2001

NFPA 2001
Standard on Clean Agent Fire Extinguishing Systems
1996 Edition

NFPA

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Standards-Making Organization

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Policy Adopted by NFPA Board of Directors on December 3, 1982

The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

Statement on NFPA Procedures

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Errata

NFPA 2001

Standard on Clean Agent Fire Extinguishing Systems

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Reference: Table A-2-2.3.1
Errata No.: 2001-96-1

The Committee on Halon Alternative Protection Options notes the following error in the 1996 edition of NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems.*

1. *Revise Table A-2-2.3.1 to read as follows:*

Table A-2-2.3.1 Piping System Fittings

Clean Agent	Initial Charging Pressure (*up to and Including*)	Acceptable Fittings	Maximum Pipe Size
All Halocarbon Agents	360 psig (2482 kPa)	Class 300 malleable or ductile iron fittings	3 in. NPS
		1000-lb rated ductile iron or forged steel fittings	> 3 in. NPS
		Class 300 flanged joints	All
	600 psig (4137 kPa)	Class 300 malleable or ductile iron fittings	3 in. NPS
		1000-lb rated ductile iron or forged steel fittings	> 3 in. NPS
		Class 600 flanged joints	All
HFC-23	609 psig (4199 kPa)	Class 300 malleable or ductile iron fittings	2 in. NPS
		1000-lb rated ductile iron or forged steel fittings	> 3 in. NPS
		Class 300 flanged joints	All - Downstream of any stop valve or in systems with no stop valve
		Class 600 flanged joints	All - Upstream of any stop valve.
IG-541	2175 psig (14,997 kPa)		
	Upstream of the pressure reducer	2000-lb forged steel	All
	Downstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
		1000-lb rated ductile iron or forged steel	> 3 in. NPS
		Class 600 flanged joints	All
	2900 psig (19,996 Pa)		
	Upstream of the pressure reducer	3000-lb forged steel	All
	Downstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
		1000-lb rated ductile iron or forged steel	> 3 in. NPS
		Class 600 flanged joints	All
IG-01	2370 psig (16,341 kPa)		
	Upstream of the pressure reducer	3000-lb forged steel	All
	Downstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
		1000-lb rated ductile iron or forged steel	> 3 in. NPS
		Class 600 flanged joints	All
IG-55	2222 psig (15,521 kPa)		
	Upstream of the pressure reducer	3000-lb forged steel	All
	Downstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
		1000-lb rated ductile iron or forged steel	> 3 in. NPS
		Class 600 flanged joints	All
	2962 psig (20,424 kPa)		
	Upstream of the pressure reducer	3000-lb forged steel	All
	Downstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
		1000-lb rated ductile iron or forged steel	> 3 in. NPS
		Class 600 flanged joints	All
	4443 psig (30,636 kPa)		
	Upstream of the pressure reducer	3000-lb forged steel	1 in. NPS
		6000-lb forged steel	> 1 in. NPS
	Downstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
		1000-lb rated ductile iron or forged steel	> 3 in. NPS
		Class 600 flanged joints	All

NOTE: The materials itemized above do not preclude the use of other materials and type and/or style of fittings that satisfy the requirements of 2-2.3.1.

Issue Date: December 3, 1996

NFPA 2001

Standard on

Clean Agent Fire Extinguishing Systems

1996 Edition

This edition of NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, was prepared by the Technical Committee on Alternative Protection Options to Halon and acted on by the National Fire Protection Association, Inc., at its Fall Meeting held November 13-15, 1995, in Chicago, IL. It was issued by the Standards Council on January 12, 1996, with an effective date of February 2, 1996, and supersedes all previous editions.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 2001 has been submitted to the American National Standards Institute for approval as an American National Standard.

Origin and Development of NFPA 2001

The Technical Committee on Alternative Protection Options to Halon was organized in 1991, and immediately started work to address the new total flooding clean agents that were being developed to replace Halon 1301. A need existed on how to design, install, maintain, and operate systems using these new clean agents, and NFPA 2001 was established to address these needs. The 1994 edition was the first edition of NFPA 2001.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on alternative protection options to Halon 1301 and 1211 fire extinguishing systems. It shall not deal with design, installation, operation, testing, and maintenance of systems employing carbon dioxide, dry chemical, wet chemical, foam, Halon 1301, Halon 1211, Halon 2402, or water as the primary extinguishing media.

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Clean Agent Fire Extinguishing Systems

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Information on referenced publications can be found in Chapter 5 and Appendix C.

Chapter 1 General

1-1 Scope. This standard contains minimum requirements for total flooding, clean agent fire extinguishing systems. It does not cover fire extinguishing systems that use carbon dioxide, Halon 1301, Halon 1211, Halon 2402, or water, which are addressed by other NFPA documents.

1-2 Purpose.

1-2.1 The agents in this standard were introduced in response to international restrictions on the production of certain halon fire extinguishing agents under the Montreal Protocol signed September 16, 1987, as amended. This standard is prepared for the use and guidance of those charged with purchasing, designing, installing, testing, inspecting, approving, listing, operating, and maintaining engineered or pre-engineered clean agent extinguishing systems, so that such equipment will function as intended throughout its life. Nothing in this standard is intended to restrict new technologies or alternate arrangements provided the level of safety prescribed by this standard is not lowered.

1-2.2 No standard can be promulgated that will provide all the necessary criteria for the implementation of a total flooding, clean agent fire extinguishing system. Technology in this area is under constant development, and this will be reflected in revisions to this standard. The user of this standard must recognize the complexity of clean agent fire extinguishing systems. Therefore, the designer is cautioned that the standard is not a design handbook. The standard does not do away with the need for the engineer or for competent engineering judgment. It is intended that a designer capable of applying a more complete and rigorous analysis to special or unusual problems shall have latitude in the development of such designs. In such cases, the designer is responsible for demonstrating the validity of the approach.

1-3 Definitions and Units.

1-3.1 Definitions. For purpose of clarification, the following general terms used with special technical meanings in this standard are defined:

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Class A Fires. Fires in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics.

Class B Fires. Fires in flammable liquids, oils, greases, tars, oil-base paints, lacquers, and flammable gases.

Class C Fires. Fires that involve energized electrical equipment where the electrical nonconductivity of the extinguishing media is of importance.

Clean Agent. Electrically nonconducting, volatile, or gaseous fire extinguishant that does not leave a residue upon evaporation. The word "agent" as used in this document shall mean "clean agent" unless otherwise indicated.

Clearance. The air distance between clean agent equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components at other than ground potential.

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

Fill Density. The mass of clean agent per unit of container volume (e.g., lb/ft^3, kg/m^3).

Halocarbon Agent. A clean agent that contains as primary components one or more organic compounds containing one or more of the elements fluorine, chlorine, bromine, or iodine. Examples are hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs or FCs), and fluoroiodocarbons (FICs).

Inert Gas Agent. A clean 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.

Listed.* Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

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

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

Normally Occupied Area.* One that is intended for occupancy.

Pre-Engineered Systems. Those having predetermined flow rates, nozzle pressures, and quantities of clean 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. The hazards protected by these systems are specifically limited as to type and size by a testing laboratory based upon actual fire tests. Limitations on hazards that can be protected by these systems are contained in the manufacturer's installation manual, which is referenced as part of the listing.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Superpressurization. The addition of a gas to the fire suppression agent container necessary to achieve the pressure required for proper system operation.

Total Flooding. A system consisting of a supply of clean agent arranged to discharge into, and fill to the proper concentration, an enclosed space or enclosure about the hazard.

1-3.2 Units.

1-3.2.1 Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI). Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection. These units are listed in Table 1-3.2 with conversion factors.

1-3.2.2 If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value might be approximate.

Table 1-3.2 Metric Conversion Factors

Name of Unit	Unit Symbol	Conversion Factor
millimeter	mm	1 in. = 25.4 mm
liter	L	1 gal = 3.785 L
cubic decimeter	dm^3	1 gal = 3.785 dm^3
cubic meter	m^3	1 ft^3 = 0.028317 m^3
kilogram	kg	1 lb = 0.4536 kg
kilograms per cubic meter	kg/m^3	1 lb/ft^3 = 16.0183 kg/m^3
pascal	Pa	1 psi = 6895 Pa
bar	bar	1 psi = 0.0689 bar
bar	bar	1 bar = 10^5 Pa

NOTE 1: For additional conversions and information see ASTM E 380, *Standard for Metric Practice*.
NOTE 2: In Canada refer to *Canadian Metric Practice Guide*, CSA Standard CAN3-Z234.1-89.

1-4 General Information.

1-4.1* Applicability of Clean Agents.

1-4.1.1 The clean agents addressed in this standard are electrically nonconductive agents that extinguish fires and leave no residue upon evaporation.

1-4.1.2* Clean agents that meet the criteria of 1-4.1.1 and are discussed in this standard are shown in Table 1-4.1.2.

Table 1-4.1.2 Clean Agents Addressed in this Standard

FC-3-1-10	Perfluorobutane	C_4F_{10}
HCFC Blend A	Dichlorotrifluoroethane HCFC-123 (4.75%)	$CHCl_2CF_3$
	Chlorodifluoromethane HCFC-22 (82%)	$CHClF_2$
	Chlorotetrafluoroethane HCFC-124 (9.5%)	$CHClFCF_3$
	Isopropenyl-1-methylcyclohexene (3.75%)	
HCFC-124	Chlorotetrafluoroethane	$CHClFCF_3$
HFC-125	Pentafluoroethane	CHF_2CF_3
HFC-227ea	Heptafluoropropane	CF_3CHFCF_3
HFC-23	Trifluoromethane	CHF_3
HFC-236fa	Hexafluoropropane	$CF_3CH_2CF_3$
FIC-1311	Trifluo458CF_3I	
IG-01	Argon (99.9%)	Ar
IG-541	Nitrogen (52%)	N_2
	Argon (40%)	Ar
	Carbon dioxide (8%)	CO_2
IG-55	Nitrogen (50%)	N_2
	Argon (50%)	Ar

NOTE 1: Other agents might become available at later dates. They might be added via the NFPA process in future editions or amendments of the standard.
NOTE 2: Composition of inert gas agents are given in percent by volume. Composition of HCFC Blend A is given in percent by weight.

1-4.1.3 The design, installation, service, and maintenance of clean agent systems shall be performed by those skilled in clean agent fire extinguishing system technology.

1-4.2 Use and Limitations.

1-4.2.1 Pre-engineered systems consist of system components designed to be installed according to pretested limitations as listed by a testing laboratory. Pre-engineered systems might incorporate special nozzles, flow rates, methods of application, nozzle placement, and pressurization levels that might differ from those detailed elsewhere in this standard. All other requirements of the standard apply. Pre-engineered systems shall be installed to protect hazards within the limitations that have been established by the testing laboratories where listed.

1-4.2.2 Clean agent fire extinguishing systems are useful within the limits of this standard in extinguishing fires in specific hazards or equipment and in occupancies where an electrically nonconductive medium is essential or desirable, or where cleanup of other media presents a problem.

1-4.2.3* Total flooding, clean agent fire extinguishing systems are used primarily to protect hazards that are in enclosures or equipment that, in itself, includes an enclosure to contain the agent. Some typical hazards that might be suitable include, but are not limited to, the following:

(a) Electrical and electronic hazards;

(b) Telecommunications facilities;

(c) Flammable and combustible liquids and gases; and

(d) Other high value assets.

1-4.2.4* Clean agent systems might also be used for explosion prevention and suppression where flammable materials might collect in confined areas.

1-4.2.5 Clean agents shall not be used on fires involving the following materials unless they have been tested to the satisfaction of the authority having jurisdiction:

(a) Certain chemicals or mixtures of chemicals, such as cellulose nitrate and gunpowder, that are capable of rapid oxidation in the absence of air;

(b) Reactive metals such as lithium, sodium, potassium, magnesium, titanium, zirconium, uranium, and plutonium;

(c) Metal hydrides; or

(d) Chemicals capable of undergoing autothermal decomposition, such as certain organic peroxides and hydrazine.

1-4.2.6 Electrostatic charging of nongrounded conductors might occur during the discharge of liquefied gases. These conductors might discharge to other objects, causing an electric arc of sufficient energy to initiate an explosion. (*See NFPA 77, Recommended Practice on Static Electricity.*)

1-4.2.7 Where clean agent systems are used, a fixed enclosure shall be provided about the hazard that is adequate to enable the specified concentration to be achieved and maintained for the specified period of time.

1-4.2.8* The effects of agent decomposition on fire protection effectiveness and equipment shall be considered where using clean agents in hazards with high ambient temperatures (e.g., furnaces and ovens).

1-5 Safety.

1-5.1* Hazards to Personnel.

1-5.1.1* Any agent that is to be recognized by this standard as acceptable for use in normally occupied spaces shall first be evaluated in a manner equivalent to the process used by the U.S. Environmental Protection Agency's SNAP Program.

NOTE: The U.S. Environmental Protection Agency's SNAP Program was originally outlined in *Federal Register* 59 FR 13044.

1-5.1.2* Halocarbon Clean Agents.

1-5.1.2.1 Unnecessary exposure to all halocarbon clean agents and their decomposition products shall be avoided. Halocarbon agents for which the design concentration is equal to or less than the NOAEL shall be permitted for use in normally occupied areas. Halocarbon agents for which the design concentration is greater than the NOAEL shall not be permitted for use in normally occupied areas.

Exception: For Class B hazards and where acceptable to the authority having jurisdiction, concentrations up to the LOAEL shall be permitted in normally occupied areas where a predischarge alarm and time delay are provided. The time delay shall be set to ensure that the occupants of the enclosure under consideration have time to evacuate prior to the start of discharge.

1-5.1.2.2 To maintain oxygen concentrations above 16 percent (sea level equivalent), the point at which onset of impaired personnel function occurs, no halocarbon fire extinguishing agents of concentration greater than 24 percent addressed in this standard shall be used in a normally occupied area.

1-5.1.3* Inert Gas Clean Agents. No inert gas agent with a design concentration above 43 percent, which corresponds to an oxygen concentration of 12 percent (sea level equivalent), shall be permitted for use in normally occupied areas.

Exception: For Class B hazards and where acceptable to the authority having jurisdiction, concentrations up to 53 percent, which corresponds to an oxygen concentration of 10 percent (sea level equivalent), are permitted in normally occupied areas where a predischarge alarm and time delay are provided. The time delay shall be set to ensure that the occupants of the enclosure under consideration have time to evacuate prior to the start of discharge.

1-5.1.4 Safety Requirements.

1-5.1.4.1* For fire situations, suitable safeguards shall be provided to ensure prompt evacuation of and prevent entry into hazardous atmospheres and also to provide means for prompt rescue of any trapped personnel. Safety items such as personnel training, warning signs, discharge alarms, self-contained breathing apparatus, evacuation plans, and fire drills shall be considered.

1-5.1.4.2* Consideration shall be given to the possibility of a clean agent migrating to adjacent areas outside of the protected space.

1-5.2 Electrical Clearances.

1-5.2.1 All system components shall be located to maintain no less than minimum clearances from energized electrical parts. The following references shall be considered as the minimum electrical clearance requirements for the installation of clean agent systems:

(a) ANSI C-2, *National Electrical Safety Code*

(b) NFPA 70, *National Electrical Code*®

(c) 29 CFR 1910 Subpart S.

1-5.2.2 Where the design basic insulation level (BIL) is not available, and where nominal voltage is used for the design criteria, the highest minimum clearance listed for this group shall be used.

1-5.2.3 The selected clearance to ground shall satisfy the greater of the switching surge or BIL duty, rather than being based on nominal voltage.

1-5.2.4 The clearance between uninsulated energized parts of the electrical system equipment and any portion of the clean agent system shall not be less than the minimum clearance provided elsewhere for electrical system insulations on any individual component.

1-5.2.5 Where BIL is not available and where nominal voltage is used for the design criteria, the highest minimum clearance listed for this group shall be used.

1-6* Environmental Factors. When an agent is being selected to protect a hazard area, the effects of the agent on the environment shall be considered. Selection of the appropriate fire suppressant agent shall include consideration of the following items:

(a) Potential environmental effect of a fire in the protected area; and

(b) Potential environmental effect of the various agents that might be used.

1-7 Retrofitability. Retrofitting of any clean agent into an existing fire extinguishing system shall result in a system that is listed or approved.

1-8 Compatibility with Other Agents.

1-8.1* Mixing of clean agents in the same container shall be permitted only if the system is listed.

1-8.2 Systems employing the simultaneous discharge of different clean agents to protect the same enclosed space shall not be permitted.

Chapter 2 Components

2-1 Agent Supply.

2-1.1 Quantity.

2-1.1.1 The amount of clean agent in the system shall be at least sufficient for the largest single hazard protected or group of hazards that are to be protected simultaneously. This quantity of agent is defined as the primary agent supply.

2-1.1.2* Where required, the reserve quantity shall be as many multiples of the primary supply as the authority having jurisdiction considers necessary.

2-1.1.3 Where uninterrupted protection is required, both the primary and the reserve supply shall be permanently connected to the distribution piping and arranged for easy changeover.

2-1.2* Quality. New clean agents shall comply with the standard of quality as shown in Tables 2-1.2(a), 2-1.2(b), and 2-1.2(c). Each manufacturer's batch shall be tested and certified to the tolerances or specifications as indicated in the tables. Clean agent blends shall remain homogeneous in storage and use under the listed temperature range and conditions of service that they will encounter.

Table 2-1.2(a) Halogenated Clean Agent Quality Requirements

	All Clean Agents Listed in Standard
Mole %, minimum	99.0
Acidity ppm (by weight HCl equivalent), maximum	3.0
Water content, % by weight, maximum	0.001
Nonvolatile residues, grams/100 mL maximum	0.05

Table 2-1.2(b) Inert Gas Clean Agent Quality Requirements

		IG-01	IG-541	IG-55
Composition, % by volume	N_2		52% ± 4%	50% ± 5%
	Ar	99.9%	40% ± 4%	50% ± 5%
	CO_2		8% + 1% − 0.0%	
Water content, % by weight		Maximum 0.005	Maximum 0.005	Maximum 0.005

Table 2-1.2(c) Blend Agent Quality Requirements

HCFC Blend A	Agent Quality Requirements
HCFC-22	82 ± 0.8%
HCFC-124	9.50 ± 0.9%
HCFC-123	4.75 ± 0.5%
isopropenyl-1-methylcyclohexene	3.75 ± 0.5%

Note percent by weight.

2-1.3 Storage Container Arrangement.

2-1.3.1 Storage containers and accessories shall be so located and arranged that inspection, testing, recharging, and other maintenance are facilitated and interruption of protection is held to a minimum.

2-1.3.2* Storage containers shall be located as close as possible to or within the hazard or hazards they protect.

2-1.3.3 Storage containers shall not be located so as to be subject to severe weather conditions or to potential damage due to mechanical, chemical, or other causes. Where potentially damaging exposures might exist, suitable enclosures or guards shall be provided.

2-1.3.4 Storage containers shall be securely installed and secured according to the manufacturer's listed installation manual and in a manner that provides for convenient individual servicing or content weighing.

2-1.3.5 Where storage containers are manifolded, automatic means such as a check valve shall be provided to prevent agent loss if the system is operated when any containers are removed for maintenance.

2-1.4 Storage Containers.

2-1.4.1* Storage Containers. The clean agent supply shall be stored in containers designed to hold that specific agent at ambient temperatures. Containers shall not be charged to a fill density or superpressurization level different from the manufacturer's listing.

2-1.4.2* Each agent container shall have a permanent nameplate or other permanent marking that indicates the following:

(a) For halocarbon agent containers, the agent, tare and gross weights, and superpressurization level (where applicable) of the container; or

(b) For inert gas agent containers, the agent, pressurization level of the container, and nominal agent volume.

2-1.4.3 The containers used in these systems shall be designed to meet the requirements of the U.S. Department of Transportation or the Canadian Transport Commission, if used as shipping containers. If not shipping containers, they shall be designed, fabricated, inspected, certified, and stamped in accordance with Section VIII of the ASME *Boiler and Pressure Vessel Code*; independent inspection and certification is recommended. The design pressure shall be suitable for the maximum pressure developed at 130°F (55°C) or at the maximum controlled temperature limit.

2-1.4.4 A reliable means of indication shall be provided to determine the pressure in refillable superpressurized containers.

2-1.4.5 Manifolded Containers.

(a) For halocarbon clean agents in a multiple container system, all containers supplying the same manifold outlet for distribution of the same agent shall be interchangeable and of one select size and charge.

(b) Inert gas agents shall be permitted to utilize multiple storage container sizes connected to a common manifold. Inert gas agents are single-phase gases in storage and at all times during discharge.

2-1.4.6 Storage temperatures shall not exceed or be less than the manufacturer's listed limits. External heating or cooling shall be used to keep the temperature of the storage container within desired ranges.

2-2 Distribution.

2-2.1* Piping.

2-2.1.1* Piping shall be of noncombustible material having physical and chemical characteristics such that its integrity under stress can be predicted with reliability. Special corrosion-resistant materials or coatings shall be required in severely corrosive atmospheres. The thickness of the piping wall shall be calculated in accordance with ASME B31.1, *Power Piping Code*. The internal pressure used for this calculation shall be the maximum pressure in the container at a maximum storage temperature of not less than 130°F (55°C) (use manufacturer's maximum allowable fill density), but in no case shall the value used for the pressure be less than the following:

(a) For clean agents in Table A-2-1.4.1 having a charging pressure up to and including 360 psig (2482 kPa) at 70°F (21°C), use an internal pressure of 620 psig (4275 kPa) at 130°F (55°C).

