications only. These systems, like other special protection systems, have a limited quantity of extinguishant and are more susceptible to failure than other fire protection systems such as automatic sprinkler systems. Proper installation of the system including appropriate acceptance tests, as well as ongoing inspection, testing, and maintenance, is critical to the successful performance of a clean agent system. The effectiveness of these systems is also dependent upon containing the gaseous agent in the enclosure, including maintaining the integrity of the enclosure and shutting down any ventilation.

2.0 LOSS PREVENTION RECOMMENDATIONS

Use FM Approved equipment, materials, and services whenever they are applicable. For a list of products and services that are FM Approved, see the *Approval Guide*, and online resource of FM Approvals.

2.1 Construction and Location

2.1.1 Provide a leak-tight enclosure for the volume protected by the clean agent system. Seal any penetrations or openings.

A. Ensure walls extend from the floor to the ceiling or roof.

B. Provide dampers for in-service ductwork designed to close upon system discharge.

C. Seal any holes, cracks, penetrations, or other openings.

D. Provide weather stripping or other appropriate safeguards around door and window joints and hardware.

2.1.2 To prevent enclosure damage due to over- or under-pressure upon system discharge, determine the need for venting the enclosure in accordance with the system manufacturer's design, installation, operation, and maintenance manual. Basic guidance for venting design is provided in Appendix D.

2.1.3 Locate agent storage containers in an area that is easily accessible for the purposes of inspection, testing, and maintenance.

2.1.4 Do not locate agent storage containers in environments subject to weather or other conditions that could damage the equipment. Where such exposure cannot be prevented, provide a protective enclosure for the equipment.

2.1.5 Locate agent storage containers outside the protected area to minimize fire exposure and provide ready accessibility for actuation, inspection, and maintenance. Storage containers may be located within protected areas that contain less severe fire hazards (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.

2.1.6 Locate or arrange agent storage containers so storage temperatures are maintained within the system manufacturer's listed limits of Approval. Refer to the *Approval Guide* and the manufacturer's design, installation, operation, and maintenance manual for details.

2.2 Protection

2.2.1 Installation and Design

2.2.1.1 Design and install all halocarbon or inert gas (clean agent) extinguishing systems in accordance with the FM Approved manufacturer's design, installation, operation, and maintenance manual.

2.2.1.2 Do not use halocarbon or inert gas (clean agent) extinguishing systems as sole protection unless recommended in the applicable occupancy specific data sheet.

2.2.2 Minimum Design Concentrations

2.2.2.1 For the following hazards, provide a minimum design concentration in accordance with the system's *Approval Guide* listing or the applicable occupancy-specific data sheet, whichever is higher. Where the minimum design concentration is not specified, design the system in accordance with Table 2.2.2.1-1.

A. Class A surface fire hazards

B. Class B ignitable liquid fire hazards

C. Class C energized electrical/electronic equipment hazards with limited ordinary combustibles present

2.2.2.2 Provide protection of electrical equipment (e.g., servers, batteries, cables) as follows:

A. When the electrical equipment is de-energized upon activation of the clean agent extinguishing system, provide the minimum design concentration for an ordinary combustible (Class A) fire in accordance with Table 2.2.2.1 or the system's FM Approval listing.

B. When the electrical equipment is not de-energized upon activation of the clean agent extinguishing system or has a time-delayed power disconnect, provide the minimum design concentration for an energized electrical fire (Class C) in accordance with Table 2.2.2.1 for the applicable equipment voltage. If the electrical equipment is not de-energized before the clean agent concentration falls below the minimum design value shown in Table 2.2.2.1, reignition is expected.

Table 2.2.2.1 Minimum Design Concentrations

Agent	*Minimum Design Concentration, %*			
	Class A	Class B[1]	Class C, ≤480 V	Class C, >480 V[2,3]
FK-5-1-12	4.5	5.9	4.7	10
HFC-125	8.7	11.3	9.0	20
HFC-227ea	6.7	8.7	7.0	12
HFC-23	18	19.5	20.3	Not tested[3]
IG-01	38.0	52.5	42.8	60.5
IG-55	37.9	39.1	42.7	Not tested[3]
IG-100	37.2	43.7	41.9	56.1
IG-541	34.2	44.7	38.5	57

Note 1. Class B values are for hydrocarbon fuels similar to n-Heptane. Class B minimum design concentrations will vary for other ignitable liquid fuels, based on the information provided in the manufacturer's design, installation, operation, and maintenance manual.

Note 2. These higher concentrations need to be reviewed for restrictions when used in normally occupied areas. See Section 3.2.4 and Table 5 for information regarding No Observed Adverse Effects Limit (NOAEL) and Lowest Observed Adverse Effects Limit (LOAEL).

Note 3. FM conducted testing that indicates higher agent concentrations are needed for high-energy arcing faults. Only certain clean agents were tested. Refer to Section 3.3 for additional information on this testing. Where an agent is listed as "not tested," additional testing is necessary if the clean agent system is intended to protect energized electrical hazards greater than 480 volts that remain energized following discharge. Do not use an agent to protect high-energy electrical hazards if this testing has not been conducted.

2.2.3 Clean Agent Quantities

2.2.3.1 Determine the mass of halocarbon clean agent needed to achieve the intended design concentration using the following equation:

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

where:

W = mass 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 minimum anticipated temperature of the protected volume [ft^3/lb (m^3/kg)].

C = halocarbon clean agent design concentration [volume percentage].

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

2.2.3.2 Determine the mass or volume of inert gas clean agent needed to achieve the intended design concentration using the following equation and multiplying X or W by the net enclosure volume:

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

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

where:

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

W = mass of inert gas clean agent [lb (kg)].

s_o = specific volume of inert gas clean agent at 14.7 psia (1.01 bar) and 70°F (21°C).

s = specific volume of inert gas clean agent at 14.7 psia (1.01 bar) and the minimum anticipated temperature of the protected volume [ft^3/lb (m^3/kg)].

C = inert gas design concentration (volume percentage).

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)].

l_n = natural log

log_{10} = log base 10

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

2.2.3.3 Where ambient pressures differ from standard atmospheric conditions [29.92 in. Hg at 70°F (760 mm Hg at 0°C)], adjust the recommended quantity of halocarbon or inert gas clean agent using the correction factor in Table 2.23.3. Multiply the quantity determined in Sections 2.2.3.1 or 2.2.3.2 by the appropriate correction factor.

Table 2.2.3.3. Atmospheric Correction Factor

Altitude ft (km)	*Absolute Enclosure Pressure psci (mm Hg)*	*Atmospheric Correction Factor*
-3000 (-0.92)	16.25 (840)	1.11
-2000 (-0.61)	15.71 (812)	1.07
-1000 (-0.30)	15.23 (787)	1.04
0 (0.00)	14.70 (760)	1.00
1000 (0.30)	14.18 (733)	0.96
2000 (0.61)	13.64 (705)	0.93
3000 (0.91)	13.12 (678)	0.89
4000 (1.22)	12.58 (650)	0.86
5000 (1.52)	12.04 (622)	0.82
6000 (1.83)	11.53 (596)	0.78
7000 (2.13)	11.03 (570)	0.75
8000 (2.45)	10.64 (550)	0.72
9000 (2.74)	10.22 (528)	0.69
10,000 (3.05)	9.77 (505)	0.66

2.2.4 System Discharge Time

2.2.4.1 Design halocarbon clean agent systems to achieve 95% of the minimum design concentration listed in Section 2.2.2 within a discharge time of 10 seconds.

2.2.4.2 Design inert gas clean agent systems to achieve 95% of the minimum design concentration listed in Section 2.2.2 within the following discharge times:

- Class A fire hazards: 120 seconds
- Class B fire hazards: 60 seconds
- Class C fire hazards: 120 seconds

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

2.2.5 Duration of Protection

2.2.5.1 Provide the agent minimum design concentration within the protected enclosure for at least 10 minutes, or longer where necessary to ensure effective emergency response by trained personnel. Determine the duration of protection using door fan and/or discharge testing (refer to Section 2.5.1.2). Note that for

Class C electrical fires, if the electrical equipment is not de-energized before the clean agent concentration falls below the minimum design value shown in Table 1, reignition is expected.