(b) For HFC-23, use an internal pressure of 2250 psig (15,514 kPa) at 130°F (55°C).

Exception: Steel piping used in HFC-23 systems shall meet the following requirements:

Pipe 1/8 in. through 3/4 in. NPS shall be a minimum of Schedule 40.

Pipe 1 in. through 4 in. NPS shall be a minimum of Schedule 80.

Black or galvanized steel pipe shall be either ASTM A-106 Seamless, Grade A, B, or C; or ASTM A-53 Seamless or Electric Welded, Grade A or B.

ASTM A-120 and ASTM A-53 Class F Furnace Welded Pipe shall not be used.

Table 2-2.1.1 Internal Pressures Used for Calculations

Normal Charging Pressure	Internal Pressure @ 130°F (55°C)	
	Piping upstream of pressure reducer	Piping downstream of pressure reducer
IG-01 charged to 2371 psig (16,341 kPa)	2650 psig (18,972 kPa)	975 psig (6723 kPa)
IG-541 charged to 2175 psig (14,997 kPa)	2575 psig (17,755 kPa)	1000 psig (6895 kPa)
IG-55 charged to 2222 psig (15,318 kPa)	2475 psig (17,065 kPa)	950 psig (6550 kPa)
IG-55 charged to 2962 psig (20,424 kPa)	3300 psig (22,753 kPa)	950 psig (6550 kPa)
IG-55 charged to 4443 psig (30,636 kPa)	4950 psig (34,130 kPa)	950 psig (6550 kPa)

(c) For clean agents in Table 2-1.4.1 having a charging pressure of 600 psig (4137 kPa) at 70°F (21°C), use an internal pressure of 1000 psig (6895 kPa) at 130°F (55°C).

(d) For inert gases use Table 2-2.1.1. The pressure-reducing device shall be readily identifiable.

(e) If higher storage temperatures are approved for a given system, the internal pressure shall be adjusted to the maximum internal pressure at maximum temperature. In performing this calculation, all joint factors and threading, grooving, or welding allowances shall be taken into account.

2-2.1.2 Cast-iron pipe, steel pipe conforming to ASTM A 120, or nonmetallic pipe shall not be used.

2-2.1.3 Stenciled pipe identification shall not be painted over, concealed, or removed prior to approval by the authority having jurisdiction.

2-2.1.4 Where used, flexible piping, tubing, or hoses (including connections) shall be of approved materials and pressure ratings.

2-2.1.5 Each pipe section shall be cleaned internally after preparation and before assembly by means of swabbing, utilizing a suitable nonflammable cleaner. The piping network shall be free of particulate matter and oil residue before installation of nozzles or discharge devices.

2-2.1.6 In sections where valve arrangement introduces sections of closed piping, such sections shall be equipped with pressure relief devices or the valves shall be designed to prevent entrapment of liquid. In systems using pressure-operated container valves, means shall be provided to vent any container leakage that could build up pressure in the pilot system and cause unwanted opening of the container valve. The means of pressure venting shall be arranged so as not to prevent reliable operation of the container valve.

2-2.1.7 All pressure relief devices shall be designed and located so that the discharge from the device will not injure personnel or pose a hazard.

2-2.2 Pipe Joints. Pipe joints other than threaded, welded, brazed, flared, compression, or flanged type shall be listed or approved.

2-2.3 Fittings.

2-2.3.1* Fittings shall have a minimum rated working pressure equal to or greater than the maximum pressure in the container at 130°F (54°C) when filled to the maximum allowable fill density for the clean agent being used, or as otherwise listed or approved. For systems that employ the use of a pressure reducing device in the distribution piping, the fittings downstream of the device shall have a minimum rated working pressure equal to or greater than the maximum anticipated pressure in the downstream piping.

2-2.3.2 Cast-iron fittings shall not be used. Class 150 lb fittings shall not be used unless it can be demonstrated that they comply with the appropriate ANSI stress calculations.

2-2.3.3 All threads used in joints and fittings shall conform to ANSI B1.20.1, *Standard for Pipe Threads, General Purpose,* or ISO 7, *Requirements for Standards Suitable for Product Certification*. Joint compound, tape, or thread lubricant shall be applied only to the male threads of the joint.

2-2.3.4 Welding and brazing alloys shall have a melting point above 1000°F (538°C).

2-2.3.5 Welding shall be performed in accordance with Section IX, "Qualification Standard for Welding and Brazing Procedures, Welders, Brazers and Welding and Brazing Operators," of the ASME *Boiler and Pressure Vessel Code*.

2-2.3.6 Where copper, stainless steel, or other suitable tubing is jointed with compression-type fittings, the manufacturer's pressure temperature ratings of the fitting shall not be exceeded.

2-2.4 Valves.

2-2.4.1 All valves shall be listed or approved for the intended use.

2-2.4.2* All gaskets, o-rings, sealants, and other valve components shall be constructed of materials that are compatible with the clean agent. Valves shall be protected against mechanical, chemical, or other damage.

2-2.4.3 Special corrosion-resistant materials or coatings shall be used in severely corrosive atmospheres.

2-2.5 Discharge Nozzles.

2-2.5.1 Discharge nozzles shall be listed for the intended use. Listing criteria shall include flow characteristics, area coverage, height limits, and minimum pressures. Discharge orifices, and discharge orifice plates and inserts, shall be of a material that is corrosion resistant to the agent used and the atmosphere in the intended application.

2-2.5.2 Special corrosion-resistant materials or coatings shall be required in severely corrosive atmospheres.

2-2.5.3 Discharge nozzles shall be permanently marked to identify the manufacturer as well as the type and size of the orifice.

2-2.5.4 Where clogging by external foreign materials is likely, discharge nozzles shall be provided with frangible discs, blowoff caps, or other suitable devices. These devices shall provide an unobstructed opening upon system operation and shall be located so they will not injure personnel.

2-3 Detection, Actuation, and Control Systems.

2-3.1 General.

2-3.1.1 Detection, actuation, alarm, and control systems shall be installed, tested, and maintained in accordance with appropriate NFPA protective signaling systems standards (*see NFPA 70, National Electrical Code, and NFPA 72, National Fire Alarm Code. In Canada refer to CAN/ULC S524-M86, Standard for the Installation of Fire Alarm Systems, and CAN/ULC S529-M87, Smoke Detectors for Fire Alarm Systems*).

2-3.1.2 Automatic detection and automatic actuation shall be used.

Exception: Manual-only actuation shall be permitted if acceptable to the authority having jurisdiction.

2-3.1.3 Initiating and releasing circuits shall be installed in raceways. AC and dc wiring shall not be combined in a common conduit or raceway.

Exception: AC and dc wiring shall be permitted to be combined in a common conduit or raceway where shielded and grounded.

2-3.2 Automatic Detection.

2-3.2.1* Automatic detection shall be by any listed method or device capable of detecting and indicating heat, flame, smoke, combustible vapors, or an abnormal condition in the hazard, such as process trouble, that is likely to produce fire.

NOTE: Detectors installed at the maximum spacing as listed or approved for fire alarm use may result in excessive delay in agent release, especially where more than one detection device is required to be in alarm before automatic actuation results.

2.3.2.2 Adequate and reliable primary and 24-hour minimum standby sources of energy shall be used to provide for operation of the detection, signaling, control, and actuation requirements of the system.

2-3.2.3 When a new clean agent system is being installed in a space that has an existing detection system, an analysis shall be made of the detection devices to assure that the detection system is in good operating condition and will respond promptly to a fire situation. This shall be done to assist in limiting the decomposition products from a suppression event.

2-3.3 Operating Devices.

2-3.3.1 Operating devices shall include agent releasing devices or valves, discharge controls, and shutdown equipment necessary for successful performance of the system.

2-3.3.2 Operation shall be by listed mechanical, electrical, or pneumatic means. An adequate and reliable source of energy shall be used.

2-3.3.3 All devices shall be designed for the service they will encounter and shall not readily be rendered inoperative or susceptible to accidental operation. Devices normally shall be designed to function properly from −20°F to 130°F (−29°C to 54°C) or marked to indicate temperature limitations.

2-3.3.4 All devices shall be located, installed, or suitably protected so that they are not subject to mechanical, chemical, or other damage that would render them inoperative.

2-3.3.5 A means of manual release of the system shall be provided. This shall be accomplished by a mechanical manual release, or by an electrical manual release when the control equipment monitors the battery voltage level of the standby battery supply and will provide a low battery signal. The release shall cause simultaneous operation of automatically operated valves controlling agent release and distribution.

2-3.3.6 The normal manual control(s) for actuation shall be located for easy accessibility at all times, including at the time of a fire. The manual control(s) shall be of distinct appearance and clearly recognizable for the purpose intended. Operation of any control shall cause the complete system to operate in its normal fashion.

2-3.3.7 Manual controls shall not require a pull of more than 40 lb (178 N) nor a movement of more than 14 in. (356 mm) to secure operation. At least one manual control for activation shall be located not more than 4 ft (1.2 m) above the floor.

2-3.3.8 Where gas pressure from the system or pilot containers is used as a means for releasing the remaining containers, the supply and discharge rate shall be designed for releasing all of the remaining containers.

2-3.3.9 All devices for shutting down supplementary equipment shall be considered integral parts of the system and shall function with the system operation.

2-3.3.10 All manual operating devices shall be identified as to the hazard they protect.

2-3.4 Control Equipment.

2-3.4.1 Electric Control Equipment. The control equipment shall supervise the actuating devices and associated wiring and, as required, cause actuation. The control equipment shall be specifically listed for the number and type of actuating devices utilized, and their compatibility shall have been listed.

2-3.4.2 Pneumatic Control Equipment. Where pneumatic control equipment is used, the lines shall be protected against crimping and mechanical damage. Where installations could be exposed to conditions that could lead to loss of integrity of the pneumatic lines, special precautions shall be taken to ensure that no loss of integrity will occur. The control equipment shall be specifically listed for the number and type of actuating devices utilized, and their compatibility shall have been listed.

2-3.5 Operating Alarms and Indicators.

2-3.5.1 Alarms or indicators or both shall be used to indicate the operation of the system, hazards to personnel, or failure of any supervised device. The type (audible, visual, or olfactory), number, and location of the devices shall be such that their purpose is satisfactorily accomplished. The extent and type of alarms or indicator equipment or both shall be approved.

2-3.5.2 Audible and visual predischarge alarms shall be provided within the protected area to give positive warning of impending discharge. The operation of the warning devices shall be continued after agent discharge until positive action has been taken to acknowledge the alarm and proceed with appropriate action.

2-3.5.3* Abort switches generally are not recommended. However, where provided, the abort switches shall be located within the protected area and shall be located near the means of egress for the area. An abort switch shall not be operated unless the cause for the condition is known and corrective action can be taken. The abort switch shall be of a type that requires constant manual pressure to cause abort. The abort switch shall not be of a type that would allow the system to be left in an aborted mode without someone present. In all cases the normal and manual emergency control shall override the abort function. Operation of the abort function shall result in both audible and distinct visual indication of system impairment. The abort switch shall be clearly recognizable for the purpose intended.

2-3.5.4 Alarms indicating failure of supervised devices or equipment shall give prompt and positive indication of any failure and shall be distinctive from alarms indicating operation or hazardous conditions.

2-3.5.5 Warning and instruction signs at entrances to and inside protected areas shall be provided.

2-3.5.6 Time Delays.

2-3.5.6.1 Where systems are designed to concentrations above NOAEL and up to LOAEL, a predischarge alarm and time delay shall be provided. For systems designed to the NOAEL, where a discharge delay does not significantly increase the threat to life or property, clean agent extinguishing systems shall incorporate a predischarge alarm with a time delay sufficient to allow personnel evacuation prior to discharge.

Where inert gas clean agent systems are designed to concentrations between 43 percent and 53 percent, a predischarge alarm and time delay shall be provided. For inert gas clean agent systems designed to a concentration up to 42 percent, where a discharge delay does not significantly increase the threat to life or property, inert gas clean agent extinguishing systems shall incorporate a predischarge alarm with a time delay sufficient to allow personnel evacuation prior to discharge.

2-3.5.6.2 Time delays shall be used only for personnel evacuation or to prepare the hazard area for discharge.

2-3.5.6.3 Time delays shall not be used as a means of confirming operation of a detection device before automatic actuation occurs.

2-3.6* Unwanted System Operation. Care shall be taken to thoroughly evaluate and correct any factors that could result in unwanted discharges.

Chapter 3 System Design

3-1 Specifications, Plans, and Approvals.

3-1.1 Specifications. Specifications for clean agent fire extinguishing systems shall be prepared under the supervision of a person fully experienced and qualified in the design of clean agent extinguishing systems and with the advice of the authority having jurisdiction. The specifications shall include all pertinent items necessary for the proper design of the system such as the designation of the authority having jurisdiction, variances from the standard to be permitted by the authority having jurisdiction, design criteria, system sequence of operations, the type and extent of the approval testing to be performed after installation of the system, and owner training requirements.

3-1.2 Working Plans.

3-1.2.1 Working plans and calculations shall be submitted for approval to the authority having jurisdiction before installation or remodeling begins. These documents shall be prepared only by persons fully experienced and qualified in the design of clean agent extinguishing systems. Deviation from these documents shall require permission of the authority having jurisdiction.

3-1.2.2 Working plans shall be drawn to an indicated scale, and shall show the following items that pertain to the design of the system:

(a) Name of owner and occupant;

(b) Location, including street address;

(c) Point of compass and symbol legend;

(d) Location and construction of protected enclosure walls and partitions;

(e) Location of fire walls;

(f) Enclosure cross section, full height or schematic diagram, including location and construction of building floor/ceiling assemblies above and below, raised access floor and suspended ceiling;

(g) Type of clean agent being used;

(h) Design extinguishing or inerting concentration;

(i) Description of occupancies and hazards being protected, designating whether or not the enclosure is normally occupied;

(j) Description of exposures surrounding the enclosure;

(k) Description of the agent storage containers used including internal volume, storage pressure, and nominal capacity expressed in units of agent mass, or volume at standard conditions of temperature and pressure;

(l) Description of nozzle(s) used including size, orifice port configuration, and equivalent orifice area;

(m) Description of pipe and fittings used including material specifications, grade, and pressure rating;

(n) Description of wire or cable used including classification, gauge (AWG), shielding, number of strands in conductor, conductor material, and color coding schedule. Segregation requirements of various system conductors shall be clearly indicated. The required method of making wire terminations shall be detailed;

(o) Description of the method of detector mounting;

(p) Equipment schedule or bill of materials for each piece of equipment or device showing device name, manufacturer, model or part number, quantity, and description;

(q) Plan view of protected area showing enclosure partitions (full and partial height); agent distribution system including agent storage containers, piping, and nozzles; type of pipe hangers and rigid pipe supports; detection, alarm, and control system including all devices and schematic of wiring interconnection between them; end-of-line device locations; location of controlled devices such as dampers and shutters; location of instructional signage;

(r) Isometric view of agent distribution system showing the length and diameter of each pipe segment; node reference numbers relating to the flow calculations; fittings including reducers and strainers; orientation of tees, nozzles including size, orifice port configuration, flow rate, and equivalent orifice area;

(s) Scale drawing showing the layout of the annunciator panel graphics if required by the authority having jurisdiction;

(t) Details of each unique rigid pipe support configuration showing method of securement to the pipe and to the building structure;

(u) Details of the method of container securement showing method of securement to the container and to the building structure;

(v) Complete step-by-step description of the system sequence of operations including functioning of abort and maintenance switches, delay timers, and emergency power shutdown;

(w) Point-to-point wiring schematic diagrams showing all circuit connections to the system control panel and graphic annunciator panel;

(x) Point-to-point wiring schematic diagrams showing all circuit connections to external or add-on relays;

(y) Complete calculations to determine enclosure volume, quantity of clean agent, and size of backup batteries. Method used to determine number and location of audible and visual indicating devices, and number and location of detectors; and

(z) Details of any special features.

3-1.2.3 The detail on the system shall include information and calculations on the amount of agent; container storage pressure; internal volume of the container; the location, type, and flow rate of each nozzle including equivalent orifice area; the location, size, and equivalent lengths of pipe, fittings, and hose; and the location and size of the storage facility. Pipe size reduction and orientation of tees shall be clearly indicated. Information shall be submitted pertaining to the location and function of the detection devices, operating devices, auxiliary equipment, and electrical circuitry, if used. Apparatus and devices used shall be identified. Any special features shall be adequately explained.

Exception: Pre-engineered systems do not require specifying internal volume of the container, nozzle flow rates, equivalent lengths of pipe and fitting and hose, or flow calculations, when used within their listed limitations. The information required by the listed system design manual, however, shall be made available to the authority having jurisdiction for verification that the system is within its listed limitations.

3-1.2.4 An as-built instruction and maintenance manual that includes a full sequence of operations and a full set of drawings and calculations shall be maintained on site.

3-1.2.5 Flow Calculations.

3-1.2.5.1 Flow calculations along with the working plans shall be submitted to the authority having jurisdiction for approval. The version of the flow calculation program shall be identified on the computer calculation printout.

3-1.2.5.2 Where field conditions necessitate any material change from approved plans, the change shall be submitted for approval.

3-1.2.5.3 When such material changes from approved plans are made, corrected "as installed" plans shall be provided.

3-1.3 Approval of Plans.

3-1.3.1 Plans and calculations shall be approved prior to installation.

3-1.3.2 Where field conditions necessitate any significant change from approved plans, the change shall be approved prior to implementation.

3-1.3.3 When such significant changes from approved plans are made, the working plans shall be updated to accurately represent the system as installed.

3-2 System Flow Calculations.

3-2.1* System flow calculations shall be performed using a calculation method listed or approved by the authority having jurisdiction for the agent. The system design shall be within the manufacturer's listed limitations.

Exception: Pre-engineered systems do not require a flow calculation where used within their listed limitations.

3-2.2 Valves and fittings shall be rated for equivalent length in terms of pipe or tubing sizes with which they will be used. The equivalent length of the container valves shall be listed and shall include siphon tube, valve, discharge head, and flexible connector.

3-2.3 The piping lengths, nozzle, and fitting orientation shall be in accordance with the manufacturer's listed limitations to ensure proper system performance.

3-2.4 If the final installation varies from the prepared drawings and calculations, new drawings and calculations representing the "as built" installation shall be prepared.

3-3 Enclosure.

3-3.1 In the design of total flooding systems, the characteristics of the enclosure shall be considered as part of Section 3-3.

3-3.2 The area of unclosable openings shall be kept to a minimum. The authority having jurisdiction can require pressurization/depressurization or other tests to assure proper performance as defined by this standard.

3-3.3 To prevent loss of agent through openings to adjacent hazards or work areas, openings shall be permanently sealed or equipped with automatic closures. Where reasonable confinement of agent is not practicable, protection shall be extended to include the adjacent connected hazards or work areas.

3-3.4* Forced-air ventilating systems shall be shut down or closed automatically where their continued operation would adversely affect the performance of the fire extinguishment agent system or result in propagation of the fire. Completely self-contained recirculating ventilation systems are not required to shut down. The volume of the system and associated ductwork shall be considered as part of the total hazard volume when determining agent quantities.

Exception: Ventilation systems necessary to ensure safety are not required to be shut down upon system activation. An extended agent discharge shall be provided to maintain the design concentration for the required duration of protection.

3-4 Design Concentration Requirements.

3-4.1 For combinations of fuels, the flame extinguishment or inerting value for the fuel requiring the greatest concentration shall be used unless tests are made on the actual mixture.

3-4.2 For a particular fuel, either flame extinguishment or inerting concentrations shall be used.

3-4.2.1* Inerting.

3-4.2.1.1 The inerting concentrations shall be used where conditions for subsequent reflash or explosion could exist. These conditions are when both:

(a) The quantity of fuel permitted in the enclosure is sufficient to develop a concentration equal to or greater than one-half of the lower flammable limit throughout the enclosure; and

(b) The volatility of the fuel before the fire is sufficient to reach the lower flammable limit in air (maximum ambient temperature or fuel temperature exceeds the close cup flash point temperature) or the system response is not rapid enough to detect and extinguish the fire before the volatility of the fuel is increased to a dangerous level as a result of the fire.

CAUTION: Under certain conditions, it may be dangerous to extinguish a burning gas jet. As a first measure, the gas supply should be shut off.

3-4.2.1.2 The minimum design concentrations used to inert atmospheres involving flammable liquids and gases shall be determined by test plus a 10 percent safety factor.

3-4.2.2* Flame Extinguishment.

3-4.2.2.1 The minimum design concentration for Class B flammable and combustible liquids and flammable gases shall be a demonstrated cup burner extinguishing concentration value for each Class B fuel, plus a 20 percent safety factor. For hazards involving multiple fuels, the value for the fuel requiring the greatest design concentration shall be used.

3-4.2.2.2* The minimum design concentration for Class A surface fires shall be an extinguishing concentration determined by test, as part of a listing program, plus a 20 percent safety factor.

3-4.2.2.3* As a minimum, the listing program shall conform to UL 1058, *Standard for Halogenated Agent Extinguishing System Units*, and UL procedure titled "Fire Extinguishment/Area Coverage Fire Test Procedure for Engineered and Preengineered Clean Agent Extinguishing System Units," or equivalent.

3-5 Total Flooding Quantity.

3-5.1* The amount of halocarbon clean agent required to achieve the design concentration shall be calculated from the following formula:

$$W = V/S\ [C/(100-C)] \qquad (1)$$

$$S = k_1 + k_2\,(T) \qquad (2)$$

Where:

W = weight of clean agent.
T = minimum anticipated temperature of the protected volume.
k_1 and k_2 = constants specific to the clean agent being used. See Table 3-5.1 for values of k_1 and k_2.
C = clean agent design concentration, % by volume.
V = net volume of hazard, ft^3 (m^3) (enclosed volume minus fixed structures impervious to clean agent).
S = $k_1 + k_2$ (T) is a linear equation determined by least squares curve fit techniques from data supplied by the clean agent manufacturers. The zero intercept is k_1 and the slope is k_2.

NOTE: This calculation includes an allowance for the normal leakage from a "tight" enclosuredue to agent expansion.

Table 3-5.1(a) Specific Volume Constants k1 and k2

	°F		°C	
Agents	**k1**	**k2**	**k1**	**k2**
FC-3-1-10	1.409	0.0031	0.0941	0.0003
HCFC Blend A	3.612	0.0079	0.2413	0.00088
HCFC-124	2.3395	0.0058	0.1575	0.0006
HFC-125	2.7200	0.0064	0.1825	0.0007
HFC-227ea	1.885	0.0046	0.1269	0.0005
HFC-23	4.7250	0.0107	0.3164	0.0012
FIC-1311	1.683	0.0044	0.1138	0.0005
IG-01	8.514	0.0185	0.5685	0.00208
IG-541	9.8579	0.2143	0.65799	0.00239
IG-55	9.8809	0.0215	0.6598	0.00242
HFC-236fa	2.098	0.0051	0.1413	0.0006

Table 3-5.1(b) FC-3-1-10 Total Flooding Quantity [1]

Temp -t- (°F)	FC-3-1-10 Specific Vapor Volume -s- (ft^3/lb)	FC-3-1-10 Weight Requirements of Hazard Volume W/V (lb/ft^3) [2] English Units Design Concentration (% by volume) [5]								
[3]	[4]	4	5	6	7	8	9	10	11	12
30	1.5020	0.0277	0.0350	0.0425	0.0501	0.0579	0.0658	0.0740	0.0823	0.0908
40	1.5330	0.0272	0.0343	0.0416	0.0491	0.0567	0.0645	0.0725	0.0806	0.0890
50	1.5640	0.0266	0.0337	0.0408	0.0481	0.0556	0.0632	0.0710	0.0790	0.0872
60	1.5950	0.0261	0.0330	0.0400	0.0472	0.0545	0.0620	0.0697	0.0775	0.0855
70	1.6260	0.0256	0.0324	0.0393	0.0463	0.0535	0.0608	0.0683	0.0760	0.0839
80	1.6570	0.0251	0.0318	0.0385	0.0454	0.0525	0.0597	0.0671	0.0746	0.0823
90	1.6880	0.0247	0.0312	0.0378	0.0446	0.0515	0.0586	0.0658	0.0732	0.0808
100	1.7190	0.0242	0.0306	0.0371	0.0438	0.0506	0.0575	0.0646	0.0719	0.0793
110	1.7500	0.0238	0.0301	0.0365	0.0430	0.0497	0.0565	0.0635	0.0706	0.0779
120	1.7810	0.0234	0.0296	0.0358	0.0423	0.0488	0.0555	0.0624	0.0694	0.0766
130	1.8120	0.0230	0.0290	0.0352	0.0415	0.0480	0.0546	0.0613	0.0682	0.0753
140	1.8430	0.0226	0.0286	0.0346	0.0408	0.0472	0.0537	0.0603	0.0671	0.0740
150	1.8740	0.0222	0.0281	0.0341	0.0402	0.0464	0.0528	0.0593	0.0660	0.0728
160	1.9050	0.0219	0.0276	0.0335	0.0395	0.0456	0.0519	0.0583	0.0649	0.0716
170	1.9360	0.0215	0.0272	0.0330	0.0389	0.0449	0.0511	0.0574	0.0638	0.0704
180	1.9670	0.0212	0.0268	0.0325	0.0383	0.0442	0.0503	0.0565	0.0628	0.0693
190	1.9980	0.0209	0.0263	0.0319	0.0377	0.0435	0.0495	0.0556	0.0619	0.0683
200	2.0290	0.0205	0.0259	0.0315	0.0371	0.0429	0.0487	0.0548	0.0609	0.0672

[1] The manufacturers listing shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (lb/ft^3)] — Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°F)] — The design temperature in the hazard area.
[4] s [Specific Volume (ft^3/lb)] — Specific volume of superheated FC-3-1-10 vapor may be approximated by the formula:
$s = 1.409 + 0.0031t$
where t = temperature (°F)
[5] C [Concentration (%)] — Volumetric concentration of FC 3-1-10 in air at the temperature indicated.

Table 3-5.1(c) FC-3-1-10 Total Flooding Quantity [1]

Temp -t- (°C) [3]	FC-3-1-10 Specific Vapor Volume -s- (m^3/kg) [4]	FC-3-1-10 Weight Requirements of Hazard Volume W/V (kg/m^3) [2] Metric Units Design Concentration (% by volume) [5]							
		5	6	7	8	9	10	11	12
0	0.0941	0.5593	0.6783	0.7998	0.9240	1.0510	1.1807	1.3134	1.4491
10	0.0976	0.5395	0.6543	0.7715	0.8913	1.0138	1.1389	1.2669	1.3978
15	0.0993	0.5301	0.6429	0.7581	0.8758	0.9961	1.1191	1.2448	1.3734
20	0.1010	0.5210	0.6319	0.7451	0.8608	0.9791	1.1000	1.2235	1.3499
25	0.1027	0.5123	0.6213	0.7326	0.8464	0.9626	1.0815	1.2030	1.3272
30	0.1045	0.5038	0.6110	0.7205	0.8324	0.9467	1.0636	1.1831	1.3053
35	0.1062	0.4956	0.6011	0.7088	0.8188	0.9313	1.0463	1.1638	1.2841
40	0.1079	0.4877	0.5914	0.6974	0.8057	0.9164	1.0295	1.1452	1.2635
45	0.1097	0.4800	0.5821	0.6864	0.7930	0.9020	1.0133	1.1272	1.2436
50	0.1114	0.4725	0.5731	0.6758	0.7807	0.8880	0.9976	1.1097	1.2243
55	0.1131	0.4653	0.5643	0.6655	0.7688	0.8744	0.9824	1.0927	1.2056
60	0.1148	0.4583	0.5558	0.6555	0.7572	0.8613	0.9676	1.0763	1.1875
65	0.1166	0.4515	0.5476	0.6457	0.7460	0.8485	0.9532	1.0603	1.1699
70	0.1183	0.4449	0.5396	0.6363	0.7351	0.8361	0.9393	1.0449	1.1528
75	0.1200	0.4385	0.5318	0.6272	0.7245	0.8241	0.9258	1.0298	1.1362
80	0.1217	0.4323	0.5243	0.6183	0.7143	0.8124	0.9127	1.0152	1.1201
85	0.1235	0.4263	0.5170	0.6096	0.7043	0.8010	0.8999	1.0010	1.1044
90	0.1252	0.4204	0.5098	0.6012	0.6945	0.7900	0.8875	0.9872	1.0892
95	0.1269	0.4147	0.5029	0.5930	0.6851	0.7792	0.8754	0.9738	1.0744
100	0.1287	0.4091	0.4961	0.5850	0.6759	0.7687	0.8636	0.9607	1.0599

[1] The manufacturers listing shall specify the temperature range for operation.

[2] W/V [Agent Weight Requirements (kg/m^3)] — Kilograms required per cubic meter of protected volume to produce indicated conc at temperature specified.

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

[3] t [Temperature (°C)] — The design temperature in the hazard area.

[4] s [Specific Volume (m^3/kg)] — Specific volume of superheated FC-3-1-10 vapor may be approximated by the formula:

$s = 0.094104 + 0.00034455t$

where t = temperature (°C)

[5] C [Concentration (%)] — Volumetric concentration of FC-3-1-10 in air at the temperature specified.

Table 3-5.1(d) HCFC Blend A Total Flooding Quantity [1]

Temp -t- (°F) [3]	HCFC Blend A Specific Vapor Volume -s- (ft^3/lb) [4]	HCFC Blend A Weight Requirements of Hazard Volume W/V (lb/ft^3) [2] English Units Design Concentration (% by volume) [5]							
		7	8	8.6	9	10	11	12	13
−30	3.3763	0.0223	0.0258	0.0279	0.0293	0.0329	0.0366	0.0404	0.0443
−20	3.4549	0.0218	0.0252	0.0272	0.0286	0.0322	0.0358	0.0395	0.0433
−10	3.5335	0.0213	0.0246	0.0266	0.028	0.0314	0.035	0.0386	0.0423
0	3.6121	0.0208	0.0241	0.026	0.0274	0.0308	0.0342	0.0378	0.0414
10	3.6906	0.0204	0.0236	0.0255	0.0268	0.0301	0.0335	0.0369	0.0405
20	3.7692	0.02	0.0231	0.025	0.0262	0.0295	0.0328	0.0362	0.0396
30	3.8478	0.0196	0.0226	0.0245	0.0257	0.0289	0.0321	0.0354	0.0388
40	3.9264	0.0192	0.0221	0.024	0.0252	0.0283	0.0315	0.0347	0.0381
50	4.0049	0.0188	0.0217	0.0235	0.0247	0.0277	0.0309	0.034	0.0373
60	4.0835	0.0184	0.0213	0.023	0.0242	0.0272	0.0303	0.0334	0.0366
70	4.1621	0.0181	0.0209	0.0226	0.0238	0.0267	0.0297	0.0328	0.0359
80	4.2407	0.0177	0.0205	0.0222	0.0233	0.0262	0.0291	0.0322	0.0352
90	4.3192	0.0174	0.0201	0.0218	0.0229	0.0257	0.0286	0.0316	0.0346
100	4.3978	0.0171	0.0198	0.0214	0.0225	0.0253	0.0281	0.031	0.034
110	4.4764	0.0168	0.0194	0.021	0.0221	0.0248	0.0276	0.0305	0.0334
120	4.555	0.0164	0.0191	0.0207	0.0217	0.0244	0.0271	0.0299	0.0328
130	4.6336	0.0162	0.0188	0.0203	0.0213	0.024	0.0267	0.0294	0.0322
140	4.7121	0.016	0.0185	0.02	0.021	0.0236	0.0262	0.0289	0.0317
150	4.7907	0.0157	0.0182	0.0196	0.0206	0.0232	0.0258	0.0285	0.0312
160	4.8693	0.0155	0.0179	0.0193	0.0203	0.0228	0.0254	0.028	0.0307
170	4.9479	0.0152	0.0176	0.019	0.02	0.0225	0.025	0.0276	0.0302
180	5.0264	0.015	0.0173	0.0187	0.0197	0.0221	0.0246	0.0271	0.0297
190	5.105	0.0147	0.017	0.0184	0.0194	0.0218	0.0242	0.0267	0.0293
200	5.1836	0.0145	0.0168	0.0182	0.0191	0.0214	0.0238	0.0263	0.0288

[1] The manufacturers listing shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (lb/ft^3)] — Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°F)] — The design temperature in the hazard area.
[4] s [Specific Volume (ft^3/lb)] — Specific volume of superheated HCFC Blend A vapor may be approximated by the formula:
$s = 3.612 + 0.0079t$
where t = temperature (°F)
[5] C [Concentration (%)] — Volumetric concentration of HCFC Blend A in air at the temperature indicated.

Table 3-5.1(e) HCFC Blend A Total Flooding Quantity [1]

Temp -t- (°C) [3]	HFCF Blend A Specfic Vapor Volume -s- m^3/kg [4]	HCFC Blend A Weight Requirements of Hazard Volume W/V (kg/m^3) [2] Metric Units Design Concentration (% by volume) [5]							
		8.6	9	10	11	12	13	14	15
−50	0.1971	0.4774	0.5018	0.5638	0.6271	0.6919	0.7582	0.8260	0.8954
−45	0.2015	0.4669	0.4908	0.5514	0.6134	0.6767	0.7415	0.8079	0.8758
−40	0.2059	0.4569	0.4803	0.5396	0.6002	0.6622	0.7256	0.7906	0.8570
−35	0.2103	0.4473	0.4702	0.5283	0.5876	0.6483	0.7104	0.7740	0.8390
−30	0.2148	0.4381	0.4605	0.5174	0.5755	0.635	0.6958	0.7580	0.8217
−25	0.2192	0.4293	0.4513	0.507	0.5639	0.6222	0.6818	0.7428	0.8052
−20	0.2236	0.4208	0.4423	0.497	0.5528	0.6099	0.6683	0.7281	0.7893
−15	0.228	0.4127	0.4338	0.4873	0.5421	0.5981	0.6554	0.7140	0.7740
−10	0.2324	0.4048	0.4255	0.4781	0.5318	0.5867	0.6429	0.7004	0.7593
−5	0.2368	0.3973	0.4176	0.4692	0.5219	0.5758	0.6309	0.6874	0.7451
0	0.2412	0.39	0.41	0.4606	0.5123	0.5652	0.6194	0.6748	0.7315
5	0.2457	0.383	0.4026	0.4523	0.5031	0.5551	0.6083	0.6627	0.7183
10	0.2501	0.3762	0.3955	0.4443	0.4942	0.5453	0.5975	0.6510	0.7057
15	0.2545	0.3697	0.3886	0.4366	0.4856	0.5358	0.5871	0.6397	0.6934
20	0.2589	0.3634	0.382	0.4291	0.4774	0.5267	0.5771	0.6288	0.6816
25	0.2633	0.3573	0.3756	0.422	0.4694	0.5178	0.5675	0.6182	0.6702
30	0.2677	0.3514	0.3694	0.415	0.4616	0.5093	0.5581	0.6080	0.6591
35	0.2722	0.3457	0.3634	0.4083	0.4541	0.501	0.549	0.5981	0.6484
40	0.2766	0.3402	0.3576	0.4017	0.4469	0.493	0.5403	0.5886	0.6381
45	0.281	0.3349	0.352	0.3954	0.4399	0.4853	0.5318	0.5793	0.6280
50	0.2854	0.3297	0.3465	0.3893	0.4331	0.4778	0.5236	0.5704	0.6183
55	0.2898	0.3247	0.3412	0.3834	0.4265	0.4705	0.5156	0.5617	0.6089
60	0.2942	0.3198	0.3361	0.3776	0.4201	0.4634	0.5078	0.5533	0.5998
65	0.2987	0.3151	0.3312	0.372	0.4138	0.4566	0.5003	0.5451	0.5909
70	0.3031	0.3105	0.3263	0.3666	0.4078	0.4499	0.493	0.5371	0.5823
75	0.3075	0.306	0.3216	0.3614	0.402	0.4435	0.486	0.5294	0.5739
80	0.3119	0.3017	0.3171	0.3562	0.3963	0.4372	0.4791	0.5219	0.5658
85	0.3163	0.2975	0.3127	0.3513	0.3907	0.4311	0.4724	0.5146	0.5579
90	0.3207	0.2934	0.3084	0.3464	0.3854	0.4252	0.4659	0.5076	0.5502
95	0.3251	0.2894	0.3042	0.3417	0.3801	0.4194	0.4596	0.5007	0.5427

[1] The manufacturers listing shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (kg/m^3)] — Kilograms required per cubic foot of protected volume to produce indicated conc at temperature specified.

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

[3] t [Temperature (°C)] — The design temperature in the hazard area.
[4] s [Specific Volume (m^3/kg)] — Specific volume of superheated HCFC Blend A vapor may be approximated by the formula:
$s = 0.2413 + 0.00088t$
where t = temperature (°C)
[5] C [Concentration (%)] — Volumetric concentration of HCFC Blend A in air at the temperature specified.

Table 3-5.1(f) HCFC-124 Total Flooding Quantity [1]

Temp (°F) -t- [3]	HCFC-124 Specific Vapor Volume (ft^3/lb) -s- [4]	HCFC-124 Weight Requirements of Hazard Volume W/V (lb/ft^3) [2] English Units Design Concentration (% by volume) [5]							
		5	6	7	8	9	10	11	12
20	2.4419	0.0216	0.0261	0.0308	0.0356	0.0405	0.0455	0.0506	0.0558
30	2.5049	0.0210	0.0255	0.0300	0.0347	0.0395	0.0444	0.0493	0.0544
40	2.5667	0.0205	0.0249	0.0293	0.0339	0.0385	0.0433	0.0482	0.0531
50	2.6277	0.0200	0.0243	0.0286	0.0331	0.0376	0.0423	0.0470	0.0519
60	2.6878	0.0196	0.0237	0.0280	0.0324	0.0368	0.0413	0.0460	0.0507
70	2.7471	0.0192	0.0232	0.0274	0.0317	0.0360	0.0404	0.0450	0.0496
80	2.8059	0.0188	0.0227	0.0268	0.0310	0.0352	0.0396	0.0440	0.0486
90	2.8642	0.0184	0.0223	0.0263	0.0304	0.0345	0.0388	0.0432	0.0476
100	2.9219	0.0180	0.0218	0.0258	0.0298	0.0338	0.0380	0.0423	0.0467
110	2.9795	0.0177	0.0214	0.0253	0.0292	0.0332	0.0373	0.0415	0.0458
120	3.0363	0.0173	0.0210	0.0248	0.0286	0.0326	0.0366	0.0407	0.0449
130	3.0931	0.0170	0.0206	0.0243	0.0281	0.0320	0.0359	0.0400	0.0441
140	3.1494	0.0167	0.0203	0.0239	0.0276	0.0314	0.0353	0.0392	0.0433
150	3.2059	0.0164	0.0199	0.0235	0.0271	0.0308	0.0347	0.0386	0.0425
160	3.2616	0.0161	0.0196	0.0231	0.0267	0.0303	0.0341	0.0379	0.0418
170	3.3176	0.0159	0.0192	0.0227	0.0262	0.0298	0.0335	0.0373	0.0411
180	3.3729	0.0156	0.0189	0.0223	0.0258	0.0293	0.0329	0.0366	0.0404
190	3.4283	0.0154	0.0186	0.0220	0.0254	0.0288	0.0324	0.0361	0.0398
200	3.4840	0.0151	0.0183	0.0216	0.0250	0.0284	0.0319	0.0355	0.0391

[1] The manufacturers listing shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (lb/ft^3)] — Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°F)] — The design temperature in the hazard area.
[4] s [Specific Volume (ft^3/lb)] — Specific volume of superheated HCFC-124 vapor may be approximated by the formula:
$s = 2.3395 + 0.0058t$
where t = temperature (°F)
[5] C [Concentration (%)] — Volumetric concentration of HCFC-124 in air at the temperature indicated.

Table 3-5.1(g) HCFC-124 Total Flooding Quantity [1]

Temp (°C) -t- [3]	HCFC-124 Specific Vapor Volume (m^3/kg) -s- [4]	HCFC-124 Weight Requirements of Hazard Volume W/V (kg/m^3) [2] Metric Units Design Concentration (% by volume) [5]							
		5	6	7	8	9	10	11	12
−10	0.1500	0.3509	0.4255	0.5018	0.5797	0.6593	0.7407	0.8240	0.9091
−5	0.1536	0.3427	0.4156	0.4900	0.5661	0.6439	0.7234	0.8047	0.8878
0	0.1572	0.3348	0.4060	0.4788	0.5532	0.6291	0.7068	0.7862	0.8675
5	0.1606	0.3277	0.3974	0.4687	0.5414	0.6158	0.6919	0.7696	0.8491
10	0.1640	0.3209	0.3892	0.4590	0.5302	0.6031	0.6775	0.7536	0.8315
15	0.1674	0.3144	0.3813	0.4496	0.5195	0.5908	0.6637	0.7383	0.8146
20	0.1708	0.3081	0.3737	0.4407	0.5091	0.5790	0.6505	0.7236	0.7984
25	0.1741	0.3023	0.3666	0.4323	0.4995	0.5681	0.6382	0.7099	0.7832
30	0.1774	0.2967	0.3598	0.4243	0.4902	0.5575	0.6263	0.6967	0.7687
35	0.1806	0.2914	0.3534	0.4168	0.4815	0.5476	0.6152	0.6844	0.7551
40	0.1839	0.2862	0.3471	0.4093	0.4728	0.5378	0.6042	0.6721	0.7415
45	0.1871	0.2813	0.3412	0.4023	0.4648	0.5286	0.5939	0.6606	0.7288
50	0.1903	0.2766	0.3354	0.3955	0.4569	0.5197	0.5839	0.6495	0.7166
55	0.1934	0.2721	0.3300	0.3892	0.4496	0.5114	0.5745	0.6391	0.7051
60	0.1966	0.2677	0.3247	0.3829	0.4423	0.5031	0.5652	0.6287	0.6936
65	0.1998	0.2634	0.3195	0.3767	0.4352	0.4950	0.5561	0.6186	0.6825
70	0.2029	0.2594	0.3146	0.3710	0.4286	0.4874	0.5476	0.6091	0.6721
75	0.2061	0.2554	0.3097	0.3652	0.4219	0.4799	0.5391	0.5997	0.6616
80	0.2092	0.2516	0.3051	0.3598	0.4157	0.4728	0.5311	0.5908	0.6518
85	0.2123	0.2479	0.3007	0.3545	0.4096	0.4659	0.5234	0.5822	0.6423
90	0.2154	0.2443	0.2963	0.3494	0.4037	0.4592	0.5158	0.5738	0.6331
95	0.2185	0.2409	0.2921	0.3445	0.3980	0.4526	0.5085	0.5657	0.6241

[1] The manufacturers listing shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (kg/m^3)] — Kilograms required per cubic foot of protected volume to produce indicated conc at temperature specified.