2.2.5.2 Maintain 85 percent of the minimum design concentration at the highest level of protected contents within the enclosure in accordance with 2.2.5.1.

2.2.6 Detection and Actuation

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

2.2.6.2 Provide a minimum of two reliable and independent power supplies (i.e., primary and secondary) for detection and release devices, designed in accordance with Data Sheet 5-40, *Fire Alarm Systems*.

2.2.6.3 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.

2.2.6.4 Where manual bypass switches are provided to prevent accidental discharge of a clean agent fire extinguishing system during testing or servicing of the system, provide supervised keyed lock-out devices located at the control panel.

A. Arrange these devices so they do not disable the alarm circuit.

B. Establish and follow written impairment procedures.

C. Put the key(s) under the control of a responsible management or fire protection person.

2.2.6.5 Provide a readily accessible manual means of operation, designed as follows:

A. A mechanical release is preferred. If an electrical release is used, ensure the control equipment monitors the power supply and provides appropriate trouble or supervisory signals.

B. Locate the release in an easily accessible area outside the protected space.

C. Ensure the release clearly identifies the hazard it protects.

D. Where a mechanical release is installed, provide a device (e.g., a discharge pressure switch) to initiate functions such as control panel actuation and operation of interlocks.

E. Ensure operation of the manual release results in complete discharge of the extinguishing system and operation of all associated interlocks.

2.2.6.6 In addition to the manual means of operation recommended in Section 2.2.6.5, provide a fully mechanical, emergency manual means of system operation. This actuation method is typically provided as a manual actuator at the storage containers.

2.2.7 Operating Devices

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

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

2.2.7.3 Supervise electric releasing devices associated with cylinder discharge valves and selector valves at the control panel to indicate their removal.

2.2.7.4 Provide interlocks to automatically perform critical functions upon operation of the extinguishing system in accordance with the occupancy or equipment specific data sheet for the protected area. Examples include, but are not limited to, closure of dampers, shut down of ventilation, stoppage of conveyors, and power-down of electrical equipment.

2.2.7.5 In areas where energized electrical equipment is installed and the agent concentration is insufficient for a Class C fire hazard, provide automatic interlocks for power isolation of the equipment to minimize the potential for sustained ignition. Note that, regardless of the agent concentration, the potential exists for halocarbons to decompose in the presence of a sustained hot spot. Where this is a concern due to a sensitive occupancy or equipment, provide automatic interlocks for power isolation of the electrical equipment.

2.2.7.6 Where abort switches are provided, use devices that require constant manual pressure to cause abort (i.e., “dead-man” switches). Locate the devices within the protected area near the path of egress. 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, arrange the abort switch so operation of the switch does not reset any time delays.

2.2.8 Alarms and Supervisory Devices

2.2.8.1 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.

2.2.8.2 Supervise the system’s fire alarm control unit in accordance with Data Sheet 9-1, *Supervision of Property*. Provide trouble alarms (e.g., when the system is disconnected) and discharge alarms distinctive from each other, to sound at a constantly attended location.

2.2.9 Supply of Extinguishing Agent

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

2.2.9.2 To enable prompt restoration of the system after a discharge, and to minimize interruption of the process and the interval of impaired protection, provide a connected reserve supply under any of the following circumstances:

A. The system is protecting two or more hazards with a single supply through selector valves. Connect the reserve supply to the distribution piping, and provide a switchover arrangement to permit actuation by normal means (e.g., a manually actuated main/reserve switch at the control panel).

B. The system cannot be restored to service within 24 hours from an outside source.

C. The system serves as sole protection for valuable and important assets of an occupancy, unless all of the following criteria are met:

1. Protection can be fully restored within 24 hours.
2. Occupancies are constantly attended.
3. Written impairment procedures have been established.

2.3 Equipment and Processes

2.3.1 General

Install only new system components. Do not use repurposed equipment.

2.3.2 Storage Containers

2.3.2.1 Provide a nameplate on each container that includes the following information:

A. Manufacturer and system information

B. Clean agent type

C. System working pressure

D. Allowable ambient storage temperature range

E. Agent quantity (tare and gross weights for halocarbons and volume for inert gases)

2.3.2.2 Provide a means to indicate that each container is correctly charged (e.g., pressure gauge or transducer, liquid level indicator, weighing device).

2.3.3 Piping, Fittings, and Valves

2.3.3.1 Provide system piping, fittings, and valves of noncombustible materials having physical and chemical characteristics such that its integrity under stress can be predicted with reliability. Do not use cast iron pipe or nonmetallic pipe or fittings. Exceptions include flexible pipe, tubing, or hose that is part of an FM Approved system.

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

2.3.3.3 Calculate the required piping and fitting 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 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.

2.3.3.4 For inert gas systems incorporating a pressure reducing valve, use a pressure for piping and fitting wall thickness calculation upstream of the valve as indicated in Section 2.3.2.3. Downstream of the pressure reducing valve, use the maximum expected pressure based on the pressure reducing valve's settings.

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

2.3.3.6 Provide automatically operated pressure relief devices where valve arrangements result in closed piping sections. Design the pressure relief devices to operate at a pressure in accordance with the manufacturer's design, installation, operation, and maintenance manual and any applicable national or international codes and standards.

2.3.3.7 Provide a minimum 2 in. (50 mm) long dirt trap (a tee with a capped nipple) at the end of each pipe run to minimize the potential for contaminants to be discharged into the protected space.

2.3.4 Nozzles

2.3.4.1 Install nozzles within the hazard enclosure in compliance with their FM Approval limitations, including area coverage and height limitations.

2.3.4.2 Use corrosion-resistant materials for nozzles located in corrosive environments.

2.3.4.3 Where clogging by foreign materials is possible, provide protective coverings, such as blow-off caps, designed to dislodge from the nozzle and provide an unobstructed discharge path upon system operation.

2.3.4.4 When equipment (e.g., hard disk drives) in the protected area is susceptible to disruption of performance by noise from the discharge of a clean agent fire extinguishing system:

A. Use an FM Approved clean agent fire extinguishing system that has an FM Approved discharge nozzle listed for the Special Application of "acoustically sensitive environments" as a component of the fire extinguishing system. Verify the following:

1. Nozzle installation distance from the acoustically sensitive equipment meets or exceeds the minimum allowable distance per the parameters in the:

a. DIOM manual, or

b. Calculation and design documentation provided by the system manufacturer's application/design group, or

c. The FM Approved sound pressure calculation tool for the related fire extinguishing system

2. The nozzle(s) is installed within the Approved limitations for area of coverage and maximum protected volume.

2.3.5 Piping Supports (Hangers)

2.3.5.1 Provide noncombustible pipe hangers installed in accordance with the manufacturer's design, installation, operation, and maintenance manual and any applicable national or international codes and standards. Where spacing is not specified, space hangers in accordance with Table 2.3.5.1.

Table 2.3.5.1. Recommended Hanger Spacing

Pipe Size, in. (mm)	*Maximum Spacing Between Hangers, ft (m)*
1/4 (8)	4 (1.3)
1/2 (15)	6 (2.0)
3/4 (20)	8 (2.6)
1 (25)	12 (3.9)
1-1/4 (32)	12 (3.9)
≥ 1-1/2 (40)	15 (4.9)

2.3.5.2 Install a hanger between fittings when the fittings are more than 2 ft (0.6 m) apart. Install a hanger a maximum of 1 ft (0.3 m) from any nozzle to prevent the nozzle from moving vertically.

2.4 Plan Review

The recommendations in this section are for clients of FM.

2.4.1 Plan Review of Clean Agent Extinguishing Systems

2.4.1.1 Submit the information listed in Sections 2.4.1.2 through 2.4.1.4 to a designated representative of FM for review and acceptance prior to the start of any clean agent system installation. If revisions to the information are made prior to installation, submit revised documentation to a designated representative of FM for review and acceptance.