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

[3] t [Temperature (°C)] — The design temperature in the hazard area.
[4] s [Specific Volume (m^3/kg)] — Specific volume of superheated HCFC-124 vapor may be approximated by the formula:
$s = 0.1575 + 0.0006t$
where t = temperature (°C)
[5] C [Concentration (%)] — Volumetric concentration of HCFC-124 in air at the temperature specified.

Table 3-5.1(h) HFC-125 Total Flooding Quantity [1]

Temp (°F) -t- [3]	HFC-125 Specific Vapor Volume (ft^3/lb) -s- [4]	HFC-125 Weight Requirements of Hazard Volume W/V (lb/ft^3) [2] English Units Design Concentration (% by volume) [5]									
		7	8	9	10	11	12	13	14	15	16
−50	2.3912	0.0315	0.0364	0.0414	0.0465	0.0517	0.0570	0.0625	0.0681	0.0738	0.0797
−40	2.4576	0.0306	0.0354	0.0402	0.0452	0.0503	0.0555	0.0608	0.0662	0.0718	0.0775
−30	2.5240	0.0298	0.0345	0.0392	0.0440	0.0490	0.0540	0.0592	0.0645	0.0699	0.0755
−20	2.5893	0.0291	0.0336	0.0382	0.0429	0.0477	0.0527	0.0577	0.0629	0.0682	0.0736
−10	2.6553	0.0283	0.0327	0.0372	0.0418	0.0465	0.0514	0.0563	0.0613	0.0665	0.0717
0	2.7203	0.0277	0.0320	0.0364	0.0408	0.0454	0.0501	0.0549	0.0598	0.0649	0.0700
10	2.7855	0.0270	0.0312	0.0355	0.0399	0.0444	0.0490	0.0536	0.0584	0.0634	0.0684
20	2.8506	0.0264	0.0305	0.0347	0.0390	0.0434	0.0478	0.0524	0.0571	0.0619	0.0668
30	2.9146	0.0258	0.0298	0.0339	0.0381	0.0424	0.0468	0.0513	0.0559	0.0605	0.0654
40	2.9789	0.0253	0.0292	0.0332	0.0373	0.0415	0.0458	0.0502	0.0546	0.0592	0.0639
50	3.0432	0.0247	0.0286	0.0325	0.0365	0.0406	0.0448	0.0491	0.0535	0.0580	0.0626
60	3.1075	0.0242	0.0280	0.0318	0.0358	0.0398	0.0439	0.0481	0.0524	0.0568	0.0613
70	3.1706	0.0237	0.0274	0.0312	0.0350	0.0390	0.0430	0.0471	0.0513	0.0557	0.0601
80	3.2342	0.0233	0.0269	0.0306	0.0344	0.0382	0.0422	0.0462	0.0503	0.0546	0.0589
90	3.2971	0.0228	0.0264	0.0300	0.0337	0.0375	0.0414	0.0453	0.0494	0.0535	0.0578
100	3.3602	0.0224	0.0259	0.0294	0.0331	0.0368	0.0406	0.0445	0.0484	0.0525	0.0567
110	3.4223	0.0220	0.0254	0.0289	0.0325	0.0361	0.0398	0.0437	0.0476	0.0516	0.0557
120	3.4855	0.0216	0.0249	0.0284	0.0319	0.0355	0.0391	0.0429	0.0467	0.0506	0.0546
130	3.5486	0.0212	0.0245	0.0279	0.0313	0.0348	0.0384	0.0421	0.0459	0.0497	0.0537
140	3.6101	0.0208	0.0241	0.0274	0.0308	0.0342	0.0378	0.0414	0.0451	0.0489	0.0528
150	3.6724	0.0205	0.0237	0.0269	0.0303	0.0337	0.0371	0.0407	0.0443	0.0481	0.0519
160	3.7341	0.0202	0.0233	0.0265	0.0298	0.0331	0.0365	0.0400	0.0436	0.0473	0.0510
170	3.7965	0.0198	0.0229	0.0261	0.0293	0.0326	0.0359	0.0394	0.0429	0.0465	0.0502
180	3.8595	0.0195	0.0225	0.0256	0.0288	0.0320	0.0353	0.0387	0.0422	0.0457	0.0494
190	3.9200	0.0192	0.0222	0.0252	0.0283	0.0315	0.0348	0.0381	0.0415	0.0450	0.0486
200	3.9825	0.0189	0.0218	0.0248	0.0279	0.0310	0.0342	0.0375	0.0409	0.0443	0.0478

[1] The manufacturers listing shall specify the temperature range for operation.

[2] W/V [Agent Weight Requirements (lb/ft^3)] — Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°F)] — The design temperature in the hazard area.

[4] s [Specific Volume (ft^3/lb)] — Specific volume of superheated HFC-125 vapor may be approximated by the formula:
$s = 2.7200 + 0.00064t$
where t = temperature (°F)

[5] C [Concentration (%)] — Volumetric concentration of HFC-125 in air at the temperature indicated.

Table 3-5.1(i) HFC-125 Total Flooding Quantity [1]

Temp (°C) -t- [3]	HFC-125 Specific Vapor Volume (m³/kg) -s- [4]	HFC-125 Weight Requirements of Hazard Volume W/V (kg/m³) [2] Metric Units Design Concentration (% by volume) [5]									
		7	8	9	10	11	12	13	14	15	16
−45	0.1497	0.5028	0.5809	0.6607	0.7422	0.8256	0.9109	0.9982	1.0874	1.1788	1.2724
−40	0.1534	0.4907	0.5669	0.6447	0.7243	0.8057	0.8889	0.9741	1.0612	1.1504	1.2417
−35	0.1572	0.4788	0.5532	0.6291	0.7068	0.7862	0.8675	0.9505	1.0356	1.1226	1.2117
−30	0.1608	0.4681	0.5408	0.6151	0.6910	0.7686	0.8480	0.9293	1.0124	1.0975	1.1846
−25	0.1645	0.4576	0.5286	0.6012	0.6754	0.7513	0.8290	0.9084	0.9896	1.0728	1.1579
−20	0.1682	0.4475	0.5170	0.5880	0.6606	0.7348	0.8107	0.8884	0.9678	1.0492	1.1324
−15	0.1719	0.4379	0.5059	0.5753	0.6464	0.7190	0.7933	0.8693	0.9470	1.0266	1.1081
−10	0.1755	0.4289	0.4955	0.5635	0.6331	0.7042	0.7770	0.8514	0.9276	1.0055	1.0853
−5	0.1791	0.4203	0.4855	0.5522	0.6204	0.6901	0.7614	0.8343	0.9089	0.9853	1.0635
0	0.1828	0.4118	0.4757	0.5410	0.6078	0.6761	0.7460	0.8174	0.8905	0.9654	1.0420
5	0.1864	0.4038	0.4665	0.5306	0.5961	0.6631	0.7316	0.8016	0.8733	0.9467	1.0219
10	0.1900	0.3962	0.4577	0.5205	0.5848	0.6505	0.7177	0.7864	0.8568	0.9288	1.0025
15	0.1935	0.3890	0.4494	0.5111	0.5742	0.6387	0.7047	0.7722	0.8413	0.9120	0.9844
20	0.1971	0.3819	0.4412	0.5018	0.5637	0.6271	0.6919	0.7581	0.8259	0.8953	0.9664
25	0.2007	0.3750	0.4333	0.4928	0.5536	0.6158	0.6794	0.7445	0.8111	0.8793	0.9491
30	0.2042	0.3686	0.4258	0.4843	0.5441	0.6053	0.6678	0.7318	0.7972	0.8642	0.9328
35	0.2078	0.3622	0.4185	0.4759	0.5347	0.5948	0.6562	0.7191	0.7834	0.8492	0.9166
40	0.2113	0.3562	0.4115	0.4681	0.5258	0.5849	0.6454	0.7072	0.7704	0.8352	0.9014
45	0.2149	0.3503	0.4046	0.4602	0.5170	0.5751	0.6345	0.6953	0.7575	0.8212	0.8863
50	0.2184	0.3446	0.3982	0.4528	0.5088	0.5659	0.6244	0.6842	0.7454	0.8080	0.8721
55	0.2219	0.3392	0.3919	0.4457	0.5007	0.5570	0.6145	0.6734	0.7336	0.7953	0.8584
60	0.2254	0.3339	0.3858	0.4388	0.4930	0.5483	0.6050	0.6629	0.7222	0.7829	0.8451
65	0.2289	0.3288	0.3799	0.4321	0.4854	0.5400	0.5957	0.6528	0.7112	0.7710	0.8321
70	0.2324	0.3239	0.3742	0.4256	0.4781	0.5318	0.5868	0.6430	0.7005	0.7593	0.8196
75	0.2358	0.3192	0.3688	0.4194	0.4712	0.5242	0.5783	0.6337	0.6904	0.7484	0.8078
80	0.2393	0.3145	0.3634	0.4133	0.4643	0.5165	0.5698	0.6244	0.6803	0.7374	0.7960
85	0.2428	0.3100	0.3581	0.4073	0.4576	0.5090	0.5616	0.6154	0.6705	0.7268	0.7845
90	0.2463	0.3056	0.3531	0.4015	0.4511	0.5018	0.5536	0.6067	0.6609	0.7165	0.7734
95	0.2498	0.3013	0.3481	0.3959	0.4448	0.4948	0.5459	0.5982	0.6517	0.7064	0.7625

[1] The manufacturers listing shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (kg/m³)] — Kilograms required per cubic foot of protected volume to produce indicated conc at temperature specified.

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

[3] t [Temperature (°C)] — The design temperature in the hazard area.
[4] s [Specific Volume (m³/kg)] — Specific volume of superheated HCFC-125 vapor may be approximated by the formula:

$s = 0.1825 + 0.0007t$

where t = temperature (°C)

[5] C [Concentration (%)] — Volumetric concentration of HCFC-125 in air at the temperature specified.

Table 3-5.1(j) HFC-227ea Total Flooding Quantity [1]

Temp -t- (°F) [3]	HFC-227ea Specific Vapor Volume -s- (ft^3/lb) [4]	HFC-227ea Weight Requirements of Hazard Volume W/V (lb/ft^3) [2] English Units Design Concentration (% by volume) [5]									
		6	7	8	9	10	11	12	13	14	15
10	1.9264	0.0331	0.0391	0.0451	0.0513	0.057	0.0642	0.0708	0.0776	0.0845	0.0916
20	1.9736	0.0323	0.0381	0.0441	0.0501	0.0563	0.0626	0.0691	0.0757	0.0825	0.0894
30	2.0210	0.0316	0.0372	0.0430	0.0489	0.0550	0.0612	0.0675	0.0739	0.0805	0.0873
40	2.0678	0.0309	0.0364	0.0421	0.0478	0.0537	0.0598	0.0659	0.0723	0.0787	0.0853
50	2.1146	0.0302	0.0356	0.0411	0.0468	0.0525	0.0584	0.0645	0.0707	0.0770	0.0835
60	2.1612	0.0295	0.0348	0.0402	0.0458	0.0514	0.0572	0.0631	0.0691	0.0753	0.0817
70	2.2075	0.0289	0.0341	0.0394	0.0448	0.0503	0.0560	0.0618	0.0677	0.0737	0.0799
80	2.2538	0.0283	0.0334	0.0386	0.0439	0.0493	0.0548	0.0605	0.0663	0.0722	0.0783
90	2.2994	0.0278	0.0327	0.0378	0.0430	0.0483	0.0538	0.0593	0.0650	0.0708	0.0767
100	2.3452	0.0272	0.0321	0.0371	0.0422	0.0474	0.0527	0.0581	0.0637	0.0694	0.0752
110	2.3912	0.0267	0.0315	0.0364	0.0414	0.0465	0.0517	0.0570	0.0625	0.0681	0.0738
120	2.4366	0.0262	0.0309	0.0357	0.0406	0.0456	0.0507	0.0560	0.0613	0.0668	0.0724
130	2.4820	0.0257	0.0303	0.0350	0.0398	0.0448	0.0498	0.0549	0.0602	0.0656	0.0711
140	2.5272	0.0253	0.0298	0.0344	0.0391	0.0440	0.0489	0.0540	0.0591	0.0644	0.0698
150	2.5727	0.0248	0.0293	0.0338	0.0384	0.0432	0.0480	0.0530	0.0581	0.0633	0.0686
160	2.6171	0.0244	0.0288	0.0332	0.0378	0.0425	0.0472	0.0521	0.0571	0.0622	0.0674
170	2.6624	0.0240	0.0283	0.0327	0.0371	0.0417	0.0464	0.0512	0.0561	0.0611	0.0663
180	2.7071	0.0236	0.0278	0.0321	0.0365	0.0410	0.0457	0.0504	0.0552	0.0601	0.0652
190	2.7518	0.0232	0.0274	0.0316	0.0359	0.0404	0.0449	0.0496	0.0543	0.0592	0.0641
200	2.7954	0.0228	0.0269	0.0311	0.0354	0.0397	0.0442	0.0488	0.0535	0.0582	0.0631

[1] The manufacturers listing shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (lb/ft^3)] = Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°F)] — The design temperature in the hazard area.
[4] s [Specific Volume (ft^3/lb)] — Specific volume of superheated HFC-227ea vapor may be approximated by the formula:
$s = 1.885 + 0.0046t$
where t = temperature (°F)
[5] C [Concentration (%)] — Volumetric concentration of HFC-227ea in air at the temperature indicated.

Table 3-5.1(k) HFC-227ea Total Flooding Quantity [1]

Temp -t- (°C) [3]	HFC-227ea Specific Vapor Volume -s- (m^3/kg) [4]	HFC-227ea Weight Requirements of Hazard Volume W/V (kg/m^3) [2] Metric Units Design Concentration (% per volume) [5]									
		6	7	8	9	10	11	12	13	14	15
−10	0.1215	0.5254	0.6196	0.7158	0.8142	0.9147	1.0174	1.1225	1.2301	1.3401	1.4527
−5	0.1241	0.5142	0.6064	0.7005	0.7987	0.8951	0.9957	1.0985	1.2038	1.3114	1.4216
0	0.1268	0.5034	0.5936	0.6858	0.78	0.8763	0.9748	1.0755	1.1785	1.2839	1.3918
5	0.1294	0.4932	0.5816	0.6719	0.7642	0.8586	0.955	1.0537	1.1546	1.2579	1.3636
10	0.132	0.4834	0.57	0.6585	0.749	0.8414	0.936	1.0327	1.1316	1.2328	1.2264
15	0.1347	0.474	0.5589	0.6457	0.7344	0.8251	0.9178	1.0126	1.1096	1.2089	1.3105
20	0.1373	0.465	0.5483	0.6335	0.7205	0.8094	0.9004	0.9934	1.0886	1.1859	1.2856
25	0.1399	0.4564	0.5382	0.6217	0.7071	0.7944	0.8837	0.975	1.0684	1.164	1.2618
30	0.1425	0.4481	0.5284	0.6104	0.6943	0.78	0.8676	0.9573	1.049	1.1428	1.2388
35	0.145	0.4401	0.519	0.5996	0.6819	0.7661	0.8522	0.9402	1.0303	1.1224	1.2168
40	0.1476	0.4324	0.5099	0.5891	0.6701	0.7528	0.8374	0.9230	1.0124	1.1029	1.1956
45	0.1502	0.425	0.5012	0.579	0.6586	0.7399	0.823	0.908	0.995	1.084	1.1751
50	0.1527	0.418	0.4929	0.5694	0.6476	0.7276	0.8093	0.8929	0.9784	1.066	1.1555
55	0.1553	0.4111	0.4847	0.56	0.6369	0.7156	0.796	0.8782	0.9623	1.0484	1.1365
60	0.1578	0.4045	0.477	0.551	0.6267	0.7041	0.7832	0.8641	0.9469	1.0316	1.1183
65	0.1604	0.398	0.4694	0.5423	0.6167	0.6929	0.7707	0.8504	0.9318	1.0152	1.1005
70	0.1629	0.3919	0.4621	0.5338	0.6072	0.6821	0.7588	0.8371	0.9173	0.9994	1.0834
75	0.1654	0.3859	0.455	0.5257	0.5979	0.6717	0.7471	0.8243	0.9033	0.9841	1.0668
80	0.1679	0.3801	0.4482	0.5178	0.0589	0.6617	0.736	0.812	0.8898	0.9694	1.0509
85	0.1704	0.3745	0.4416	0.5102	0.5803	0.6519	0.7251	0.8	0.8767	0.9551	1.0354
90	0.173	0.369	0.4351	0.5027	0.5717	0.6423	0.7145	0.7883	0.8638	0.9411	1.0202

[1] The manufacturers listing shall specify the temperature range for operation.

[2] For W/V [Agent Weight Requirements (kg/m^3)] — Kilograms of agent per cubic meter of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°C)] — The design temperature in the hazard area.

[4] s [Specific Volume (m^3/kg)] — Specific volume of superheated HFC-227ea vapor may be approximated by the formula:

$s = 0.1269 + 0.0005t$

where t = temperature (°C).

[5] C [Concentration (%)] — Volumetric concentration of HFC-227ea in air at the temperature indicated.

Table 3-5.1(l) HFC-23 Total Flooding Quantity [1]

Temp (°F) -t- [3]	HFC-23 Specific Vapor Volume (ft^3/lb) -s- [4]	HFC-23 Weight Requirements of Hazard Volume W/V (lb/ft^3) [2] English Units Design Concentration (% by volume) [5]									
		10	12	14	15	16	17	18	20	22	24
−70	3.9573	0.0281	0.0345	0.0411	0.0446	0.0481	0.0518	0.0555	0.0632	0.0713	0.0798
−60	4.0700	0.0273	0.0335	0.0400	0.0434	0.0468	0.0503	0.0539	0.0614	0.0693	0.0776
−50	4.1817	0.0266	0.0326	0.0389	0.0422	0.0455	0.0490	0.0525	0.0598	0.0674	0.0755
−40	4.2926	0.0259	0.0318	0.0379	0.0411	0.0444	0.0477	0.0511	0.0582	0.0657	0.0736
−30	4.4029	0.0252	0.0310	0.0370	0.0401	0.0433	0.0465	0.0499	0.0568	0.0641	0.0717
−20	4.5125	0.0246	0.0302	0.0361	0.0391	0.0422	0.0454	0.0486	0.0554	0.0625	0.0700
−10	4.6216	0.0240	0.0295	0.0352	0.0382	0.0412	0.0443	0.0475	0.0541	0.0610	0.0683
0	4.7302	0.0235	0.0288	0.0344	0.0373	0.0403	0.0433	0.0464	0.0529	0.0596	0.0668
10	4.8384	0.0230	0.0282	0.0336	0.0365	0.0394	0.0423	0.0454	0.0517	0.0583	0.0653
20	4.9463	0.0225	0.0276	0.0329	0.0357	0.0385	0.0414	0.0444	0.0505	0.0570	0.0638
30	5.0538	0.0220	0.0270	0.0322	0.0349	0.0377	0.0405	0.0434	0.0495	0.0558	0.0625
40	5.1610	0.0215	0.0264	0.0315	0.0342	0.0369	0.0397	0.0425	0.0484	0.0547	0.0612
50	5.2680	0.0211	0.0259	0.0309	0.0335	0.0362	0.0389	0.0417	0.0475	0.0535	0.0599
60	5.3748	0.0207	0.0254	0.0303	0.0328	0.0354	0.0381	0.0408	0.0465	0.0525	0.0588
70	5.4814	0.0203	0.0249	0.0297	0.0322	0.0347	0.0374	0.0400	0.0456	0.0515	0.0576
80	5.5878	0.0199	0.0244	0.0291	0.0316	0.0341	0.0367	0.0393	0.0447	0.0505	0.0565
90	5.6940	0.0195	0.0239	0.0286	0.0310	0.0335	0.0360	0.0386	0.0439	0.0495	0.0555
100	5.8001	0.0192	0.0235	0.0281	0.0304	0.0328	0.0353	0.0378	0.0431	0.0486	0.0544
110	5.9061	0.0188	0.0231	0.0276	0.0299	0.0323	0.0347	0.0372	0.0423	0.0478	0.0535
120	6.0119	0.0185	0.0227	0.0271	0.0294	0.0317	0.0341	0.0365	0.0416	0.0469	0.0525
130	6.1176	0.0182	0.0223	0.0266	0.0288	0.0311	0.0335	0.0359	0.0409	0.0461	0.0516
140	6.2233	0.0179	0.0219	0.0262	0.0284	0.0306	0.0329	0.0353	0.0402	0.0453	0.0507
150	6.3289	0.0176	0.0215	0.0257	0.0279	0.0301	0.0324	0.0347	0.0395	0.0446	0.0499
160	6.4343	0.0173	0.0212	0.0253	0.0274	0.0296	0.0318	0.0341	0.0389	0.0438	0.0491
170	6.5398	0.0170	0.0209	0.0249	0.0270	0.0291	0.0313	0.0336	0.0382	0.0431	0.0483
180	6.6451	0.0167	0.0205	0.0245	0.0266	0.0287	0.0308	0.0330	0.0376	0.0424	0.0475
190	6.7504	0.0165	0.0202	0.0241	0.0261	0.0282	0.0303	0.0325	0.0370	0.0418	0.0468

[1] The manufacturers listing shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (lb/ft^3)] — Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°F)] — The design temperature in the hazard area.
[4] s [Specific Volume (ft^3/lb)] — Specific volume of superheated HFC-23 vapor may be approximated by the formula:
$s = 4.7250 + 0.0107t$
where t = temperature (°F)
[5] C [Concentration (%)] — Volumetric concentration of HFC-23 in air at the temperature indicated.