2.4.1.2 Provide the following information on the working drawings submitted for review and acceptance:

A. Protected enclosure information, including ambient conditions, hazard classification, and enclosure dimensions

B. Agent and agent design concentration

C. Anticipated maximum pressures (positive and negative) expected to be developed upon system discharge, and pressure relief vent area or equivalent leakage area needed to prevent enclosure damage

D. System component details, including each component's name, manufacturer, model or part number, quantity, and description, as well as additional information on specific equipment, as follows:

1. Storage containers (capacity, storage pressure, securement method)
2. Nozzles (size, equivalent orifice area)
3. Pipe and fittings (material, grade, pressure rating)
4. Pipe supports (spacing, size, securement)
5. Detectors (type, number, location)

E. Drawings of the distribution system, including the following:

1. Agent storage containers
2. Piping (layout, length, diameter, pipe hangers/supports)
3. Fittings (e.g., reducers, strainers, tees)
4. Nozzles (layout, size, equivalent orifice area)
5. Node reference numbers relating to the flow calculations
6. Detection, alarm, and control devices
7. Controlled devices (dampers, doors, other auxiliary equipment)

F. Description of the system sequence of operations, including functioning of abort and maintenance switches, delay timers, and emergency power shutdown

G. Wiring schematic diagrams

H. Calculations related to the enclosure volume and clean agent quantity

2.4.1.3 For engineered systems, provide documentation on the flow calculation software used to determine the design of the agent distribution system.

2.4.1.4 Confirm that the contractor/installer is an authorized distributor/representative of the clean agent system manufacturer, trained to design and install the system in accordance with the manufacturer's FM Approved design, installation, operation, and maintenance manual.

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

2.5 Operation and Maintenance

2.5.1 Acceptance of Installations

2.5.1.1 Verify that the clean agent fire extinguishing system has been installed in accordance with the FM Approved manufacturer's design, installation, operation, and maintenance manual, as well as any applicable national or international codes and standards.

2.5.1.2 Enclosure Integrity

2.5.1.2.1 Conduct an enclosure integrity procedure (door fan test) of the protected occupancy in accordance with Appendix C. Based on this procedure, calculate the time for a descending clean agent-air interface to fall below the minimum desired protected height (for heavier-than-air clean agents such as halocarbons) or the time for the concentration to fall below the specified minimum design concentration (for instances with continuous mixing). The minimum protected height is the height of equipment, combustibles, and other potential fire sources within the enclosure.

2.5.1.2.2 Ensure the predicted hold time for the clean agent concentration from the door fan test exceeds the minimum design concentration recommended in Section 2.2.2 for the duration of protection recommended in Section 2.2.5.

2.5.1.2.3 If the door fan test shows that the peak pressure exceeds the strength of the enclosure, provide additional venting in accordance with the manufacturer's design, installation, operation, and maintenance manual. In providing this venting, do not allow the predicted hold time to fall below the recommended duration of protection per Section 2.2.5.

2.5.1.3 Pneumatically test open-ended piping in a closed circuit for a period of 10 minutes at 40 psig (276 kPa). Confirm the pressure drop does not exceed 20% of the test pressure at the end of 10 minutes. Conduct pneumatic testing of open-ended piping prior to any planned system discharge test.

2.5.1.4 Hydrostatically test any closed-section piping to a minimum of 1.5 times the maximum working pressure for two minutes.

2.5.1.5 Discharge Testing

2.5.1.5.1 Conduct a full discharge acceptance test to verify the following:

A. Activation of the detection devices initiates extinguishing system discharge and associated alarms.

B. The settings for time delays and any selector valves are correct.

C. Interlocks, such as compartment ventilation shutdown and/or operation of dampers, function in the proper sequence prior to discharge of the agent.

D. Specified minimum design concentrations are achieved and maintained above the highest level of combustibles/equipment within the hazard enclosure for the entire duration of protection.

E. All discharge nozzles flow free and clear.

F. Venting for the hazard enclosure is adequate.

2.5.1.5.2 For system components whose performance cannot be confirmed during the full discharge test, conduct additional standalone functional tests in accordance with Section 2.4.1.5.4.

2.5.1.5.3 For systems that have not been subjected to a full discharge test, conduct a flow test (i.e., a “puff test”) using nitrogen or an inert gas on the piping network to verify flow is continuous and the piping and nozzles are unobstructed. Refer to Section 2.3.3.5 to best ensure this unobstructed flow condition.

A. Conduct the test at a pressure not exceeding the system’s normal operating pressure.

B. Conduct the test for a time period that allows verification of unobstructed flow from all nozzles.

C. If discharging into a sensitive occupancy (e.g., a computer room), cover the nozzles with a sock or similar material to prevent potential discharge of debris into the room.

D. If obstructed flow is observed during the puff test, or trapped debris is identified by visual inspection of the nozzles and dirt trap following the test, remove, clear, and reinstall the nozzle and dirt trap.

2.5.1.5.4 For systems that have not been subjected to a full discharge test, conduct complete component functional tests to verify the following, at a minimum:

A. Activation of detection devices, including manual releases, initiates the proper cylinder actuation device. Note that the actuation device will be disconnected from the cylinder.

B. Interlocks, such as compartment ventilation shutdown and/or operation of dampers, function in the proper sequence.

C. The settings for time delays are correct.

D. Where multiple areas are protected by a single system, activation of each area’s detection device(s) operates the appropriate selector valve.

E. If installed, abort switches are operable, activate appropriate visual and audible signals, and are overridden by emergency manual pull stations.

E. Integrity and continuity of discharge piping flow via pneumatic pressure testing of the piping (Section 2.5.1.3) and a “puff test” (Section 2.5.1.5.3).

F. Proper pipe flow orifice, as applicable, and proper nozzles are installed.

2.5.2 System Restoration

Develop a plan to bring the clean agent system and protected enclosure to working order following a system discharge. Include the following at a minimum:

A. Where applicable, purging of the clean agent from the enclosure using a dedicated, independent exhaust system. This is particularly important where sensitive equipment may be subject to products of agent decomposition.

B. Adherence to established impairment procedures. Refer to Data Sheet 10-7, *Fire Protection Impairment Management*, for additional details.

C. Cleanup and salvage of the enclosure, particularly if it includes sensitive equipment.

D. Replenishment of agent, particularly if a reserve supply is not available on site.

E. Use of an authorized agent filling station listed in the *Approval Guide*.

F. Adherence to other items listed in the manufacturer’s design, installation, operation, and maintenance manual.

2.5.3 Inspection, Testing, and Maintenance

2.5.3.1 Maintain clean agent systems and conduct inspection and testing in accordance with Data Sheet 2-81, *Fire Protection System Inspection*, as well as the manufacturer’s design, installation, operation, and maintenance manual.

2.5.3.2 Perform annual inspection on the protected enclosure, including any installed pressure relief vents.

2.5.3.3 Develop a procedure to monitor document changes to the integrity of the enclosure or enclosure dimensions. Immediately seal any penetrations through the protected enclosure.

2.6 Training

2.6.1 Provide training for all personnel responsible for the operation and maintenance of the system. Address all of the following, at a minimum:

A. A review of the manufacturer's design, installation, operation, and maintenance manual.

B. The purpose of the clean agent system relative to the protected equipment and enclosure.

C. The functionality of the system and major system components.

D. Associated equipment and interlocks (enclosure venting, dampers, power and ventilation shutdown, etc.)

E. Operation of the system under normal and emergency circumstances (i.e., automatic and manual operation), including the location of manual release devices.

F. The importance of maintaining enclosure integrity (e.g., sealing of holes, cracks, penetrations, or other openings) and resulting impact on system performance.

G. Necessary inspection, testing, and maintenance of the extinguishing system and protected enclosure.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Clean Agent History

3.1.1 Halon

Gaseous extinguishing systems have been used as a means of fire protection since the early 1900s. Halons (hydrocarbons in which one or more hydrogen atoms have been replaced by fluorine, chlorine, bromine, or iodine) were introduced at that time, including Halon 104 (carbon tetrachloride) in 1907, and Halon 1001 (methyl bromide) and Halon 1011 (bromochloromethane) in the 1930s. Some of these agents were highly toxic, and a 1947 study by the United States Army determined that Halon 1202 was the most effective fire extinguishant but also the most toxic. Halon 1301 was the second most effective agent and the least toxic.

Based on this study, Halon 1301 total flooding systems became available based primarily on carbon dioxide system technology and hardware. In the late 1960s, NFPA 12A and 12B for Halon 1301 and Halon 1211 were developed. In the ensuing decades, these two agents, along with carbon dioxide, served as the predominant forms of gaseous fire protection systems.

In 1987, the Montreal Protocol restricted the production and use of halons for environmental reasons, given the significant global warming and ozone depletion potential of these chemicals. This resulted in the need for halon replacements, including the development of clean agents.

3.1.2 Clean Agents

Clean agents are electrically nonconducting, volatile, or gaseous fire extinguishants that do not leave a residue upon evaporation. There are two types of clean agents: halocarbons and inert gases. Both types are used in total flooding extinguishing systems, where the agent is discharged throughout an entire protected area to quickly reach a minimum design concentration needed for fire extinguishment. Minimum design concentrations vary depending on the agent type, extinguishing system hardware (e.g., efficiency of the system's discharge nozzles), and hazard to be protected (ordinary combustibles, ignitable liquids, or electrical fire hazards).

A halocarbon is a clean agent that contains one or more of the elements fluorine, chlorine, or iodine. Halocarbon clean agents do not contain bromine. Categories of halocarbon agents are hydrofluorocarbons (HFC), hydrochlorofluorocarbons (HCFC), perfluorocarbons (PFC), and fluoroiodocarbons (FIC). Halocarbons extinguish a fire primarily by interrupting the chemical combustion process, and to a lesser degree by extracting heat from the flame reaction zone to reduce the flame temperature. Minimum design concentrations in the range of 4% to 9% within 10 seconds are usually targeted to achieve this goal.

The second type of clean agent is an inert gas, which contains one or more of the gases helium, neon, argon, nitrogen, or carbon dioxide. The primary extinguishing mechanism of inert gases is oxygen displacement. Typically, inert gas minimum design concentrations range from 34% to 42% within 120 seconds, which corresponds to an oxygen concentration of less than 14%.

See Table 3.1.2 for a list of currently recognized clean agents within NFPA 2001 and 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 3.1.2. Currently Recognized Clean Agents[1]

Agent Designation	*Chemical Name*
Halocarbons	
FIC-13I1	Trifluoroiodomethane
HCFC Blend A	
HCFC-123	Dichlorotrifluoroethane (4.75)
HCFC-22	Chlorodifluoromethane (82)
HCFC-124	Chlorotetratflouoroethane (9.5)
HCFC-124	Chlorotetratflouoroethane (9.5)
HFC Blend B	Tetrafluoroethane (86)
	Pentafluoroethane (9)
	Carbone dioxide (5)
HFC-23	Trifluoromethane
HFC-125	Pentafluoroethane
HFC-227ea	Heptafluoropropane
HFC-236fa	Hexafluoropropane
FK-5-1-12	Dodecafluoro-2 methylpentan-3-one
Inert Gases	
IG-01	Argon
IG-100	Nitrogen
IG-55	Nitrogen (50), Argon (50)
IG-541	Nitrogen (52), Argon (42), Carbon Dioxide (8)

[1] This table includes all agents listed in NFPA 2001 and ISO 14520. Refer to the Approval Guide for a list of the agents that are currently FM Approved.

3.2 Clean Agent Applications

3.2.1 Special Protection Systems vs. Conventional Sprinkler Systems

Clean agent systems are special protection systems. Special protection systems are typically used to control fires involving volatile, fast-burning substances (e.g., ignitable liquids). They are also used to minimize property damage and business interruption in processes or occupancies of high value or particular susceptibility to fire.

Clean agent systems usually supplement automatic sprinklers and are not a substitute for them unless an exception is made within the appropriate occupancy-specific data sheet. Sprinklers can function much longer than clean agent systems and can be restored more quickly to service. Their effectiveness is much less affected by physical changes in a hazard. More importantly, the reliability of conventional sprinkler systems is unequaled. Clean agent systems are more complex than conventional sprinkler systems and consequently subject to more electrical and mechanical failure modes as well as possible accidental discharges. Reflash or reignition potential is also a concern.

In spite of the above concerns, a clean agent system can be expected to perform reliably provided the following conditions are met:

A. The system is specifically recommended or recognized as suitable for the hazard or occupancy being protected.

B. The system is designed and installed in accordance with accepted plans.System acceptance tests are satisfactorily performed.

C. System impairment procedures are established and followed.

D. The system and the hazard or protected occupancy is maintained in accordance with the guidelines in this data sheet and any additional recommendations in the applicable occupancy-specific data sheet.

3.2.2 Suitable Applications

Suitable applications for clean agent systems are listed in other occupancy-specific data sheets. Data Sheet 4-0, *Special Protection Systems*, provides a summary of these applications and data sheets. Examples of typical clean agent system applications include the following:

- Electrical equipment
- Aviation facilities
- Electronic control rooms
- Data processing equipment rooms/halls
- Medical facilities
- Museums
- Power generation plants
- Tape storage and vaults
- Telecommunications switch rooms
- Pharmaceutical plants

3.3 Clean Agent Testing

3.3.1 Energized Electrical (Class C) Testing

For energized electrical equipment, higher concentrations of clean agent are needed for extinguishment as a function of the power level. FM conducted research to determine the required minimum extinguishing concentrations for various clean agents exposed to electrical faults. This research program included a series of tests using FM's Fire Propagation Apparatus (FPA). In each test, a sample of polymethyl methacrylate (PMMA) was placed in the FPA and exposed to a specific agent concentration. With this known concentration of agent established, an 1100 W electrical arc was introduced and the sample was observed for signs of ignition. If the PMMA sample ignited, the agent concentration was raised in subsequent tests until ignition of the PMMA samples could not be achieved. This ignition threshold concentration was then considered the minimum design concentration for sustained high-energy electrical hazards.

Other standards, such as NFPA 2001, include requirements for similar testing to determine the agent minimum design concentration for energized electrical hazards. However, a standardized test method has not been established. FM has implemented the testing described above as a consistent method of determining an appropriate minimum design concentration. Tests have been conducted on a number of clean agents, as listed in Table 2.2.2.1.

3.4 Personnel Safety

Halocarbon clean agents are potentially cardiotoxic, while inert gas clean agents can present physiological effects associated with an hypoxic (low oxygen) atmosphere. The experimentally determined approximate lethal concentration (ALC), no observed adverse effects level (NOAEL), and lowest observed adverse effects level (LOAEL) values, which are defined in Appendix A, are given in Table 3.4 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.

Table 3.4. Reported NOAEL/LOAEL Values for Halocarbon Agents

Agent	*NOAEL (%)*	*LOAEL (%)*	*ALC (%)*
FIC-13I1	0.2	0.4	>12.8
HCFC Blend A	10	>10	64
HCFC Blend B	5.0	7.5	56.7
HCFC-124	1.0	2.5	23-29
HFC-23	30	>30	>65
HFC-125	7.5	10	>70
HFC-227ea	9.0	10.5	>80
HFC-236fa	10	15	>45.7
FK-5-1-12	10	>10	>10

Clean agent system design concentrations exceeding the agent's NOAEL are not recommended in potentially occupied spaces unless the exposure time is limited. These exposure times will vary depending on the specific agent and the actual design concentration. For instance, the maximum permitted exposure time for an HFC-125 concentration of 8% is 5 minutes. Similarly, an inert gas design concentration of 43% to 52% (corresponding to 10% to 12% oxygen) would restrict human exposure to 3 minutes or less. At certain levels, the agent concentration is so high that they can only be used in unoccupied areas where personnel will not be exposed to a system discharge. Specific human exposure times for various agents are included in NFPA 2001 and ISO 14520.