Table 3-5.1(m) HFC-23 Total Flooding Quantity [1]

Temp (°C) -t- [3]	HFC-23 Specific Vapor Volume (m^3/kg) -s- [4]	HFC-23 Weight Requirements of Hazard Volume W/V (kg/m^3) [2] Metric Units Design Concentration (% by volume) [5]									
		10	12	14	15	16	17	18	20	22	24
−60	0.2428	0.4576	0.5616	0.6705	0.7268	0.7845	0.8436	0.9041	1.0297	1.1617	1.3006
−55	0.2492	0.4459	0.5472	0.6533	0.7081	0.7644	0.8219	0.8809	1.0032	1.1318	1.2672
−50	0.2555	0.4349	0.5337	0.6371	0.6907	0.7455	0.8016	0.8591	0.9785	1.1039	1.2360
−45	0.2617	0.4246	0.5211	0.6221	0.6743	0.7278	0.7826	0.8388	0.9553	1.0778	1.2067
−40	0.2680	0.4146	0.5088	0.6074	0.6585	0.7107	0.7643	0.8191	0.9328	1.0524	1.1783
−35	0.2742	0.4052	0.4973	0.5937	0.6436	0.6947	0.7470	0.8006	0.9117	1.0286	1.1517
−30	0.2803	0.3964	0.4865	0.5808	0.6296	0.6795	0.7307	0.7831	0.8919	1.0062	1.1266
−25	0.2865	0.3878	0.4760	0.5682	0.6160	0.6648	0.7149	0.7662	0.8726	0.9845	1.1022
−20	0.2926	0.3797	0.4660	0.5564	0.6031	0.6510	0.7000	0.7502	0.8544	0.9639	1.0793
−15	0.2987	0.3720	0.4565	0.5450	0.5908	0.6377	0.6857	0.7349	0.8370	0.9443	1.0572
−10	0.3047	0.3647	0.4475	0.5343	0.5792	0.6251	0.6722	0.7204	0.8205	0.9257	1.0364
−5	0.3108	0.3575	0.4388	0.5238	0.5678	0.6129	0.6590	0.7063	0.8044	0.9075	1.0161
0	0.3168	0.3507	0.4304	0.5139	0.5570	0.6013	0.6465	0.6929	0.7891	0.8903	0.9968
5	0.3229	0.3441	0.4223	0.5042	0.5465	0.5899	0.6343	0.6798	0.7742	0.8735	0.9780
10	0.3289	0.3378	0.4146	0.4950	0.5365	0.5791	0.6227	0.6674	0.7601	0.8576	0.9601
15	0.3349	0.3318	0.4072	0.4861	0.5269	0.5688	0.6116	0.6555	0.7465	0.8422	0.9429
20	0.3409	0.3259	0.4000	0.4775	0.5177	0.5587	0.6008	0.6439	0.7334	0.8274	0.9263
25	0.3468	0.3204	0.3932	0.4694	0.5089	0.5492	0.5906	0.6330	0.7209	0.8133	0.9106
30	0.3528	0.3149	0.3865	0.4614	0.5002	0.5399	0.5806	0.6222	0.7086	0.7995	0.8951
35	0.3588	0.3097	0.3801	0.4537	0.4918	0.5309	0.5708	0.6118	0.6968	0.7861	0.8801
40	0.3647	0.3047	0.3739	0.4464	0.4839	0.5223	0.5616	0.6019	0.6855	0.7734	0.8659
45	0.3707	0.2997	0.3679	0.4391	0.4760	0.5138	0.5525	0.5922	0.6744	0.7609	0.8519
50	0.3766	0.2950	0.3621	0.4323	0.4686	0.5058	0.5439	0.5829	0.6638	0.74489	0.8385
55	0.3826	0.2904	0.3564	0.4255	0.4612	0.4978	0.5353	0.5737	0.6534	0.7372	0.8254
60	0.3885	0.2860	0.3510	0.4190	0.4542	0.4903	0.5272	0.5650	0.6435	0.7260	0.8128
65	0.3944	0.2817	0.3457	0.4128	0.4474	0.4830	0.5193	0.5566	0.6339	0.7151	0.8007
70	0.4004	0.2775	0.3406	0.4066	0.4407	0.4757	0.5115	0.5482	0.6244	0.7044	0.7887

[1] The manufacturers listing shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (kg/m^3)] — Kilograms required per cubic foot of protected volume to produce indicated conc at temperature specified.

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

[3] t [Temperature (°C)] — The design temperature in the hazard area.
[4] s [Specific Volume (m^3/kg)] — Specific volume of superheated HFC-23 vapor may be approximated by the formula:
$s = 0.3164 + 0.0012t$
where t = temperature (°C)
[5] C [Concentration (%)] — Volumetric concentration of HFC-23 in air at the temperature specified.

Table 3-5.1(n) FIC-13I1 Total Flooding Quantity [1]

Temp -t- (°F) [3]	FIC-13I1 Specific Vapor Volume -s- (ft^3/lb) [4]	FIC-13I1 Weight Requirements of Hazard Volume W/V (lb/ft^3) [2] English Units Design Concentration (% by volume) [5]							
		3	4	5	6	7	8	9	10
0	1.6826	0.0184	0.0248	0.0313	0.0379	0.0447	0.0517	0.0588	0.0660
10	1.7264	0.0179	0.0241	0.0305	0.0370	0.0436	0.0504	0.0573	0.0644
20	1.7703	0.0175	0.0235	0.0297	0.0361	0.0425	0.0491	0.0559	0.0628
30	1.8141	0.0170	0.0230	0.0290	0.0352	0.0415	0.0479	0.0545	0.0612
40	1.8580	0.0166	0.0224	0.0283	0.0344	0.0405	0.0468	0.0532	0.0598
50	1.9019	0.0163	0.0219	0.0277	0.0336	0.0396	0.0457	0.0520	0.0584
60	1.9457	0.0159	0.0214	0.0270	0.0328	0.0387	0.0447	0.0508	0.0571
70	1.9896	0.0155	0.0209	0.0265	0.0321	0.0378	0.0437	0.0497	0.0558
80	2.0335	0.0152	0.0205	0.0259	0.0314	0.0370	0.0428	0.0486	0.0546
90	2.0773	0.0149	0.0201	0.0253	0.0307	0.0362	0.0419	0.0476	0.0535
100	2.1212	0.0146	0.0196	0.0248	0.0301	0.0355	0.0410	0.0466	0.0524
110	2.1650	0.0143	0.0192	0.0243	0.0295	0.0348	0.0402	0.0457	0.0513
120	2.2089	0.0140	0.0189	0.0238	0.0289	0.0341	0.0394	0.0448	0.0503
130	2.2528	0.0137	0.0185	0.0234	0.0283	0.0334	0.0286	0.0439	0.0493
140	2.2966	0.0135	0.0181	0.0229	0.0278	0.0328	0.0379	0.0431	0.0484
150	2.3405	0.0132	0.0178	0.0225	0.0273	0.0322	0.0372	0.0423	0.0475
160	2.3843	0.0130	0.0175	0.0221	0.0268	0.0316	0.0365	0.0415	0.0466
170	2.4282	0.0127	0.0172	0.0217	0.0263	0.0310	0.0358	0.0407	0.0458
180	2.4721	0.0125	0.0169	0.0213	0.0258	0.0304	0.0352	0.0400	0.0449
190	2.5159	0.0123	0.0166	0.0209	0.0254	0.0299	0.0346	0.0393	0.0442
200	2.5598	0.0121	0.0163	0.0206	0.0249	0.0294	0.0340	0.0386	0.0434

[1] The manufacturers shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (lb/ft^3)] — Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°F)] — The design temperature in the hazard area.
[4] s [Specific Volume (ft^3/lb)] — Specific volume of superheated FIC-13I1 vapor may be approximated by the formula:
$s = 1.683 + 0.0044t$
where t = temperature (°F)
[5] C [Concentration (%)] — Volumetric concentration of FIC-13I1 in air at the temperature indicated.

Table 3-5.1(o) FIC-13I1 Total Flooding Quantity [1]

Temp -t- (°C) [3]	FIC-13I1 Specific Vapor Volume -s- (m^3/kg) [4]	FIC-13I1 Weight Requirements of Hazard Volume W/V (kg/m^3) [2] Metric Units Design Concentration (% by volume) [5]							
		3	4	5	6	7	8	9	10
−40	0.0941	0.3287	0.4429	0.5594	0.6784	0.8000	0.9242	1.0512	1.1810
−30	0.0968	0.3194	0.4303	0.5436	0.6592	0.7774	0.8981	1.0214	1.1476
−20	0.0996	0.3106	0.4185	0.5286	0.6411	0.7560	0.8734	0.9934	1.1160
−10	0.1023	0.3023	0.4073	0.5145	0.6239	0.7358	0.8500	0.9668	1.0861
0	0.1050	0.2944	0.3967	0.5011	0.6077	0.7166	0.8279	0.9416	1.0578
10	0.1078	0.2870	0.3866	0.4883	0.5922	0.6984	0.8068	0.9176	1.0309
20	0.1105	0.2799	0.3770	0.4762	0.5776	0.6811	0.7868	0.8949	1.0054
30	0.1133	0.2731	0.3679	0.4647	0.5636	0.6646	0.7678	0.8733	0.9811
40	0.1160	0.2666	0.3592	0.4538	0.5503	0.6489	0.7497	0.8527	0.9579
50	0.1187	0.2605	0.3509	0.4433	0.5376	0.6339	0.7324	0.8330	0.9358
60	0.1215	0.2546	0.3430	0.4333	0.5255	0.6197	0.7159	0.8142	0.9147
70	0.1242	0.2490	0.3355	0.4237	0.5139	0.6060	0.7001	0.7963	0.8946
80	0.1269	0.2436	0.3282	0.4146	0.5028	0.5929	0.6850	0.7791	0.8753
90	0.1297	0.2385	0.3213	0.4058	0.4922	0.5804	0.6705	0.7626	0.8568
100	0.1324	0.2336	0.3147	0.3975	0.4820	0.5684	0.6567	0.7469	0.8391

[1] The manufacturers listing shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (kg/m^3)] — Kilograms required per cubic foot of protected volume to produce indicated conc at temperature specified.

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

[3] t [Temperature (°C)] — The design temperature in the hazard area.
[4] s [Specific Volume (m^3/kg)] — Specific volume of superheated FIC-13I1 vapor may be approximated by the formula:
$s = 0.1138 + 0.0005t$
where t = temperature (°C)
[5] C [Concentration (%)] — Volumetric concentration of FIC-13I1 in air at the temperature specified.

Table 3-5.1(p) IG-01 Total Flooding Quantity [1]

Temp -t- (°F) [3]	IG-01 Specific Volume -s- (ft^3/lb) [4]	IG 01 Weight Requirements of Hazard Volume W/V (lb/ft^3) [2] English Units Design Concentration (% by volume) [5]							
		34	37	40	42	47	49	58	62
-40	7.67176	0.524	0.583	0.645	0.688	0.801	0.850	1.095	1.221
-30	7.85457	0.512	0.570	0.630	0.672	0.783	0.830	1.069	1.193
-20	8.03738	0.501	0.557	0.615	0.656	0.765	0.811	1.045	1.166
-10	8.22019	0.489	0.544	0.602	0.642	0.748	0.793	1.022	1.140
0	8.40299	0.479	0.532	0.589	0.628	0.732	0.776	1.000	1.115
10	8.58580	0.469	0.521	0.576	0.614	0.716	0.759	0.978	1.091
20	8.76861	0.459	0.510	0.564	0.602	0.701	0.744	0.958	1.088
30	8.95142	0.449	0.500	0.553	0.589	0.687	0.728	0.938	1.047
40	9.13422	0.440	0.490	0.541	0.577	0.673	0.714	0.920	1.026
50	9.31703	0.432	0.480	0.531	0.566	0.660	0.700	0.902	1.006
60	9.49984	0.424	0.471	0.521	0.555	0.647	0.686	0.884	0.986
70	9.68265	0.416	0.462	0.511	0.545	0.635	0.673	0.868	0.958
80	9.86545	0.408	0.453	0.501	0.535	0.623	0.661	0.851	0.950
90	10.04826	0.400	0.445	0.492	0.525	0.612	0.649	0.836	0.932
100	10.23107	0.393	0.437	0.483	0.516	0.601	0.637	0.821	0.916
110	10.41988	0.386	0.430	0.475	0.506	0.590	0.626	0.807	0.900
120	10.59668	0.380	0.422	0.467	0.498	0.580	0.615	0.793	0.884
130	10.77949	0.373	0.415	0.459	0.489	0.570	0.605	0.779	0.869
140	10.96230	0.367	0.408	0.451	0.481	0.561	0.595	0.766	0.855
150	11.14511	0.361	0.401	0.444	0.473	0.552	0.585	0.754	0.841
160	11.32791	0.355	0.395	0.437	0.466	0.543	0.576	0.742	0.827
170	11.51072	0.350	0.389	0.430	0.458	0.534	0.586	0.730	0.814
180	11.69353	0.344	0.383	0.423	0.451	0.526	0.558	0.718	0.801
190	11.87634	0.339	0.377	0.416	0.444	0.518	0.549	0.707	0.789
200	12.05914	0.334	0.371	0.410	0.437	0.510	0.541	0.697	0.777

[1] The manufacturers listing shall specify the temperature range for operation.

[2] W/V [Agent Weight Requirements (lb/ft^3)] — Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s} * \ln\left(\frac{100}{100-C}\right) [6]$$

[3] t [Temperature (°F)] — The design temperature in the hazard area.

[4] s [Specific Volume (ft^3/lb)] — Specific volume of superheated IG-01 vapor may be approximatedby the formula:

$s = 8.514 + 0.0185t$

where t = temperature (°F)

[5] C [Concentration (%)] — Volumetric concentration of IG-01 in air at the temperatue indicated at 1013 mbar and storage temperature of 70°F.

[6] The term $W = \ln \frac{100}{100-C}$

gives the volume at a rated concentration (%) and temperature to reach an air-agent mixture at the end of flooding time in a volume of 1 ft^3.

Table 3-5.1(q) IG-01 Total Flooding Quantity [1]

Temp -t- (°C) [3]	IG-01 Specific Volume -s- (m^3/kg) [4]	IG-01 Weight Requirements of Hazard Volume W/V (kg/m^3) [2] Metric Units Design Concentration (% by volume) [5]							
		34	37	40	42	47	49	58	62
−20	0.5201	0.4812	0.5350	0.5915	0.6308	0.7352	0.7797	1.0046	1.1205
−10	0.5406	0.4629	0.5147	0.5691	0.6068	0.7073	0.7501	0.9664	1.0779
0	0.5612	0.4459	0.4950	0.5482	0.5846	0.6814	0.7226	0.9310	1.0384
10	0.5817	0.4302	0.4784	0.5289	0.5640	0.6573	0.6971	0.8981	1.0018
15	0.5920	0.4227	0.4701	0.5197	0.5542	0.6459	0.6850	0.8828	0.9844
20	0.6023	0.4155	0.4620	0.5108	0.5447	0.6349	0.6733	0.8675	0.9676
30	0.6228	0.4018	0.4468	0.4940	0.5268	0.6139	0.6511	0.8389	0.9357
35	0.6331	0.3953	0.4395	0.4860	0.5182	0.6040	0.6406	0.8253	0.9205
40	0.6434	0.3890	0.4325	0.4762	0.5099	0.5943	0.0303	0.8121	0.9058
50	0.6639	0.3769	0.4191	0.4634	0.4942	0.5759	0.6108	0.7870	0.8778
60	0.6845	0.3656	0.4066	0.4495	0.4793	0.5587	0.5925	0.7633	0.8514
70	0.7050	0.3550	0.3947	0.4304	0.4054	0.5424	0.5752	0.7411	0.0200
80	0.7256	0.3449	0.3835	0.4240	0.4522	0.5270	0.5589	0.7201	0.8032
90	0.7461	0.3354	0.3730	0.4124	0.4397	0.5125	0.5436	0.7003	0.7811
100	0.7666	0.3264	0.3630	0.4013	0.4270	0.4988	0.5290	0.6815	0.7601
110	0.7872	0.3179	0.3535	0.3008	0.4168	0.4857	0.5152	0.6637	0.7403
120	0.8077	0.3098	0.3445	0.3809	0.4062	0.4734	0.5021	0.6468	0.7215

[1] The manufacturers listing shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (kg/m^3)] — Kilograms of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s} * \ln\left(\frac{100}{100-C}\right) \quad [6]$$

[3] t [Temperature (°C)] – The design temperature in the hazard area.
[4] s [Specific Volume (m^3/kg)] — The specific volume of superheated IG-01 vapor may be approximated by the formula:
$s = 0.5685 + 0.00208t$
where t = temperature (°C)
[5] C [Concentration (%)] — Volumetric concentration of IG-01 in air at the temperatue indicated at 1013 mbar and storage temperature of 20°C.

[6] The term $W = \ln \frac{100}{100-C}$
gives the volume at a rated concentration (%) and temperature to reach an air-agent mixture at the end of flooding time in a volume of 1 m^3.

Table 3-5.1(r) IG-541 Total Flooding Quantity [1]

Temp -t- (°F) [3]	IG-541 Specific Volume -s- (ft^3/lb) [4]	IG-541 Weight Requirements of Hazard Volume W/V (lb/ft^3) [2] English Units Design Concentration (% by volume) [5]							
		34	38	42	46	50	54	58	62
−40	9.001	0.524	0.603	0.686	0.802	0.873	0.977	1.096	1.218
−30	9.215	0.513	0.590	0.672	0.760	0.855	0.958	1.070	1.194
−20	9.429	0.501	0.576	0.657	0.743	0.836	0.936	1.046	1.166
−10	9.644	0.490	0.563	0.642	0.726	0.817	0.915	1.022	1.140
0	9.858	0.479	0.551	0.628	0.710	0.799	0.895	1.000	1.116
10	10.072	0.469	0.539	0.615	0.695	0.782	0.876	0.979	1.092
20	10.286	0.459	0.528	0.602	0.681	0.766	0.858	0.958	1.069
30	10.501	0.450	0.517	0.590	0.667	0.750	0.840	0.939	1.047
40	10.715	0.441	0.507	0.578	0.653	0.735	0.824	0.920	1.026
50	10.929	0.432	0.497	0.566	0.641	0.721	0.807	0.902	1.006
60	11.144	0.424	0.487	0.555	0.628	0.707	0.792	0.885	0.987
70	11.358	0.416	0.478	0.545	0.616	0.693	0.777	0.868	0.968
80	11.572	0.408	0.469	0.535	0.605	0.681	0.762	0.852	0.950
90	11.787	0.401	0.461	0.525	0.594	0.668	0.749	0.836	0.933
100	12.001	0.393	0.453	0.516	0.583	0.656	0.735	0.821	0.916
110	12.215	0.386	0.445	0.507	0.573	0.645	0.722	0.807	0.900
120	12.429	0.380	0.437	0.498	0.563	0.634	0.710	0.793	0.884
130	12.644	0.373	0.430	0.489	0.554	0.623	0.698	0.779	0.869
140	12.858	0.367	0.422	0.481	0.544	0.612	0.686	0.766	0.855
150	13.072	0.361	0.415	0.473	0.535	0.602	0.675	0.754	0.841
160	13.287	0.355	0.409	0.466	0.527	0.593	0.664	0.742	0.827
170	13.501	0.350	0.402	0.458	0.518	0.583	0.653	0.730	0.814
180	13.715	0.344	0.396	0.451	0.510	0.574	0.643	0.718	0.801
190	13.930	0.339	0.390	0.444	0.502	0.565	0.633	0.707	0.789
200	14.144	0.334	0.384	0.437	0.495	0.557	0.624	0.697	0.777

[1] The manufacturers shall specify the temperature range for operation.