In addition to limitations related to safe exposure, halocarbon clean agents may decompose into strong acids (e.g., hydrogen fluoride) when exposed to a fire. This may result in additional human exposure issues, as well as nonthermal damage to equipment in sensitive occupancies.

3.5 Clean Agent Quality

Quality requirements vary by specific agent type and by local regulations, but representative requirements included in standards such as NFPA 2001 and ISO 14520 are shown in Table 3.5a and 3.5b (these standards differ in specific requirements, so ranges have been given in the table). Refer to the manufacturer's design, installation, operation, and maintenance manual for agent specific quality requirements.

Table 3.5a. Halocarbon Quality Specifications[1]

Property	*Specification*
Agent purity	99.0% to 99.9% (minimum mole %)
Acidity	3.0 to 6.0 ppm (maximum by weight)
Water content	0.001% to 0.006% (maximum by weight)
Nonvolatile residues	0.01% to 0.03% (by weight, maximum)
Suspended matter or sediment	None visible

Note 1. Does not include HCFC Blend A or HFC Blend B Quality Specifications

Table 3.56b. Inert Gas Quality Specifications

Composition	*IG-01*	*IG-100*	*IG-541*	*IG-55*
Composition, % by volume	Ar: minimum 99.9%	N_2: minimum 99.6%	N_2: 52% ± 4% Ar: 40% ± 4% CO_2: 8% ± 0.4%	N_2: 50% ± 5% Ar: 50% ± 5%
Water content, % by weight	Maximum 0.005%	Maximum 0.005%	Maximum 0.005%	Maximum 0.005%

3.6 Halocarbon vs. Inert Gas Clean Agent Systems

Halocarbons and inert gases are generally interchangeable in terms of the level of fire protection provided. Other factors, however, may dictate the use of one agent type over the other. For example, one concern frequently cited with regard to halocarbon clean agents is the formation of hydrogen fluoride due to thermal breakdown/decomposition. Hydrogen fluoride can be toxic to human beings, causing eye, skin, and respiratory irritation, the effects of which worsen with increasing concentrations and exposure time. Hydrogen fluoride may also be corrosive to sensitive equipment.

The extent of decomposition of a halocarbon agent is dependent on the intensity/size of a fire (i.e., the heat release rate) at the time the system is discharged. Consequently, halocarbon clean agent systems are designed with rapid fire detection and system actuation and discharge (i.e., recommended maximum 10-second system discharge limitation) to achieve quick fire extinguishment, thereby minimizing fire damage and extinguishing agent decomposition.

Halocarbon agent decomposition could be a concern with fast growing, high heat release rate fires such as those involving ignitable liquids. Despite its extinguishing efficacy, an inert gas clean agent system or carbon dioxide system may be preferable in these cases. This is reflected in certain data sheets related to ignitable liquids. Halocarbon agent decomposition may also be an issue where heated equipment or surfaces are present within the protected area, or where electrical equipment is not deenergized upon agent discharge.

Another factor frequently cited or noted in making this choice is environmental considerations. Inert gases are naturally occurring substances. They are environmentally benign and more environmentally acceptable to some end-users and/or governing environmental authorities. For example, inert gas systems are preferred in some countries for environmental reasons.

Available installation space is another factor to consider in determining an appropriate clean agent. The number of cylinders needed to achieve minimum design concentrations can be significantly more for inert gases compared to halocarbons.

Cost is another factor in determining an appropriate clean agent. Typically, inert gas clean agent systems are moderately more expensive than halocarbon clean agent systems because of equipment costs. Inert gases require higher minimum design concentrations and are stored as high pressure gases [e.g., 2175 psig (150 bars) or higher) as opposed to liquefied gases for the halocarbons, which are typically pressurized with nitrogen to 360 psig (25 bars). Consequently, inert gas clean agent systems require many more storage containers (much larger storage ″footprint″) and higher pressure rated equipment and piping.

3.7 Enclosure Integrity and Venting

The successful performance of a clean agent fire extinguishing system is dependent on the integrity of the enclosure. A tight enclosure to prevent the discharged gas from escaping the space is essential to achieve and maintain the concentration needed for fire extinguishment. Enclosure integrity can initially be confirmed with a simple visual check of the protected enclosure for any obvious penetrations or openings that might allow the escape of agent. Once any obvious openings have been addressed, final confirmation of the room's integrity can be determined via a door fan test and/or a full discharge test.

When a clean agent extinguishing system is discharged, a positive or negative pressure is created within the enclosure. Inert gas clean agents, for example, cause a rapid positive pressure within the enclosure upon discharge. This is shown in Figure 3.7.-1. As shown in Figure 3.7-2, halocarbon clean agents can cause a vacuum within the enclosure due to cooling from vaporization and expansion of the liquefied gas followed by a positive pressure due to the added gas. The change in ambient pressure following discharge could impact the structural strength of the space if the enclosure is overly tight.

In many cases, natural ventilation occurs such that the structural strength of the enclosure is not exceeded. However, if the peak pressure or reduced pressure developed during a clean agent discharge exceeds the enclosure strength, additional venting may be required to limit enclosure damage. Vents include gravity vents, counter weighted flap vents, electrically operated vents, and pneumatically operated vents. These vents remain closed, keeping discharged agent within the enclosure, until a specifically designed opening pressure is reached. These vents may be uni-directional or bi-directional to account for both positive and negative pressures.

Guidance for determining the necessary free vent area, selecting an appropriate type of vent, correctly sizing the vents, and determining the appropriate opening pressure is provided in several publications, including the following:

- ISO TS 21805 (E), *Guidance on Design, Selection and Installation of Vents to Safeguard the Structural Integrity of Enclosures Protected by Gaseous Fire-Extinguishing Systems*
- Fire Suppression Systems Association (FSSA) Guide to Estimating Pressure Relief Vent Areas

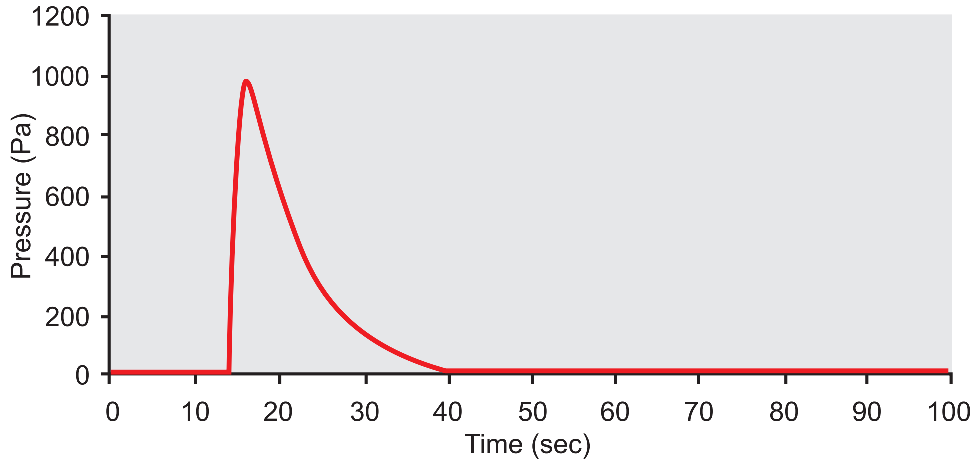

Fig. 3.7-1. Pressure in an enclosure protected by an inert gas

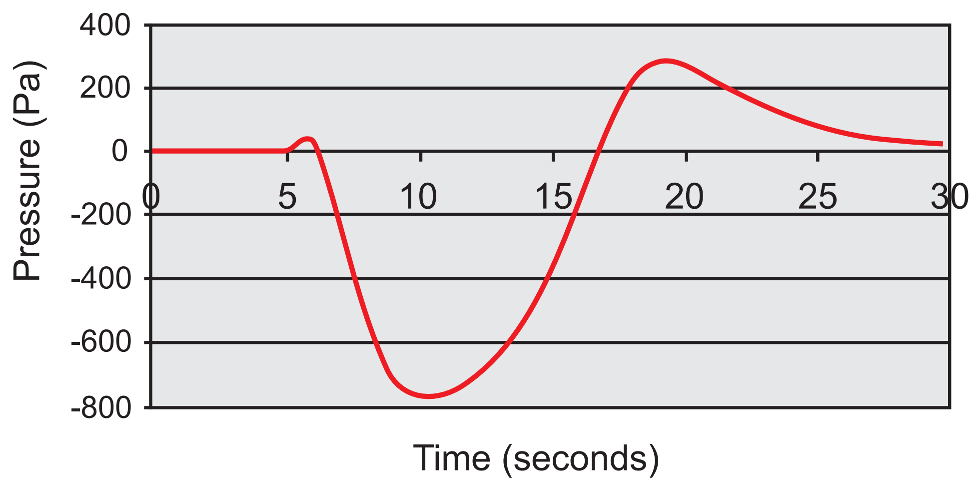

Fig. 3.7-2. Pressure in an enclosure protected by a halocarbon

Additional information is provided in Appendices C and D.

3.8 Equipment Susceptible to Clean Agent System Discharge Noise

Very short discharge times (less than 60 seconds) should not be used with inert gas fire extinguishing systems if equipment (such as hard disk drives) are susceptible to disruption of performance by noise from the discharge. A minimum 30-second discharge time is part of the FM Approval listing, but should be avoided for occupancies with susceptible equipment.

4.0 REFERENCES

4.1 FM

Data Sheet 2-81, *Fire Protection System Inspection*
Data Sheet 4-0, *Special Protection Systems*
Data Sheet 4-11N, *Carbon Dioxide Extinguishing Systems*
Data Sheet 5-32, *Data Center and Related Facilities*
Data Sheet 5-40, *Fire Alarm Systems*
Data Sheet 5-48, *Automatic Fire Detectors*

Data Sheet 9-1, *Supervision of Property*
Data Sheet 10-7, *Fire Protection Impairment Management*

FM Red Tag Permit System

4.2 Others

American Society of Mechanical Engineers (ASME). ASME B31.1, *Power Piping*.

European Standard EN 15004, *Fixed Firefighting Systems. Gas Extinguishing Systems. Design, Installation and Maintenance*.

Fire Suppression Systems Association (FSSA). *Guide to Estimating Pressure Relief Vent Areas*.

International Organization for Standardization (ISO). ISO 14520, *Gaseous Fire-Extinguishing Systems: Physical Properties and System Design*.

- Part 1: General Requirements
- Part 2: CF_3I Extinguishant
- Part 5: FK-5-1-12 Extinguishant
- Part 6: HCFC Blend A 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

International Organization for Standardization (ISO). ISO TS 21805 (E), *Guidance on Design, Selection and Installation of Vents to Safeguard the Structural Integrity of Enclosures Protected by Gaseous Fire-Extinguishing Systems*.

National Fire Protection Association (NFPA). NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2015 Edition.

APPENDIX A GLOSSARY OF TERMS

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 that normally involves the use of a proprietary flow calculation program. The flow calculation program is 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).

FM Approved: Products and services that have satisfied the criteria for FM Approval. Refer to the *Approval Guide*, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

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.

Lock-out device: A manual shut-off valve installed in the discharge piping downstream of the agent containers, or another type of device that mechanically prevents agent container actuation, to prevent the discharge of agent into the hazard area when the lock-out device is activated. Actuation of the device provides an indication of system isolation.

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.

Sole protection: A special protection system may be considered sole protection (i.e., in lieu of automatic sprinklers) if the system has been tested for the protected hazard, and the duration of the agent supply is equivalent to that required for the same hazard protected by an automatic sprinkler system.

Special protection system: A protection system suitable to extinguish all of the fire scenarios for the hazard protected, and where it has a limited agent supply. The agent supply is usually specified as the greater of (a) twice the time to extinguish the worse-case fire scenario in an accepted fire test scenario, (b) the total time to shutdown process equipment including the time it takes surfaces to decrease to a safe temperature, or (c) 10 minutes. Equipment hazard and occupancies suitable for protection by special protection systems are described in FM data sheets.

Supplementary protection: A system provided in addition to automatic sprinkler protection in an effort to reduce the size of a loss.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

April 2025. Interim revision. Significant changes include the following:

A. Revised Section 2.2.2, Minimum Design Concentrations for Table 2.2.2.1-1 to include:

1. IG-541 minimum design concentration for Class B fires, based upon the cup-burner test value specified in NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2025 Edition.

2. IG-01 minimum design concentration for Class C greater than 480 volts, based upon FM Approvals testing

3. IG-100 minimum design concentration for Class C greater than 480 volts, based upon FM Approvals testing

B. Revised Section 2.3.4, Nozzles, to update the terminology “silencers” to be FM Approved discharge nozzle for “acoustically sensitive environments” and included associated design parameters. This terminology is consistent with Data Sheet 5-32, *Data Centers and Related Facilities* and FM Approval Class Number 5600, *Examination Standard for Clean Agent Extinguishing Systems*.

July 2023. Interim Revision. Made editorial change to Table 1 of Class C design concentration for FK-5-1-12. Revised the minimum design concentration percentage to include the proper safety factor based upon the Class A minimum extinguishment concentration.

July 2021. Interim revision. Made editorial changes to Table 1 for Class C design concentrations at the designated electrical hazard voltage to be consistent with Note 3.

April 2019. Interim revision. Clarification was made to Table 1.

January 2019. Interim revision. Clarification was made to Section C.4.2.1.

October 2018. This data sheet has been completely revised. Major changes include the following:

A. Changed the name of the document from *Clean Agent Fire Extinguishing Systems* to *Halocarbon and Inert Gas (Clean Agent) Fire Extinguishing Systems*.

B. Removed many of the previous references to NFPA 2001 and ISO 14520. Data Sheet 4-9 can now be used as stand-alone guidance for clean agent systems.

C. Added information on designing the protected enclosure, including proper sealing of the space and design of pressure relief systems.

D. Added details on acceptance of installations, including functional component testing, “puff” testing, enclosure integrity testing, door fan testing, and full discharge testing.

E. Updated Table 1, Minimum Design Concentrations, to include all currently FM Approved clean agents. Added Class C minimum design concentrations for both low-energy (<480 volts) and high-energy (≥480 volts) energized electrical hazards.

F. Added guidance on adjusting the necessary agent quantity due to atmospheric conditions.

G. Added information on the design of system components, including detection and actuating devices, storage containers, piping, piping supports, fittings, valves, and nozzles.

H. Added details on mitigation methods to prevent equipment damage from clean agent discharge noise.

I. Added guidance on training personnel.

J. Added guidance on restoring a system and enclosure to working order following a discharge.

K. Added guidance on the plan review of clean agent system installations.

L. Provided additional background information on clean agent systems in Section 3.0, Support for Recommendations.

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 DOOR FAN TESTING

A door fan test is used primarily to confirm the integrity of the enclosure; the ability of the walls, ceiling, and floor to keep agent in, as well as the peak pressure produced from the discharge to determine the need for pressure-relief vents to prevent room damage. A door fan apparatus is placed at the door to produce a pressure differential, and the resulting pressure and flow data is used to determine the predicted agent hold time and peak pressures.

The test method is conservative in that it will predict the worst case leakage from the enclosure. It will typically result in more sealing than would be needed to pass a full discharge test of the system.

This appendix provides general guidance on door fan testing, and is intended to be used in conjunction with other national or international standards on door fan testing and/or guidance from contractors who perform these tests.