[2] W/V [Agent Weight Requirements (lb/ft^3)] — Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°F)] — The design temperature in the hazard area

[4] s [Specific Volume (ft^3/lb)] — Specific volume of superheated IG-541 vapor may be approximated by the formula:

$s = 9.8579 + 0.2143t$

where t = temperature (°F)

[5] C [Concentration (%)] — Volumetric concentration of IG-541 in air at the temperature indicated

Table 3-5.1(s) IG-541 Total Flooding Quantity [1]

Temp -t- (°C) [3]	IG-541 Specific Volume -s- (m^3/kg) [4]	IG-541 Weight Requirements of Hazard Volume W/V (kg/m^3) [2] Metric Units Design Concentration (% by volume) [5]							
		34	38	42	46	50	54	58	62
−40	0.562	0.524	0.603	0.686	0.802	0.873	0.977	1.093	1.218
−30	0.591	0.502	0.578	0.657	0.769	0.837	0.936	1.048	1.167
−20	0.611	0.482	0.555	0.631	0.738	0.803	0.899	1.006	1.121
−10	0.635	0.464	0.534	0.608	0.711	0.774	0.866	0.969	1.080
0	0.659	0.447	0.515	0.568	0.685	0.745	0.834	0.933	1.040
10	0.683	0.431	0.496	0.565	0.660	0.719	0.804	0.900	1.003
20	0.707	0.417	0.480	0.546	0.639	0.695	0.778	0.870	0.970
30	0.731	0.403	0.464	0.528	0.617	0.672	0.752	0.841	0.937
40	0.755	0.390	0.449	0.511	0.597	0.650	0.727	0.814	0.907
50	0.780	0.378	0.435	0.495	0.579	0.630	0.705	0.788	0.878
60	0.804	0.367	0.422	0.480	0.562	0.611	0.684	0.766	0.853
70	0.828	0.356	0.410	0.466	0.545	0.593	0.664	0.743	0.828
80	0.852	0.346	0.398	0.453	0.530	0.576	0.645	0.722	0.804
90	0.876	0.337	0.387	0.441	0.516	0.561	0.628	0.702	0.783
100	0.900	0.328	0.377	0.429	0.502	0.546	0.611	0.684	0.762

[1] The manufacturers shall specify the temperature range for operation.
[2] W/V [Agent Weight Requirements (kg/m^3)] — Kilograms of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°C)] — The design temperature in the hazard area.
[4] s [Specific Volume (m^3/kg)] — Specific volume of superheated IG-541 vapor may be approximated by the formula:
$s = 0.65799 + 0.00239t$
where t = temperature (°C)
[5] C [Concentration (%)] — Volumetric concentration of IG-541 in air at the temperature indicated.

Table 3-5.1(t) IG-55 Total Flooding Quantity [1]

Temp -t- (°F) [3]	IG-55 Specific Vapor Volume -s- (ft^3/lb) [4]	IG-55 Weight Requirements of Hazard Volume W/V (lb/ft^3) [2] English Units Design Concentration (% by volume) [5]							
		34	38	42	46	50	54	58	62
-40	9.02108	0.524	0.603	0.688	0.778	0.875	0.980	1.095	1.221
-30	9.23603	0.512	0.589	0.672	0.760	0.854	0.957	1.069	1.193
-20	9.45099	0.501	0.576	0.656	0.742	0.835	0.935	1.045	1.166
-10	9.66594	0.489	0.563	0.642	0.726	0.816	0.915	1.022	1.140
0	9.88090	0.479	0.551	0.628	0.710	0.799	0.895	1.000	1.115
10	10.09586	0.469	0.539	0.614	0.695	0.782	0.876	0.978	1.091
20	10.31081	0.459	0.528	0.602	0.680	0.765	0.857	0.958	1.068
30	10.52577	0.449	0.517	0.589	0.667	0.750	0.840	0.938	1.047
40	10.74073	0.440	0.507	0.577	0.653	0.735	0.823	0.920	1.026
50	10.95568	0.432	0.497	0.566	0.640	0.720	0.807	0.902	1.006
60	11.17064	0.424	0.487	0.555	0.628	0.706	0.791	0.884	0.986
70	11.38560	0.416	0.478	0.545	0.616	0.693	0.777	0.868	0.968
80	11.60055	0.408	0.469	0.535	0.605	0.680	0.762	0.851	0.950
90	11.81551	0.400	0.461	0.525	0.594	0.668	0.748	0.836	0.932
100	12.03046	0.393	0.452	0.516	0.583	0.656	0.735	0.821	0.916
110	12.24542	0.386	0.444	0.506	0.573	0.644	0.722	0.807	0.900
120	12.46038	0.380	0.437	0.498	0.563	0.633	0.710	0.793	0.884
130	12.67533	0.373	0.429	0.489	0.553	0.623	0.698	0.779	0.869
140	12.89029	0.367	0.422	0.481	0.544	0.612	0.686	0.766	0.855
150	13.10525	0.361	0.415	0.473	0.535	0.602	0.675	0.754	0.841
160	13.32020	0.355	0.409	0.466	0.527	0.592	0.664	0.742	0.827
170	13.53516	0.350	0.402	0.458	0.518	0.583	0.653	0.730	0.814
180	13.75012	0.344	0.396	0.451	0.510	0.574	0.643	0.718	0.801
190	13.96507	0.339	0.390	0.444	0.502	0.565	0.633	0.707	0.789
200	14.18003	0.334	0.384	0.437	0.495	0.557	0.623	0.697	0.777

[1] The manufacturers listing shall specify the temperature range for operation.

[2] W/V [Agent Weight Requirements (lb/ft^3)] — Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°F)] — The design temperature in the hazard area.

[4] s [Specific Volume (ft^3/lb)] — Specific volume of superheated IG-55 vapor may be approximated by the formula:

$s = 9.8809 + 0.0215t$

where t = temperature (°F).

[5] C [Concentration (%)] — Volumetric concentration of IG-55 in air at the temperature indicated.

Table 3-5.1(u) IG-55 Total Flooding Quantity [1]

Temp -t- (°C) [3]	IG-55 Specific Vapor Volume -s- (m^3/kg) [4]	IG-55 Volume Weight of Hazard Volume W/V (kg/m^3) [2] Metric Units Design Concentration (% by volume) [5]							
		34	38	42	46	50	54	58	62
–40	0.56317	0.524	0.603	0.688	0.778	0.875	0.980	1.095	1.221
–35	0.56324	0.513	0.591	0.673	0.761	0.856	0.959	1.072	1.196
–30	0.58732	0.503	0.579	0.659	0.746	0.839	0.940	1.050	1.171
–25	0.59940	0.493	0.567	0.646	0.731	0.822	0.921	1.029	1.147
–20	0.61148	0.483	0.556	0.633	0.716	0.806	0.903	1.008	1.125
–15	0.62355	0.474	0.545	0.621	0.702	0.790	0.885	0.989	1.103
–10	0.63563	0.465	0.535	0.609	0.689	0.775	0.868	0.970	1.082
–5	0.64771	0.456	0.525	0.598	0.676	0.761	0.852	0.952	1.062
0	0.65979	0.448	0.515	0.587	0.664	0.747	0.837	0.935	1.042
5	0.67186	0.440	0.506	0.576	0.652	0.733	0.822	0.918	1.024
10	0.68394	0.432	0.497	0.566	0.640	0.720	0.807	0.902	1.006
15	0.69602	0.424	0.488	0.556	0.629	0.708	0.793	0.886	0.988
20	0.70810	0.417	0.480	0.547	0.619	0.696	0.779	0.871	0.971
25	0.72017	0.410	0.472	0.538	0.608	0.684	0.766	0.856	0.955
30	0.73225	0.403	0.464	0.529	0.598	0.673	0.754	0.842	0.939
35	0.74433	0.397	0.456	0.520	0.588	0.662	0.742	0.828	0.924
40	0.75641	0.390	0.449	0.512	0.579	0.651	0.730	0.815	0.909
45	0.76848	0.384	0.442	0.504	0.570	0.641	0.718	0.802	0.895
50	0.78056	0.378	0.435	0.496	0.561	0.631	0.707	0.790	0.881
55	0.79264	0.373	0.429	0.488	0.553	0.622	0.696	0.778	0.868
60	0.80471	0.367	0.422	0.481	0.544	0.612	0.686	0.766	0.855
65	0.81679	0.362	0.416	0.474	0.536	0.603	0.676	0.755	0.842
70	0.82887	0.356	0.410	0.467	0.528	0.594	0.666	0.744	0.830
75	0.84095	0.351	0.404	0.460	0.521	0.586	0.656	0.733	0.818
80	0.85302	0.346	0.398	0.454	0.513	0.578	0.647	0.723	0.806
85	0.86510	0.341	0.393	0.448	0.506	0.569	0.638	0.713	0.795
90	0.87718	0.337	0.387	0.441	0.499	0.562	0.629	0.703	0.784
95	0.88926	0.332	0.382	0.435	0.493	0.554	0.621	0.693	0.773
100	0.90133	0.328	0.377	0.430	0.486	0.547	0.612	0.684	0.763

[1] The manufacturer's listing shall specify the temperature range for operation.

[2] W/V [Agent Weight Requirements (kg/m^3)] — Kilograms of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°C)] — The design temperature in the hazard area.

[4] s [Specific Volume (m^3/kg)] — Specific volume of superheated IG-55 vapor may be approximated by the formula:

$s = 0.6598 + 0.00242t$

where t = temperature (°C).

[5] C [Concentration (%)] — Volumetric concentration of IG-55 in air at the temperature indicated.

Table 3-5.1(v) HFC-236fa Total Flooding Quantity [1]

Temp (°F) -t- [3]	HFC-236fa Specific Vapor Volume (ft^3/lb) -s- [4]	HFC-236fa Weight Requirements of Hazard Volume W/V (lb/ft^3) [2] English Units Design Concentration (% by volume) [5]										
		5	6	7	8	9	10	11	12	13	14	15
30	2.2520	0.0234	0.0283	0.0334	0.0386	0.0439	0.0493	0.0549	0.0606	0.0664	0.0723	0.0784
40	2.3034	0.0228	0.0277	0.0327	0.0378	0.0429	0.0482	0.0537	0.0592	0.0649	0.0707	0.0766
50	2.3547	0.0224	0.0271	0.0320	0.0369	0.0420	0.0472	0.0525	0.0579	0.0635	0.0691	0.0749
60	2.4060	0.0219	0.0265	0.0313	0.0361	0.0411	0.0462	0.0514	0.0567	0.0621	0.0677	0.0733
70	2.4574	0.0214	0.0260	0.0306	0.0354	0.0402	0.0452	0.0503	0.0555	0.0608	0.0662	0.0718
80	2.5087	0.0210	0.0254	0.0300	0.0347	0.0394	0.0443	0.0493	0.0544	0.0596	0.0649	0.0703
90	2.5601	0.0206	0.0249	0.0294	0.0340	0.0386	0.0434	0.0483	0.0533	0.0584	0.0636	0.0689
100	2.6114	0.0202	0.0244	0.0288	0.0333	0.0379	0.0425	0.0473	0.0522	0.0572	0.0623	0.0676
110	2.6627	0.0198	0.0240	0.0283	0.0327	0.0371	0.0417	0.0464	0.0512	0.0561	0.0611	0.0663
120	2.7141	0.0194	0.0235	0.0277	0.0320	0.0364	0.0409	0.0455	0.0502	0.0551	0.0600	0.0650
130	2.7654	0.0190	0.0231	0.0272	0.0314	0.0358	0.0402	0.0447	0.0493	0.0540	0.0589	0.0638
140	2.8168	0.0187	0.0227	0.0267	0.0309	0.0351	0.0394	0.0439	0.0484	0.0530	0.0578	0.0626
150	2.8681	0.0184	0.0223	0.0262	0.0303	0.0345	0.0387	0.0431	0.0475	0.0521	0.0568	0.0615
160	2.9194	0.0180	0.0219	0.0258	0.0298	0.0339	0.0381	0.0423	0.0467	0.0512	0.0558	0.0604
170	2.9708	0.0177	0.0215	0.0253	0.0293	0.0333	0.0374	0.0416	0.0459	0.0503	0.0548	0.0594
180	3.0221	0.0174	0.0211	0.0249	0.0288	0.0327	0.0368	0.0409	0.0451	0.0494	0.0539	0.0584
190	3.0735	0.0171	0.0208	0.0245	0.0283	0.0322	0.0362	0.0402	0.0444	0.0486	0.0530	0.0574
200	3.1248	0.0168	0.0204	0.0241	0.0278	0.0317	0.0356	0.0396	0.0436	0.0478	0.0521	0.0565

[1] The manufacturers listing shall specify the temperature range for operation.

[2] W/V [Agent Weight Requirements (lb/ft^3)] — Pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°F)] — The design temperature in the hazard area.

[4] s [Specific Volume (ft^3/lb)] — Specific volume of superheated HFC-236fa vapor may be approximated by the formula:

$s = 2.098 + 0.0051t$

where t = temperature (°F).

[5] C [Concentration (%)] — Volumetric concentration of HFC-236fa in air at the temperature indicated

Table 3-5.1(w) HFC-236fa Total Flooding Quantity [1]

Temp (°C) -t- [3]	HFC-236fa Specific Vapor Volume (m^3/kg) -s- [4]	HFC-236fa Weight Requirements of Hazard Volume W/V (kg/m^3) [2] Metric Units Design Concentration (% by volume) [5]										
		5	6	7	8	9	10	11	12	13	14	15
0	0.1413	0.3725	0.4517	0.5327	0.6154	0.6999	0.7863	0.8747	0.9651	1.0575	1.1521	1.2489
5	0.1442	0.3650	0.4427	0.5220	0.6031	0.6860	0.7706	0.8572	0.9458	1.0364	1.1291	1.2240
10	0.1471	0.3579	0.4340	0.5118	0.5913	0.6725	0.7555	0.8404	0.9273	1.0161	1.1070	1.2000
15	0.1499	0.3510	0.4257	0.5020	0.5799	0.6596	0.7410	0.8243	0.9095	0.9966	1.0857	1.1769
20	0.1528	0.3444	0.4177	0.4925	0.5690	0.6472	0.7271	0.8088	0.8923	0.9778	1.0652	1.1548
25	0.1557	0.3380	0.4100	0.4834	0.5585	0.6352	0.7136	0.7938	0.8758	0.9597	1.0455	1.1334
30	0.1586	0.3319	0.4025	0.4746	0.5483	0.6237	0.7007	0.7794	0.8599	0.9423	1.0266	1.1128
35	0.1615	0.3260	0.3953	0.4662	0.5386	0.6125	0.6882	0.7655	0.8446	0.9255	1.0082	1.0930
40	0.1643	0.3203	0.3884	0.4580	0.5291	0.6018	0.6761	0.7521	0.8298	0.9092	0.9906	1.0738
45	0.1672	0.3147	0.3817	0.4501	0.5200	0.5914	0.6645	0.7391	0.8155	0.8936	0.9735	1.0553
50	0.1701	0.3094	0.3752	0.4425	0.5112	0.5814	0.6532	0.7266	0.8017	0.8785	0.9570	1.0375
55	0.1730	0.3043	0.3690	0.4351	0.5027	0.5717	0.6423	0.7145	0.7883	0.8638	0.9411	1.0202
60	0.1759	0.2993	0.3630	0.4280	0.4945	0.5624	0.6318	0.7028	0.7754	0.8497	0.9257	1.0035
65	0.1787	0.2945	0.3571	0.4211	0.4865	0.5533	0.6216	0.6915	0.7629	0.8360	0.9108	0.9873
70	0.1816	0.2898	0.3514	0.4144	0.4788	0.5445	0.6118	0.6805	0.7508	0.8227	0.8963	0.9716
75	0.1845	0.2853	0.3460	0.4080	0.4713	0.5360	0.6022	0.6699	0.7391	0.8099	0.8823	0.9565
80	0.1874	0.2809	0.3406	0.4017	0.4641	0.5278	0.5930	0.6596	0.7277	0.7974	0.8688	0.9418
85	0.1903	0.2766	0.3355	0.3956	0.4570	0.5198	0.5840	0.6496	0.7167	0.7854	0.8556	0.9275
90	0.1931	0.2725	0.3305	0.3897	0.4502	0.5121	0.5753	0.6399	0.7060	0.7737	0.8429	0.9137
95	0.1960	0.2685	0.3256	0.3840	0.4436	0.5045	0.5668	0.6305	0.6957	0.7623	0.8305	0.9003

[1] The manufacturers listing shall specify the temperature range for operation.

[2] W/V [Agent Weight Requirements (kg/m^3)] — Kilograms of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

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

[3] t [Temperature (°C)] — The design temperature in the hazard area.

[4] s [Specific Volume (m^3/kg)] — Specific volume of superheated HFC-236fa vapor may be approximated by the formula:

$s = 0.1413 + 0.0006t$

where t = temperature (°C).

[5] C [Concentration (%)] — Volumetric concentration of HFC-236fa in air at the temperature indicated.

3-5.2* The amount of inert gas clean agent required to achieve the design concentration shall be calculated from the following formula:

$$X = 2.303 \left[\frac{V_S}{S} \right] \text{Log}_{10} \left[\frac{100}{100\text{-}C} \right]$$

Where:

X = Volume of inert gas added (at STP) per volume of space, ft^3/ft^3

k_1 and k_2 = Constants specific to the inert gas being used. See Table 3-5.1(a) for values of k_1 and k_2.

S = k_1 and k_2 (T), is a linear equation determined by least squares curve fit techniques from data supplied by inert gas manufacturer. The zero intercept is k_1 and the slope is k_2.

T = Minimum anticipated temperature of the protected volume.

C = Inert gas design concentration, % by volume.

V_S = Specific volume of inert gas agent at 70°F (21°C).

NOTE: This calculation includes an allowance for the leakage of agent from a "tight" enclosure.

An alternative equation for calculating the inert gas clean agent concentrations is shown below:

$$X = 2.303\ [530/(460 + t)]\ \text{Log}_{10}\ [100/(100\text{-}C)]$$

3-5.3 In addition to the concentration requirements, additional quantities of agent are required to compensate for any special conditions that would affect the extinguishing efficiency.

3-6* Pressure Adjustment. The design quantity of the clean agent shall be adjusted to compensate for ambient pressures that vary more than 11 percent [equivalent to approximately 3000 ft (915 m) of elevation change] from standard sea level pressures [29.92 in. Hg at 70°F (760 mm Hg at 0°C)]. The ambient pressure is affected by changes in altitude, pressurization or depressurization of the protected enclosure, and weather-related barometric pressure changes. The agent quantity is determined by multiplying the quantity determined in 3-5.1 or 3-5.2 by the ratio of average ambient enclosure pressure to standard sea level pressure.

Table 3-6 Atmospheric Correction Factors

Equivalent Altitude	Enclosure Pressure	Atmospheric Correction Factor
-3000 ft (-0.92 km)	16.25 psia (84.0 cm Hg)	1.11
-2000 ft (-0.61 km)	15.71 psia (81.2 cm Hg)	1.07
-1000 ft (-0.30 km)	15.23 psia (78.7 cm Hg)	1.04
0 ft (0.00 km)	14.71 psia (76.0 cm Hg)	1.00
1000 ft (0.30 km)	14.18 psia (73.3 cm Hg)	0.96
2000 ft (0.61 km)	13.64 psia (70.5 cm Hg)	0.93
3000 ft (0.91 km)	13.12 psia (67.89 cm Hg)	0.89
4000 ft (1.22 km)	12.58 psia (65.0 cm Hg)	0.86
5000 ft (1.52 km)	12.04 psia (62.2 cm Hg)	0.82
6000 ft (1.83 km)	11.53 psia (59.6 cm Hg)	0.78
7000 ft (2.13 km)	11.03 psia (57.0 cm Hg)	0.75
8000 ft (2.45 km)	10.64 psia (55.0 cm Hg)	0.72
9000 ft (2.74 km)	10.22 psia (52.8 cm Hg)	0.69
10,000 ft (3.05 km)	9.77 psia (50.5 cm Hg)	0.66

3-7* Duration of Protection. It is important that the agent design concentration not only shall be achieved, but also shall be maintained for a sufficient period of time to allow effective emergency action by trained personnel. This is equally important in all classes of fires since a persistent ignition source (e.g., an arc, heat source, oxyacetylene torch, or "deep-seated" fire) can lead to resurgence of the initial event once the clean agent has dissipated.

3-8 Distribution System.

3-8.1 Rate of Application.

3-8.1.1 The minimum design rate of application shall be based on the quantity of agent required for the desired concentration and the time allotted to achieve the desired concentration.

3-8.1.2* Discharge Time.

3-8.1.2.1 The discharge time for halocarbon agents shall not exceed 10 sec, or as otherwise required by the authority having jurisdiction.

3-8.1.2.2 The discharge time for inert gas agents shall not exceed 60 seconds to achieve 95 percent of the design concentration or as otherwise required by the authority having jurisdiction.

3-8.1.2.3 For halocarbon agents, the discharge time period is defined as the time required to discharge from the nozzles 95 percent of the agent mass [at 70°F (21°C)] necessary to achieve the minimum design concentration.

3-8.1.2.4 Flow calculations performed in accordance with Section 3-2, or in accordance with the listed pre-engineered systems instruction manuals, shall be used to demonstrate compliance with 3-8.1.2.

3-8.2* Extended Discharge. When an extended discharge is necessary, the rate shall be sufficient to maintain the desired concentration for the required hold time.

3-9 Nozzle Choice and Location.

3-9.1 Nozzles shall be of the type listed for the intended purpose and shall be placed within the protected enclosure in compliance with listed limitations with regard to spacing, floor coverage, and alignment.

3-9.2 The type of nozzles selected, their number, and their placement shall be such that the design concentration will be established in all parts of the hazard enclosure and such that the discharge will not unduly splash flammable liquids or create dust clouds that might extend the fire, create an explosion, or otherwise adversely affect the contents or integrity of the enclosure.

Chapter 4 Inspection, Maintenance, Testing, and Training

4-1 Inspection and Tests.

4-1.1 At least annually, all systems shall be thoroughly inspected and tested for proper operation by competent personnel. Discharge tests are not required.

4-1.2 The inspection report with recommendations shall be filed with the owner.

4-1.3 At least semiannually, the agent quantity and pressure of refillable containers shall be checked.