C.1 General

C.1.1 Set up and conduct testing in accordance with NFPA 2001, ISO 14520, EN 15004, or other applicable code or standard. Note that the methods outlined in these documents (NFPA 2001, ISO 14520, EN 15004, etc.) will typically yield slightly different results. Use the applicable code or standard based on the jurisdiction of the installed system.

C.1.2 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 a nationally or internationally recognized test protocol.

C.2 Enclosure Considerations

C.2.1 Review the sealing of the enclosure prior to running the test. Seal any obvious leak sources that could adversely impact the test results, such as penetrations, wall to floor joints, wall to ceiling joints, ductwork, doors, windows, etc.).

C.2.2 Establish the existence of false ceilings and/or other attached volumes that would allow leakage of the clean agent discharge that may not be measured by the door fan.

C.2.3 Establish the presence of non-uniform enclosure cross sectional areas, as this may impact the results. For example, for agents that are heavier than air protecting an enclosure where the cross sectional area increases from the top of the enclosure to the bottom, the hold time may be overestimated.

C.2.4 Deduct the volume of large solid objects to obtain the net volume of the enclosure.

C.2.5 Establish the state of the protected space that would normally be expected during a clean agent discharge (e.g., continuous ventilation vs. HVAC shut down). Run the door fan test under the same conditions that would be expected during a system discharge.

C.2.6 Install the appropriate door fan apparatus in accordance with the manufacturer’s instructions (placement of the fan, sealing, etc.) based on the size of the enclosure.

C.2.7 A pressure differential, called the bias pressure difference, will naturally exist across the enclosure envelope when the fan is not running. Large bias pressures will increase the uncertainty of the door fan test results. This bias pressure is normally measured by the contractor for the following conditions:

A. The bias pressure present during the actual enclosure integrity test.

B. The bias pressure expected during the agent hold time. This may need to be estimated rather than specifically measured.

Address any excessive bias pressures (i.e., greater than 25% of the initial column pressure caused by the clean agent discharge), which may be caused by leakage from dampers, ducts, continued operation of HVAC equipment, etc.

C.3 Test Considerations

C.3.1 Conduct testing in accordance with the applicable code or standard to determine the leakage of the entire enclosure envelope.

C.3.1.1 The enclosure is pressurized to various negative and positive pressures using the door fan apparatus, and the air flow is measured. Arrange the door fan to both pressurize and depressurize the enclosure, and record both measurements. The door fan flow measurement system is turned around accordingly to measure the pressurization or depressurization.

C.3.1.2 Note that some codes include an optional test method to determine the leakage area below any suspended ceilings, assuming that the system is not designed to protect the area above the suspended ceiling.

C.3.2 Ensure the test equipment and personnel conducting the test are in accordance with the applicable code or standard being applied, including the following:

A. The contractor performing the test is trained and authorized to do so.

B. The test equipment used is in accordance with what is specified in the code. Note that some codes and standards may allow alternative test equipment, such as acoustic sensors.

C. The test equipment is properly calibrated.

C.4 Calculations

C.4.1 Standard calculations are specified in most relevant codes and standards (NFPA 2001, ISO 14520, EN 15004, etc.). The measured inputs from the door fan test (pressure, flow, etc.) are used in these calculations to determine the average pressure and flow over the series of tests.

C.4.2 The process for determining the agent hold time varies depending on the clean agent and the potential for continuous mixing of the agent following discharge.

C.4.2.1 If the agent is heavier than air, a descending interface is expected to occur. Uniform mixing will occur upon discharge, followed by an interface forming as the agent settles and fresh air enters the room at the top of the enclosure through natural leakage from holes, penetrations, cracks, etc. Note that the NFPA 2001 model assumes a sharp interface between the agent and fresh air, but some mixing and spreading of the interface will actually occur as compared to the ISO 1452 model, which uses a wide interface. The NFPA 2001 calculation method therefore produces a conservative result. See Figure C.4.2.1.

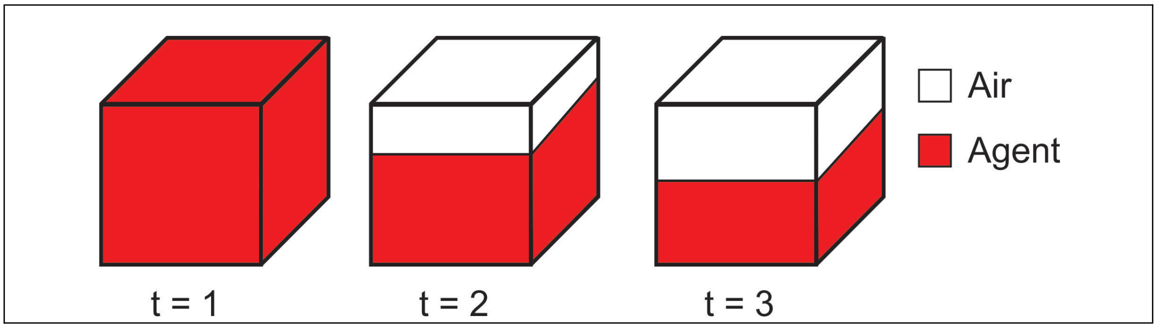

Fig. C.4.2.1. Sharp descending interface

An important consideration, therefore, is the highest level of equipment, combustible materials, and other potential fire sources within the enclosure. The descending interface should not fall below this height for the duration of the agent hold time (i.e., the duration of protection specified in Section 2.2.5).

C.4.2.2 If continual mixing is expected to occur (e.g., due to mechanical ventilation), a descending interface is not assumed to form. Continuous mixing of the clean agent may be necessary to maintain the required extinguishing concentration due to combustibles located near the ceiling (e.g., combustible cables). See Figure C.4.2.2. A different set of calculations are used to determine the time that for the concentration within the enclosure to drop from the initial concentration to the minimum concentration at the end of the hold time.

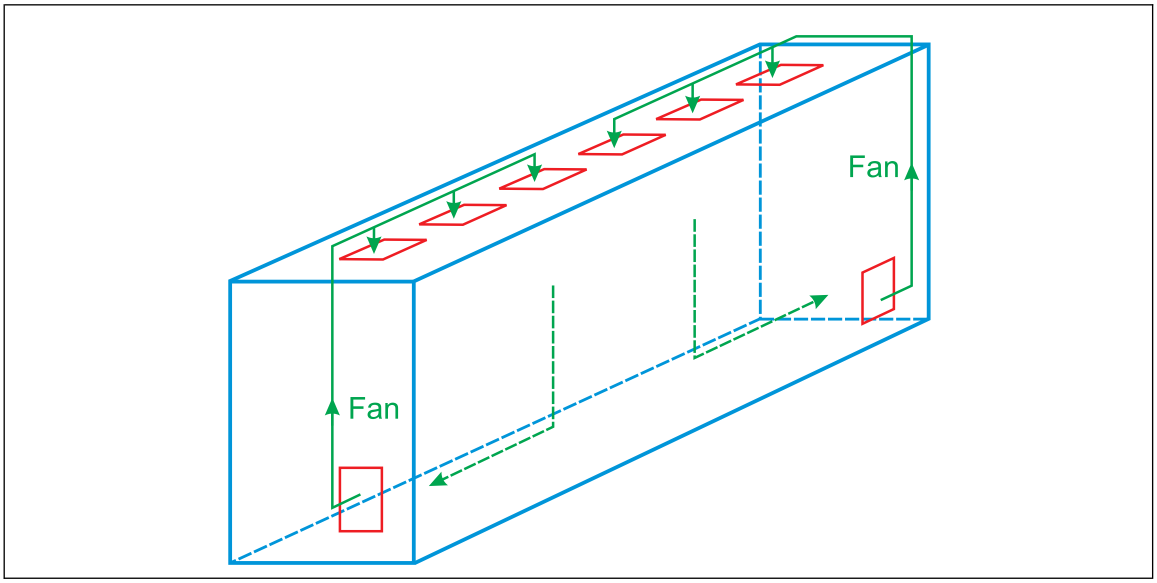

Fig. C.4.2.2. Continuous agent mixing

C.4.3 The door fan test will also yield measurements needed to determine the enclosure's equivalent leakage area. The equivalent leakage area is the combined area of cracks, joints, and other leakage sources in the enclosure. The equivalent leakage area may be used in determining necessary relief venting (see Section 2.1.2 and Appendix D).