4-1.3.1 For halocarbon clean agents, if a container shows a loss in agent quantity of more than 5 percent or a loss in pressure (adjusted for temperature) of more than 10 percent, it shall be refilled or replaced.

4-1.3.2 For inert gas clean agents that are not liquefied, pressure is an indication of agent quantity. If an inert gas clean agent container shows a loss in pressure (adjusted for temperature) of more than 5 percent, it shall be refilled or replaced. Where container pressure gauges are used for this purpose, they shall be compared to a separate calibrated device at least annually.

4-1.3.3 Where the amount of agent in the container is determined by special measuring devices, these devices shall be listed.

4-1.4 All halocarbon clean agent removed from refillable containers during service or maintenance procedures shall be collected and recycled or disposed of in an environmentally sound manner and in accordance with existing laws and regulations. All inert gas clean agents based on those gases normally found in the earth's atmosphere need not be recycled.

4-1.5 Factory-charged, nonrefillable containers that do not have a means of pressure indication shall have the agent quantity checked at least semiannually. If a container shows a loss in agent quantity of more than 5 percent, it shall be replaced. All factory-charged, nonrefillable containers removed from useful service shall be returned for recycling of the agent or disposed of in an environmentally sound manner and in accordance with existing laws and regulations.

4-1.6 For halocarbon clean agents, the date of inspection, gross weight of cylinder plus agent or net weight of agent, type of agent, person performing the inspection, and, where applicable, the pressure at a recorded temperature shall be recorded on a tag attached to the container. For inert gas clean agents, the date of inspection, type of agent, person performing the inspection, and the pressure at a recorded temperature shall be recorded on a tag attached to the container.

4-2 Container Test.

4-2.1 Department of Transportation (D.O.T.), Canadian Transport Commission (C.T.C.), or similar design clean agent containers shall not be recharged without retest if more than 5 years have elapsed since the date of the last test and inspection. For halocarbon agent storage containers, the retest shall be permitted to consist of a complete visual inspection as described in the *Code of Federal Regulations*, Title 49, Section 173.34 (e) (10).

NOTE: Transporting charged containers that have not been tested within 5 years might be illegal. Federal and local regulations should be consulted.

4-2.2* Visual Inspection. Cylinders continuously in service without discharging shall be given a complete external visual inspection every 5 years or more frequently if required. The visual inspection shall be in accordance with Compressed Gas Association pamphlet C-6, *Standard for Visual Inspection of Compressed Gas Cylinders (Steel)*, Section 3, except that the cylinders need not be emptied or stamped while under pressure. Inspections shall be made only by competent personnel and the results recorded on:

(a) A record tag permanently attached to each cylinder; and

(b) A suitable inspection report. A completed copy of the inspection report shall be furnished to the owner of the system or an authorized representative. These records shall be retained by the owner for the life of the system.

4-2.3 Where external visual inspection indicates that the container has been damaged, additional strength tests shall be required.

4-3 Hose Test.

4-3.1 General. All system hose shall be examined annually for damage. If visual examination shows any deficiency, the hose shall be immediately replaced or tested as specified in 4-3.3.

4-3.2 Testing. All hose shall be tested every 5 years.

4-3.3 All hose shall be tested at $1\frac{1}{2}$ times the maximum container pressure at 130°F (54.4°C) as follows:

(a) The hose shall be removed from any attachment;

(b) The hose assembly is then to be placed in a protective enclosure designed to permit visual observation of the test;

(c) The hose must be completely filled with water before testing;

(d) Pressure then is applied at a rate-of-pressure rise to reach the test pressure within a minimum of 1 minute. The test pressure is to be maintained for 1 full minute. Observations are then made to note any distortion or leakage;

(e) If the test pressure has not dropped or if the couplings have not moved, the pressure is released. The hose assembly is then considered to have passed the hydrostatic test if no permanent distortion has taken place;

(f) Hose assembly passing the test must be completely dried internally. If heat is used for drying, the temperature must not exceed the manufacturer's specifications;

(g) Hose assemblies failing a hydrostatic test must be marked and destroyed. They shall be replaced with new assemblies; and

(h) Each hose assembly passing the hydrostatic test shall be marked to show the date of test.

4-4 Enclosure Inspection. At least every 12 months, the enclosure protected by the clean agent shall be thoroughly inspected to determine if penetrations or other changes have occurred that could adversely affect agent leakage or change volume of hazard or both. Where the inspection indicates conditions that could result in inability to maintain the clean agent concentration, they shall be corrected. If uncertainty still exists, the enclosures shall be retested for integrity in accordance with 4-7.2.3.

Exception: An enclosure inspection is not required every 12 months if a documented administrative control program exists that addresses barrier integrity.

4-5 Maintenance.

4-5.1 These systems shall be maintained in full operating condition at all times. Actuation, impairment, and restoration of this protection shall be reported promptly to the authority having jurisdiction.

4-5.2 Any troubles or impairments shall be corrected in a timely manner consistent with the hazard protected.

4-5.3* Any penetrations made through the enclosure protected by the clean agent shall be sealed immediately. The method of sealing shall restore the original fire resistance rating of the enclosure.

4-6 Training.

4-6.1 All persons who might be expected to inspect, test, maintain, or operate fire extinguishing systems shall be thoroughly trained and kept thoroughly trained in the functions they are expected to perform.

4-6.2* Personnel working in an enclosure protected by a clean agent shall receive training regarding agent safety issues.

4-7 Approval of Installations.

4-7.1 The completed system shall be reviewed and tested by qualified personnel to meet the approval of the authority having jurisdiction. Only listed equipment and devices shall be used in the systems. To determine that the system has been properly installed and will function as specified, the following tests shall be performed.

4-7.2 Installation Acceptance.

4-7.2.1 It shall be determined that the protected enclosure is in general conformance with the construction documents.

4-7.2.2 Review Mechanical Components.

4-7.2.2.1 The piping distribution system shall be inspected to determine that it is in compliance with the design and installation documents.

4-7.2.2.2 Nozzles and pipe size shall be in accordance with system drawings. Means of pipe size reduction and attitudes of tees shall be checked for conformance to the design.

4-7.2.2.3 Piping joints, discharge nozzles, and piping supports shall be securely fastened to prevent unacceptable vertical or lateral movement during discharge. Discharge nozzles shall be installed in such a manner that piping cannot become detached during discharge.

4-7.2.2.4 During assembly, the piping distribution system shall be inspected internally to detect the possibility of any oil or particulate matter soiling the hazard area or affecting the agent distribution due to a reduction in the effective nozzle orifice area.

4-7.2.2.5 The discharge nozzle shall be oriented in such a manner that optimum agent dispersal can be effected.

4-7.2.2.6 If nozzle deflectors are installed, they shall be positioned to obtain maximum benefit.

4-7.2.2.7 The discharge nozzles, piping, and mounting brackets shall be installed in such a manner that they will not potentially cause injury to personnel. Agent shall not directly impinge on areas where personnel might be found in the normal work area. Agent shall not directly impinge on any loose objects or shelves, cabinet tops, or similar surfaces where loose objects could be present and become missiles.

4-7.2.2.8 All agent storage containers shall be properly located in accordance with an approved set of system drawings.

4-7.2.2.9 All containers and mounting brackets shall be fastened securely in accordance with the manufacturer's requirements.

4-7.2.2.10 A discharge test is generally not recommended; however, if a discharge test is to be conducted, containers for the agent to be used shall be weighed before and after discharge. Fill weight of container shall be verified by weighing or other approved methods. For inert gas clean agents, container pressure shall be recorded before and after discharge.

4-7.2.2.11 Adequate quantity of agent to produce the desired specified concentration shall be provided. The actual room volumes shall be checked against those indicated on the system drawings to ensure the proper quantity of agent. Fan coastdown and damper closure time shall be taken into consideration.

4-7.2.2.12 The piping shall be pneumatically tested in a closed circuit for a period of 10 min at 40 psig (276 kPa). At the end of 10 min, the pressure drop shall not exceed 20 percent of the test pressure.

Exception: The pressure test shall be permitted to be omitted if the total piping contains no more than one change in direction fitting between the storage container and the discharge nozzle, and where all piping is physically checked for tightness.

4-7.2.2.13* A flow test using nitrogen or an inert gas shall be performed on the piping network to verify that flow is continuous, and that the piping and nozzles are unobstructed.

4-7.2.3* Review Enclosure Integrity. All total flooding systems shall have the enclosure examined and tested to locate and then effectively seal any significant air leaks that could result in a failure of the enclosure to hold the specified agent concentration level for the specified holding period. The currently preferred method is using a blower door fan unit and smoke pencil. If quantitative results are recorded, these could be useful for comparison at future tests. (*For guidance, refer to Appendix B of this standard.*)

4-7.2.4 Review Electrical Components.

4-7.2.4.1 All wiring systems shall be properly installed in compliance with local codes and the system drawings. AC and dc wiring shall not be combined in a common conduit or raceway unless properly shielded and grounded.

4-7.2.4.2 All field circuits shall be free of ground faults and short circuits. Where field circuitry is being measured, all electronic components (such as smoke and flame detectors or special electronic equipment for other detectors or their mounting bases) shall be removed and jumpers shall be properly installed to prevent the possibility of damage within these devices. Components shall be replaced after measuring.

4-7.2.4.3 Power shall be supplied to the control unit from a separate dedicated source that will not be shut down on system operation.

4-7.2.4.4 Adequate and reliable primary and 24-hour minimum standby sources of energy shall be used to provide for operation of the detection, signaling, control, and actuation requirements of the system.

4-7.2.4.5 All auxiliary functions such as alarm-sounding or displaying devices, remote annunciators, air-handling shutdown, power shutdown, and so on shall be checked for proper operation in accordance with system requirements and design specifications. If possible, all air-handling and power-cutoff controls shall be of the type that, once interrupted, require manual restart to restore power.

4-7.2.4.6 Silencing of alarms (if desirable) shall not affect other auxiliary functions such as air handling or power cutoff if required in the design specification.

4-7.2.4.7 The detection devices shall be checked for proper type and location as specified on the system drawings.

4-7.2.4.8 Detectors shall not be located near obstructions or air ventilation and cooling equipment that would appreciably affect their response characteristics. Where applicable, air changes for the protected area shall be taken into consideration.

NOTE: Refer to NFPA 72, *National Fire Alarm Code*, and the manufacturer's recommended guidelines.

4-7.2.4.9 The detectors shall be installed in a professional manner and in accordance with technical data regarding their installation.

4-7.2.4.10 Manual pull stations shall be properly installed, readily accessible, accurately identified, and properly protected to prevent damage.

4-7.2.4.11 All manual stations used to release agents shall require two separate and distinct actions for operation. They shall be properly identified. Particular care shall be taken where manual release devices for more than one system are in close proximity and could be confused or the wrong system actuated. Manual stations in this instance shall be clearly identified as to which zone or suppression area they affect.

4-7.2.4.12 For systems with a main/reserve capability, the main/reserve switch shall be properly installed, readily accessible, and clearly identified.

4-7.2.4.13 For systems using abort switches, the switches shall be of the deadman type requiring constant manual pressure, properly installed, readily accessible within the hazard area, and clearly identified. Switches that remain in the abort position when released shall not be used for this purpose. Manual pull stations shall always override abort switches.

4-7.2.4.14 The control unit shall be properly installed and readily accessible.

4-7.2.5 Functional Testing.

4-7.2.5.1 Preliminary Functional Tests. The following preliminary functional tests shall be provided:

(a) If the system is connected to an alarm receiving office, the alarm receiving office shall be notified that the fire system test is to be conducted and that an emergency response by the fire department or alarm station personnel is not desired. All concerned personnel at the end-user's facility shall be notified that a test is to be conducted and shall be instructed as to the sequence of operation.

(b) Disable each agent storage container release mechanism so that activation of the release circuit will not release agent. Reconnect the release circuit with a functional device in lieu of each agent storage container release mechanism. For electrically actuated release mechanisms, these devices can include 24-volt lamps, flash bulbs, or circuit breakers. Pneumatically actuated release mechanisms can include pressure gauges. Refer to the manufacturer's recommendations in all cases.

(c) Check each detector for proper response.

(d) Check that polarity has been observed on all polarized alarm devices and auxiliary relays.

(e) Check that all end-of-line resistors have been installed across the detection and alarm bell circuits where required.

(f) Check all supervised circuits for proper trouble response.

4-7.2.5.2 System Functional Operational Test. The following system functional operational tests shall be performed:

(a) Operate detection initiating circuit(s). All alarm functions shall occur according to the design specification.

(b) Operate the necessary circuit to initiate a second alarm circuit if present. Verify that all second alarm functions occur according to design specifications.

(c) Operate manual release. Verify that manual release functions occur according to design specifications.

(d) If supplied, operate abort switch circuit. Verify that abort functions occur according to design specifications. Confirm that visual and audible supervisory signals are received at the control panel.

(e) Test all automatic valves unless testing the valve will release agent or damage the valve (destructive testing).

(f) Where required, check pneumatic equipment for integrity to ensure proper operation.

4-7.2.5.3 Remote Monitoring Operations. The following testing of remote monitoring operations, if applicable, shall be performed:

(a) Operate one of each type of input device while on standby power. Verify that an alarm signal is received at remote panel after device is operated. Reconnect primary power supply.

(b) Operate each type of alarm condition on each signal circuit and verify receipt of trouble condition at the remote station.

4-7.2.5.4 Control Panel Primary Power Source. The following testing of the control panel primary power source shall be performed:

(a) Verify that the control panel is connected to a dedicated circuit and labeled properly. This panel shall be readily accessible, yet restricted from unauthorized personnel.

(b) Test a primary power failure in accordance with the manufacturer's specification with the system fully operated on standby power.

4-7.2.5.5 When all predischarge work is completed, reconnect each agent storage container so that activation of the release circuit will release the agent. The system shall be returned to its fully operational design condition. The alarm-receiving office and all concerned personnel at the end-user's facility shall be notified that the fire system test is complete and that the system has been returned to full service condition.

Chapter 5 Referenced Publications

5-1 The following documents or portions thereof are referenced within this standard and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

5-1.1 NFPA Publication. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 70, *National Electrical Code*, 1996 edition.

5-1.2 Other Publications.

5-1.2.1 ANSI Publications. American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ANSI B1.20.1, *Standard for Pipe Threads, General Purpose*, 1983.

ANSI C2, *National Electrical Safety Code*, 1993.

5-1.2.2 ASME Publications. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

ASME *Boiler and Pressure Vessel Code*, 1992.

ASME B31.1, *Power Piping Code*, 1992.

5-1.2.3 ASTM Publications. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A 53, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless*, 1994.

ASTM A 106, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*, 1994.

ASTM A 120, *Specifications for Welded and Seamless Steel Pipe*, 1984.

5-1.2.4 CGA Publication. Compressed Gas Association, 1235 Jefferson Davis Highway, Arlington, VA 22202.

CGA C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders*, 1993.

5-1.2.5 ISO Publication. International Organization for Standardization, Case Postale 56, CH-1211, Genève Ave 20, Switzerland.

ISO/IEC Guide 7, *Requirements for Standards Suitable for Use for Conformity Assessment*, 1994 edition.

5-1.2.6 UL Publication. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062.

UL 1058, *Standard for Halogenated Agent Extinguishing System Units*, 1989 edition.

5-1.2.7 ULC Publications. Underwriters Laboratories of Canada, 7 Crouse Road, Scarborough, Ontario, Canada M1R 3A9.

ULC S524-M91, *Standard for the Installation of Fire Alarm Systems*.

ULC S529-M87, *Smoke Detectors for Fire Alarm Systems*.

5-1.2.8 U.S. Government Publication. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20401.

Code of Federal Regulations, Title 29, Part 1910, Subpart S.

Code of Federal Regulations, Title 49 Transportation, Parts 170-190.

Federal Register, Volume 59, Page 13044, EPA SNAP Program.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

A-1-3.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations that is in a position to determine compliance with appropriate standards for the current production of listed items.

A-1-3.1 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-3.1 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A-1-3.1 Normally Occupied Areas. Spaces occasionally visited by personnel, such as transformer bays, switchhouses, pump rooms, vaults, engine test stands, cable trays, tunnels, microwave relay stations, flammable liquid storage areas, enclosed energy systems, etc., are examples of areas considered not normally occupied.

A-1-4.1 The clean halocarbon agents currently listed possess the physical properties as detailed in Tables A-1-4.1(a) and A-1-4.1(b). This data will be revised from time to time as new information becomes available. Additional background information and data on these agents can be found in several references: Fernandez, R. (1991); Hanauska, C. (1991); Robin, M.L. (1991); Sheinson, R.S. (1991).

A-1-4.1.2 The designations for perfluorocarbons (FCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and fluoroiodocarbons (FICs) are an extension of halocarbon designations in a standard prepared by the American National Standards Institute (ANSI) and the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE): ANSI/ASHRAE Standard 34, *Number Designation and Safety Classification of Refrigerants*. HCFC Blend A is a designation for a blend of HCFCs and a hydrocarbon. The designation IG-541 is used in this standard for a blend of three inert gases: nitrogen, argon, and carbon dioxide (52 percent, 40 percent, and 8 percent, respectively). The designation IG-01 is used in this standard for an unblended inert gas: argon. The designation IG-55 is used in this standard for a blend of two inert gases: nitrogen and argon (50 percent and 50 percent, respectively).

A-1-4.2.3 While an attractive feature of these agents is their suitability for use in environments containing energized electrical equipment without damaging that equipment, in some instances the electrical equipment might be the source of ignition. In such cases, the energized equipment should be de-energized prior to or during agent discharge.

A-1-4.2.4 The provision of an enclosure can create an unnecessary explosion hazard where otherwise only a fire hazard exists. A hazard analysis should be conducted to determine the relative merits of differing design concepts (i.e., with and without enclosures) and the most relevant means of fire protection.

Table A-1-4.1(a) Physical Properties of Clean Halocarbon Agents (SI Units)

	Units	FC-3-1-10	HCFC Blend A	HCFC-124	HFC-125	HFC-227ea	HFC-23	HFC-236fa	FIC-13I1
Molecular weight	N/A	238.03	92.90	136.5	120.02	170.03	70.01	152	195.91
Boiling point @ 760 mm Hg	°C	−2.0	−38.3	−11.0	−48.5	−16.4	−82.1	−1.4	−22.5
Freezing point	°C	−128.2	< −107.2	198.9	−102.8	−131	−155.2	−93.6*	−110
Critical temperature	°C	113.2	124.4	122.2	66.0	101.7	25.9	124.9	122
Critical pressure	kPa	2323	6647	3614	3595	2912	4836	3199.9	4041
Critical volume	cc/mole	371	162	241.6	210	274	133	268.5*	225
Critical density	kg/m^3	629	577	565	571	621	525	565.3*	871
Specific heat, liquid @ 25°C	kJ/kg°C	1.047	1.256	1.13	1.260	1.184	1.549	1.2653	0.592
Specific heat, vapor @ constant pressure (1 atm.) & 25°C	kJ/kg°C	0.804	0.67	0.741	0.800	0.808	0.737	0.8403	0.3618
Heat of vaporization at boiling point @ 25°C	kJ/kg	96.3	225.6	194	164.7	132.6	239.6	160.4	112.4
Thermal conductivity of liquid @ 25°C	W/m°C	0.0537	0.0900	0.0722	0.0651	0.069	0.0779	0.0697	0.07
Viscosity, liquid @ 25°C	centipoise	0.324	0.21	0.299	0.145	0.184	0.083	0.2923	0.196
Relative dielectric strength @ 1 atm. @ 734 mm Hg, 25°C (N_2 = 1.0)	N/A	5.25	1.32	1.55	0.955 @21°C	2.00	1.04	unknown	1.41
Solubility of water in agent @ 21°C	N/A	0.001% by weight	0.12% by weight	0.07% by weight @ 25°C	0.07% by weight @ 25°C	0.06% by weight	500 ppm @ 50°F (10°C)	unknown	0.0062% by weight
Vapor Pressure @ 25°C	kPa	289.6	948	386	1371	457.7	TBD	272.4	439.2

*DuPont estimated values.