For existing installations, where venting is already installed, the vent performance can also be evaluated during this test.

APPENDIX D ENCLOSURE PRESSURE-RELIEF VENTING SYSTEM

D.1 Introduction

A characteristic of clean agent fire protection systems is the potential overpressurization or underpressurization of the protected enclosure, or a combination of both. Inert gases and some halocarbons cause an immediate spike in pressure following discharge. Most halocarbons, however, are characterized by an initial temperature drop upon discharge resulting in depressurization of the room, followed shortly by a smaller overpressurization. As no room is completely air-tight, some natural pressure stabilization may occur due to leakage through cracks in the walls, windows, doors, and other seals. These natural leaks all contribute to an equivalent leakage area, which can be quantified via a door fan test. However, the rapid change in pressure can exceed the enclosure's natural leakage, causing the damage to the room and allowing the clean agent to escape before fire extinguishment.

Instead of relying on an enclosure's equivalent leakage area, which often changes over time due to modifications or settling of the building, a better solution is an engineered venting system specific to the enclosure and clean agent system. This venting system must limit the over/under-pressurization in the room below the structural strength of the walls, windows, doors, etc., while simultaneously maintaining a suitable agent concentration within the room for the specified duration.

D.2 Determination of Enclosure Pressures

Clean agent system manufacturers typically provide guidance on pressure relief venting in the design, installation, operation, and maintenance manual. Design information is also provided in various publications, such as ISO TS 21805 (E), Guidance on Design, Selection and Installation of Vents to Safeguard the Structural Integrity of Enclosures Protected by Gaseous Fire-Extinguishing Systems, and the Fire Suppression Systems Association's Guide to Estimating Pressure Relief Vent Areas.

These documents provide guidance for determining the amount of free venting area required to prevent excessive positive and negative pressure within the protected enclosure. As discussed in Appendix C, door fan test procedures allow for the determination of peak enclosure pressures from system discharges and the necessary venting to prevent enclosure damage. The following information, at a minimum, is generally needed to determine the peak enclosure pressure and necessary pressure relief area:

- Volume of enclosure
- Type of clean agent used in the system
- Design concentration
- Discharge time
- Relative humidity (for halocarbons, lower humidity will result in more dramatic cooling, resulting in larger negative peak pressures)
- Equivalent Leakage Area (i.e., as determined by a door fan test)
- Enclosure strength

D.3 Equivalent Leakage Area

The door fan test can determine the enclosure's equivalent leakage area, which is the combined area of natural venting in the room due to cracks, seals, etc. Some jurisdictions will allow the use of this area as part of the required pressure relief. For instance, in the United States, enclosure designs will typically account for any natural leakage and only incorporate additional pressure relief vents if the under- or over-pressurization remains too high. Conversely, Europe generally designs enclosures as tight as possible resulting in the need for pressure relief vents. Additionally, the equivalent leakage area is usually ignored in the design, which produces a more conservative result with regard to the peak enclosure pressure at system discharge.

D.4 Damper Types

Once the necessary vent area is determined, a number of damper types are available to achieve the necessary venting, as follows:

A. Backdraft Dampers

- Non-motorized uni-directional flow dampers, usually constructed of steel or aluminum.
- Because they are only uni-directional, only used for inert gas systems or HFC-23 systems.
- Typical equivalent free flow area is between 55 and 80% of total frontal area.
- Not air tight when closed and can contribute to equivalent leakage area.

B. Pressure Relief Dampers

- Also known as balanced blade vents and dampers.
- Similar to backdraft dampers, but have weights and manually adjustable levers for relieving pressure in a room above a certain point.
- Typical equivalent free flow area is between 55% and 80% of total frontal area.

C. Clean Agent Pressure Relief Vents and Dampers

- Made specifically for the purposes of clean agent enclosure venting.
- Can be installed as uni-directional vents for inert gas systems or bi-directional vents for halocarbon systems.
- Spring powered damper blades only open when a specified differential pressure is exceeded, and close when the differential pressure drops below that set point.

D. Motorized Dampers

- A motor keeps the damper closed; a spring returns the damper blade to an open position once the motor is turned off.
- Once pressure is equalized, a control module powers the damper closed.
- Motorized dampers are generally tight and do not contribute significantly to the equivalent leakage area.

E. Pneumatic Dampers

- Similar to motorized dampers, but have a pneumatic actuator operated with compressed air.
- Less common as they are more mechanically involved and expensive.

D.5 Venting Design Considerations

D.5.1 Minimum Opening and Closing Pressures

The opening and closing damper pressures will vary for each system, installation, and accessory components. The pressure set points must be carefully considered to maintain structural integrity of the enclosure. Even after a vent opens, the pressure in the enclosure will continue to rise. The opening pressure must be set low enough to prevent enclosure damage. Conversely, non-motorized dampers such as backdraft dampers are notoriously leaky. If these dampers open too easily, weights may be needed to increase the resistance.

D.5.2 Vent Direction

For halocarbon clean agents, due to the negative pressure at discharge followed by a positive pressure within the enclosure, bi-directional vents are needed. Alternatively, two uni-directional vents can be used, with each installed in an opposite direction. Bi-directional venting is not an issue for inert gases.

D.5.3 Vent Selection

A number of considerations will impact the selection of a vent, including the need necessary free flow area, the need for bi-directional venting, opening and closing pressures, and cost, among other factors.

D.5.4 Vent Placement

Vents must be placed such that they cannot be obstructed, are out of the way of normal work activity, and are away from discharge nozzles to avoid directly venting agent from the room. This can be accomplished in part by placing the vents as high as possible. Additionally, placing the vents high in the enclosure ensures that for a descending interface, air is being vented rather than the agent.

D.5.5 Efficiency

All types of dampers limit effective free-flow area in some way. Additionally, various accessories, such as exterior louvers, hoods, and insect screens, may further reduce the effective vent area. Relief ducts must be sized to adjust for the collective loss of pressure in the entirety of the pressure relief system.

D.5.6 Venting Pathways

The most preferred form of venting is directly to the outdoors. This often necessitates the use of accessories such as ducts, exterior louvers, and other components that decrease the effectiveness of the venting system. Other considerations include venting away from heavy traffic areas, as the exhausted gases will contain inert gas or halocarbons, as well as products of combustion.

Venting outdoors may not be feasible, and alternative pathways can often be used. For example, venting to an adjacent space. The secondary enclosure must be suitably large to withstand the increased pressure. The structural integrity of both rooms must be considered: if the secondary room is not large enough for the primary room to vent into, the walls of the primary room may be compromised. For this reason, venting into a ceiling cavity is often not possible, as these areas are generally not large enough to relieve pressure from the primary room. Consideration must also be given to impact of the vented gases in the secondary space.

Cascade venting compounds the issues inherent with secondary enclosure venting. It occurs when adjacent spaces are not large enough to accommodate the pressure from the system discharge, and multiple rooms must be used for the vented gas. Enough of a pressure differential must exist to allow the vented gas to flow into each subsequent space. If the necessary differential pressure is not reached and intermediary vents do not open, there is a risk that the pressure will exceed the strength of the adjacent space(s). This pressure differential, as well as the strength of each individual enclosure, must be considered.

D.5.7 Inspection, Testing, and Maintenance

Like other components of a clean agent system, vents require a degree of ongoing inspection and maintenance. This will vary depending on the type of vent, but may include the following activities:

- Visual inspection to ensure the vent is installed in the appropriate direction
- Testing to ensure the vent fully opens
- Confirmation that the vents are unobstructed
- Testing of motorized dampers to make sure they open as part of the alarm sequence and close at the appropriate time