Table A-1-4.1(a) Physical Properties of Inert Gas Agents (SI Units)

	Units	IG-01	IG-541	IG-55
Molecular weight	N/A	39.9	34.0	33.95
Boiling point @ 760 mm Hg	°C	−189.85	−196	−190.1
Freezing point	°C	−189.35	−78.5	−199.7
Critical temperature	°C	−122.3	N/A	−134.7
Critical pressure	kPa	48.7	N/A	41.5
Critical volume	cc/mole	N/A	N/A	N/A
Critical density	kg/m^3	N/A	N/A	N/A
Specific heat, liquid @ 25°C	kJ/kg°C	N/A	N/A	N/A
Specific heat, vapor @ constant pressure (1 atm.) & 25°C	kJ/kg°C	0.519	0.574	0.782
Heat of vaporization at boiling point @ 25°C	kJ/kg	163	220	181
Thermal conductivity of liquid @ 25°C	W/m°C	N/A	N/A	N/A
Viscosity, liquid @ 25°C	centipoise	N/A	N/A	N/A
Relative dielectric strength @ 1 atm. @ 734 mm Hg, 25°C (N_2 = 1.0)	N/A	1.01	1.03	1.01
Solubility of water in agent @ 21°C	N/A	0.006%	0.015%	0.006%
Vapor Pressure @ 25°C	kPa	N/A	15200	N/A

Table A-1-4.1(b) Physical Properties of Clean Halocarbon Agents (English Units)

	Units	FC-3-1-10	HCFC Blend A	HCFC-124	HFC-125	HFC-227ea	HFC-23	HFC-236fa	FIC-1311
Molecular weight	N/A	238.03	92.90	136.5	120.02	170.03	70.01	152	195.91
Boiling point @ 760 mm Hg	°F	28.4	−37.0	12.2	−55.3	2.6	−115.7	29.4	−8.5
Freezing point	°F	−198.8	< −161.0	−326.0	−153	−204	−247.4	−136.5*	−166
Critical temperature	°F	235.8	256.0	252.0	150.8	215.0	78.6	256.9	252
Critical pressure	psia	337	964	524.5	521	422	701	464.1	586
Critical volume	ft^3/lbm	0.0250	0.0280	0.0283	0.0281	0.0258	0.0305	0.0283*	0.0184
Critical density	lbm/ft^3	39.30	36.00	35.28	35.68	38.76	32.78	35.29*	54.38
Specific heat, liquid @ 77°F	BTU/ lb-°F	0.25	0.30	0.270	0.301	0.2831	0.370	0.3022	0.1414
Specific heat, vapor @ constant pressure (1 atm.) & 77°F	BTU/ lb-°F	0.192	0.16	0.177	0.191	0.1932	0.176	0.2007	0.0864
Heat of vaporization at boiling point	BTU/lb	41.4	97	83.2	70.8	57.0	103.0	68.97	48.44
Thermal conductivity of liquid @ 77°F	BTU/ h ft°F	0.0310	0.052	0.0417	0.0376	0.040	0.0450	0.04025	0.04
Viscosity, liquid @ 77°F	lb/ft hr	0.783	0.508	0.723	0.351	0.443	0.201	0.7014	0.473
Relative dielectric strength @ 1 atm. @ 734 mm Hg 77°F (N_2 = 1.0)	N/A	5.25	1.32	1.55	0.955 @ 70°F	2.00	1.04	unknown	1.41
Solubility of water in agent @ 70°F	N/A	0.001% by weight	0.12% by weight	0.07% by weight @ 77F	0.07% by weight @ 77F	0.06% by weight	500 ppm @ 50°F (10°C)	unknown	0.0062% by weight
Vapor pressure @ 77°F	psi	42.0	137	56	199	66.4	686.0	39.51	63.70

*DuPont estimated values.

Table A-1-4.1(b) Physical Properties of Inert Gases (English Units)

	Units	IG-01	IG-541	IG-55
Molecular weight	N/A	39.9	34.0	33.95
Boiling point @ 760 mm Hg	°F	−302.6	−320	−310.2
Freezing point	°F	−308.9	−109	−327.5
Critical temperature	°F	−188.1	N/A	−210.5
Critical pressure	psia	711	N/A	602
Critical volume	ft^3/lbm	N/A	N/A	N/A
Critical density	lbm/ft^3	N/A	N/A	N/A
Specific heat, liquid @ 77°F	BTU/lb-°F	N/A	N/A	N/A
Specific heat, vapor @ constant pressure (1 atm.) & 77°F	BTU/lb-°F	0.125	0.195	0.187
Heat of vaporization at boiling point	BTU/lb	70.1	94.7	77.8
Thermal conductivity of liquid @ 77°F	BTU/h ft°F	N/A	N/A	N/A
Viscosity, liquid @ 77°F	lb/ft hr	N/A	N/A	N/A
Relative dielectric strength @ 1 atm. @ 734 mm Hg 77°F (N_2 = 1.0)	N/A	1.01	1.03	1.01
Solubility of water in agent @ 70°F	N/A	0.006%	0.015%	0.006%
Vapor pressure @ 77°F	psi	N/A	2207	N/A

A-1-4.2.8 This provides consideration for using a clean agent in an environment that might result in an inordinate amount of products of decomposition (i.e., within an oven).

A-1-5.1 Potential hazards to be considered for individual systems are the following:

(a) *Noise.* Discharge of a system can cause noise loud enough to be startling but ordinarily insufficient to cause traumatic injury.

(b) *Turbulence.* High-velocity discharge from nozzles might be sufficient to dislodge substantial objects directly in the path. System discharge can cause enough general turbulence in the enclosures to move unsecured paper and light objects.

(c) *Cold Temperature.* Direct contact with the vaporizing liquid being discharged from a system will have a strong chilling effect on objects and can cause frostbite burns to the skin. The liquid phase vaporizes rapidly when mixed with air and thus limits the hazard to the immediate vicinity of the discharge point. In humid atmospheres, minor reduction in visibility can occur for a brief period due to the condensation of water vapor.

A-1-5.1.1 The discharge of clean agent systems to extinguish a fire might create a hazard to personnel from the natural form of the clean agent or from the products of decomposition that result from exposure of the agent to the fire or hot surfaces. Unnecessary exposure of personnel either to the natural agent or to the decomposition products should be avoided.

A-1-5.1.2 Table A-1-5.1.2 provides information on the toxicological and physiological effects of halocarbon agents covered by this standard. The No Observed Adverse Effect Level (NOAEL) is the highest concentration at which no adverse physiological or toxicological effect has been observed. The Lowest Observed Adverse Effect Level (LOAEL) is the lowest concentration at which an adverse physiological or toxicological effect has been observed.

Restrictions on the use of certain halocarbon agents covered in this standard for use in normally occupied areas are based on a comparison of the actual agent concentration to the NOAEL. Where the actual concentration will be higher than the NOAEL or where the needed data are unavailable, the agents are restricted to use only in areas that are not normally occupied. To keep oxygen concentrations above 16 percent (sea level equivalent), the point at which onset of impaired personnel function occurs, no halogenated fire extinguishing agents addressed in this standard should be used at a concentration greater than 24 percent in a normally occupied area.

Although most of the clean agents have a low level of toxicity, the decomposition products generated by the clean agent breaking down in the presence of very high amounts of heat can be hazardous. All of the present halocarbon agents contain fluorine. In the presence of available hydrogen (from water vapor, or the combustion process itself), the main decomposition product is hydrogen fluoride (HF).

These decomposition products have a sharp, acrid odor, even in minute concentrations of only a few parts per million. This characteristic provides a built-in warning system for the agent, but at the same time creates a noxious, irritating atmosphere for those who must enter the hazard following a fire.

The amount of agent that can be expected to decompose in extinguishing a fire depends to a large extent on the size of the fire, the particular clean agent, the concentration of the agent, and the length of time the agent is in contact with the flame or heated surface. If there is a very rapid buildup of concentration to the critical value, then the fire will be extinguished quickly and the decomposing will be limited to the minimum possible with that agent. Should that agent's specific composition be such that it could generate large quantities of decomposition products, and the time to achieve the critical value is lengthy, then the quantity of decomposition products can be quite great. The actual concentration of the decomposition products must then depend on the volume of the room in which the fire was burning and on the degree of mixing and ventilation.

Clearly, longer exposure of the agent to high temperatures would produce greater concentrations of these gases. The type and sensitivity of detection, coupled with the rate of discharge, should be selected to minimize the exposure time of the agent to the elevated temperature if the concentration of the breakdown products must be minimized. In most cases the area would be untenable for human occupancy due to the heat and breakdown products of the fire itself.

Table A-1-5.1.2 Toxicity Information for Halocarbon Clean Agents

Agent	LC_{50} or ALC	No Observable Adverse Effect Level (NOAEL)	Lowest Observable Adverse Effect Level (LOAEL)
FC-3-1-10	>80%	40%	>40%
HCFC Blend A	64%	10.0%	>10.0%
HCFC-124	23% – 29%	1.0%	2.5%
HFC-125	>70%	7.5%	10.0%
HFC-227ea	>80%	9.0%	>10.5%
HFC-23	>65%	50%	>50%
HFC-236fa	>18.9%	10%	15%
Halon 1301	>80%	5%	7.5%

NOTE 1: LC_{50} is the concentration lethal to 50% of a rat population during a 4-hour exposure. The ALC is the approximate lethal concentration.
NOTE 2: The cardiac sensitization levels are based on the observance or nonobservance of serious heart arrhythmias in a dog. The usual protocol is a 5-minute exposure followed by a challenge with epinephrine.
NOTE 3: High concentration values are determined with the addition of oxygen to prevent asphyxiation.
NOTE 4. Values for Halon 1301 are included in this table for sake of comparison.

A-1-5.1.3 Table A-1-5.1.3 provides information on physiological effects of inert gas agents covered by this standard. The health concern for inert gas clean agents is asphyxiation due to the lowered oxygen levels. With inert gas agents, an oxygen concentration of no less than 12 percent (sea level equivalent) is required for normally occupied areas. This corresponds to an agent concentration of no more than 43 percent.

IG-541 uses carbon dioxide to promote breathing characteristics intended to sustain life in the oxygen-deficient environment for protection of personnel. Care should be used not to design inert gas-type systems for normally occupied areas using design concentrations higher than that specified in the system manufacturer's listed design manual for the hazard being protected.

Inert gas clean agents do not decompose measurably in extinguishing a fire. As such, toxic or corrosive decomposition products are not found. However, heat and breakdown products of the fire itself can still be substantial and could make the area untenable for human occupancy.

Table A-1-5.1.3 Physiological Effects for Inert Gas Agents

Agent	No Effect Level*	Low Effect Level*
IG-01	43%	52%
IG-55	43%	52%
IG-541	43%	52%

* Based on physiological effects in humans in hypoxic atmospheres. These values are the functional equivalents of NOAEL and LOAEL values, and correspond to 12 percent minimum oxygen for the No Effect Level and 10 percent minimum oxygen for the Low Effect Level.

A-1-5.1.4.1 The steps and safeguards necessary to prevent injury or death to personnel in areas whose atmospheres will be made hazardous by the discharge or thermal decomposition of clean agents can include the following:

(a) Provision of adequate aisleways and routes of exit, and procedures to keep them clear at all times.

(b) Provision of emergency lighting and directional signs as necessary to ensure quick, safe evacuation.

(c) Provision of alarms within such areas that will operate immediately upon detection of the fire.

(d) Provision of only outward-swinging, self-closing doors at exits from hazardous areas and, where such doors are latched, provision of panic hardware.

(e) Provision of continuous alarms at entrances to such areas until the atmosphere has been restored to normal.

(f) Provision of warning and instruction signs at entrances to and inside such areas. These signs should inform persons in or entering the protected area that a clean agent system is installed, and should contain additional instructions pertinent to the conditions of the hazard.

(g) Provision for the prompt discovery and rescue of persons rendered unconscious in such areas. This should be accomplished by having such areas searched immediately by trained personnel equipped with proper breathing equipment. Self-contained breathing equipment and personnel trained in its use and in rescue practices, including artificial respiration, should be readily available.

(h) Provision of instruction and drills for all personnel within or in the vicinity of such areas, including maintenance or construction people who might be brought into the area, to ensure their correct action when a clean agent system operates.

(i) Provision of means for prompt ventilation of such areas. Forced ventilation will often be necessary. Care should be taken to readily dissipate hazardous atmospheres and not merely move them to another location.

(j) Prohibition against smoking by persons until the atmosphere has been determined to be free of the clean agent.

(k) Provision of such other steps and safeguards that a careful study of each particular situation indicates is necessary to prevent injury or death.

A-1-5.1.4.2 A certain amount of leakage from a protected space to adjacent areas is anticipated during and following agent discharge. Consideration should be given to agent concentration [when above (NOAEL)], decomposition products, products of combustion, and relative size of adjacent spaces. Additional consideration should be given to exhaust paths when opening or venting the enclosure after a discharge.

A-1-6 Many factors impact the environmental acceptability of a fire suppression agent. Uncontrolled fires pose significant impact by themselves. All extinguishing agents should be used in ways that eliminate or minimize the potential environmental impact. General guidelines to be followed to minimize this impact include the following:

(a) Do not perform unnecessary discharge testing;

(b) Consider the ozone depletion and global warming impact of the agent under consideration and weigh these impacts against the fire safety concerns;

(c) Recycle all agents where possible; and

(d) Consult the most recent environmental regulations on each agent.

The unnecessary emission of clean extinguishing agents with either the potential of ozone depletion, the potential of global warming, or the potential of both, should be avoided. All phases of design, installation, testing, and maintenance of systems using these agents should be performed with the goal of no emission to the environment.

A-1-8.1 It is generally believed that, because of the highly stable nature of the compounds that are derived from the families including halogenated hydrocarbons and inert gases, incompatibility will not be a problem. These materials tend to behave in a similar fashion and, as far as is known, the reactions that might occur as the result of mixing of these materials within the container is not thought to be a real consideration with regard to their application to a fire protection hazard.

It is clearly not the intent of this section to deal with compatibility of the agents with components of the extinguishing hardware. This particular consideration is addressed elsewhere in this document. It is also clearly not the intent of this section to deal with the subject of storability or storage life of individual agents or mixtures of those agents. This also is addressed in another section of this standard.

A-2-1.1.2 An extra full complement of charged cylinders (connected reserve) manifolded and piped to feed into the automatic system should be considered on all installations. The reserve supply is normally actuated by manual operation of the main/reserve switch on either electrically operated or pneumatically operated systems. A connected reserve is desirable for the following reasons:

(a) Provides protection should a reflash occur.

(b) Provides reliability should the main bank malfunction.

(c) Provides protection during impaired protection when main tanks are being replaced.

(d) Provides protection of other hazards if selector valves are involved and multiple hazards are protected by the same set of cylinders.

If a full complement of charged cylinders cannot be obtained, or the empty cylinder recharged, delivered, and reinstalled within 24 hours, a third complement of fully charged nonconnected spare cylinders should be considered and made available on the premises for emergency use. The need for spare cylinders might depend on whether or not the hazard is under the protection of automatic sprinklers.

A-2-1.2 The normal and accepted procedures for making these quality measurements will be provided by the chemical manufacturers in a future submittal. As each clean agent varies in its quality characteristics, a more comprehensive table than the one currently in the standard will be developed. It will be submitted through the public proposal process. Recovered or recycled agents are currently not available, and thus quality standards do not exist at this time. As data becomes available, this criteria will be developed.

A-2-1.3.2 Storage containers should not be exposed to a fire in a manner likely to impair system performance.

A-2-1.4.1 Containers used for agent storage should be fit for the purpose. Materials of construction of the container, closures, gaskets, and other components should be compatible with the agent and designed for the anticipated pressures. Each container is equipped with a pressure relief device to protect against excessive pressure conditions.

The variations in vapor pressure with temperature for the various clean agents are shown in Figures A-2-1.4.1(a) through A-2-1.4.1(k).

With the exception of inert gas-type systems, all of the other clean agents are classified as liquefied compressed gases at 70°F (21°C). For these agents, the pressure in the container is significantly affected by fill density and temperature. At elevated temperatures the rate of increase in pressure is very sensitive to fill density. If the maximum fill density is exceeded, the pressure will increase rapidly with temperature increase so as to present a hazard to personnel and property. Therefore, it is very important that the maximum fill density limit specified for each liquefied clean agent not be exceeded. Adherence to the limits for fill density and pressurization levels specified in Table A-2-1.4.1 should prevent excessively high pressures from occurring if the agent container is exposed to elevated temperatures, and will minimize the possibility of an inadvertent discharge of agent through the pressure relief device. The manufacturer should be consulted for superpressurization levels other than those shown in Table A-2-1.4.1.

A-2-1.4.2 Although it is not a requirement of this particular paragraph, all new and existing halocarbon agent storage containers should be affixed with a label advising the user that the product in question may be returned for recovery and recycling to a qualified recycler when the halocarbon agent is no longer needed. The qualified recycler may be a halocarbon agent manufacturer, a fire equipment manufacturer, a fire equipment distributor or installer, or an independent commercial venture. It is not the intent to set down specific requirements but to indicate the factors that need to be taken into consideration with regard to recycling and reclamation of the halocarbon agent products, once facilities are available. As more information becomes available, more definitive requirements can be set forth in this section regarding quality, efficiency, recovery, and qualifications and certifications of facilities recycling halocarbon agents. At this point, no such facilities exist that would apply to the halocarbon agents covered by this document.

Inert gas agents need not be collected or recycled.

Table A-2-1.4.1 Storage Container Characteristics

	FC-3-1-10	HCFC Blend A	HCFC-124	HFC-125	HFC-227ea	HFC-23	FIC-13I1	IG-01	IG-541	IG-541 (200)	IG-55 (222)	IG-55 (2962)	IG-55 (4443)
Maximum fill density for conditions listed below (lb/ft³)	80.0	56.2	71.0	58.0	72.0	54.0	104.7	NA	N/A	N/A	N/A	N/A	N/A
Minimum Container Design Level Working Pressure (psig)	500	500	240.0	320.0	500	1800	500	2120	2015+	2746	2057+	2743+	4114+
Total Pressure Level at 70°F (psig)	360	360	195.0	166.4*	360	608.9*	360	2370	2175	2900	2222**	2962***	4443****

NOTE: The maximum fill density requirement is not applicable for IG-541. Cylinders for IG-541 shall be DOT 3A or 3AA, 2015+ stamped, or greater.
* Vapor pressure for HFC-23 and HFC-125.
** Cylinders for IG-55 shall be stamped 2060+.
*** Cylinders for IG-55 shall be stamped 2750+ or greater DOT 3A or 3AA.
**** Cylinders for IG-55 shall be stamped 4120+ or greater DOT 3A or 3AA
For SI units: 1 lb/ft³ = 16.018 kg/m³; 1 psig = 6895 Pa; T(F) = [T(C)]⁹⁄₅ + 32.

NOTE. Total pressure level at 70°F is calculated from filling conditions:
IG-55 (2222). 2175 psig (15 MPa) and 59°F (15°C).
IG-55 (2962): 2901 psig (20 MPa) and 59°F (15°C)
IG-55 (4443): 4352 psig (30 MPa) and 59°F (15°C).

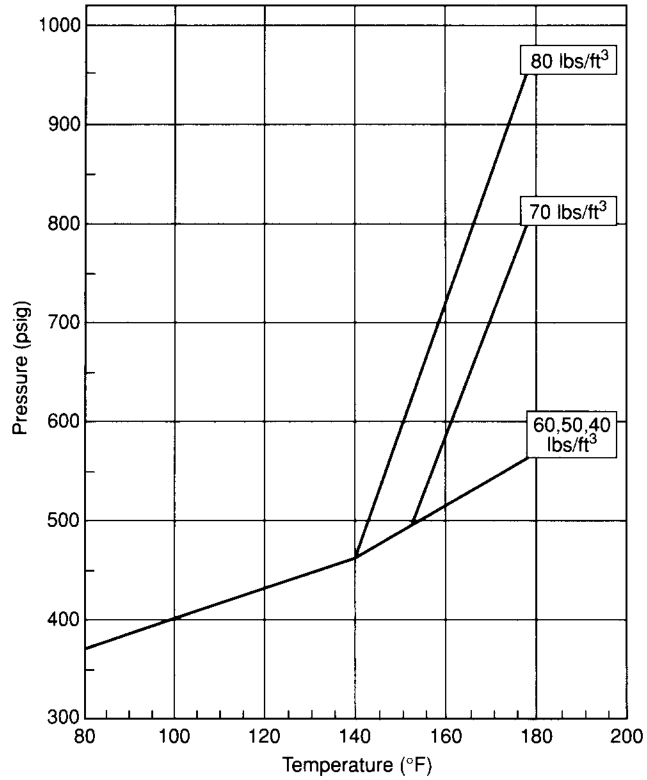

Figure A-2-1.4.1(a) Isometric diagram of FC-3-1-10 (for 360 psig containers).

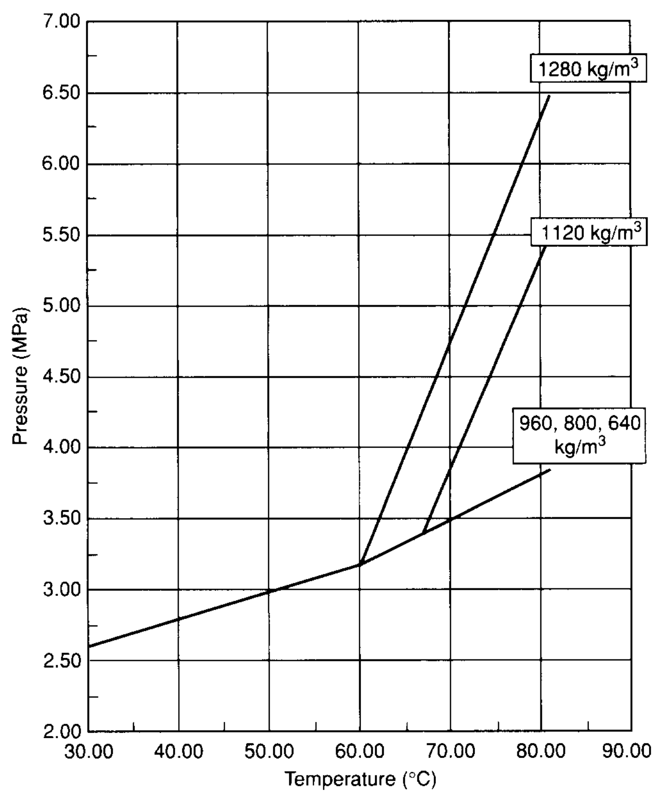

Figure A-2-1.4.1(b) Isometric diagram of FC-3-1-10 (for 2.5 MPa containers).

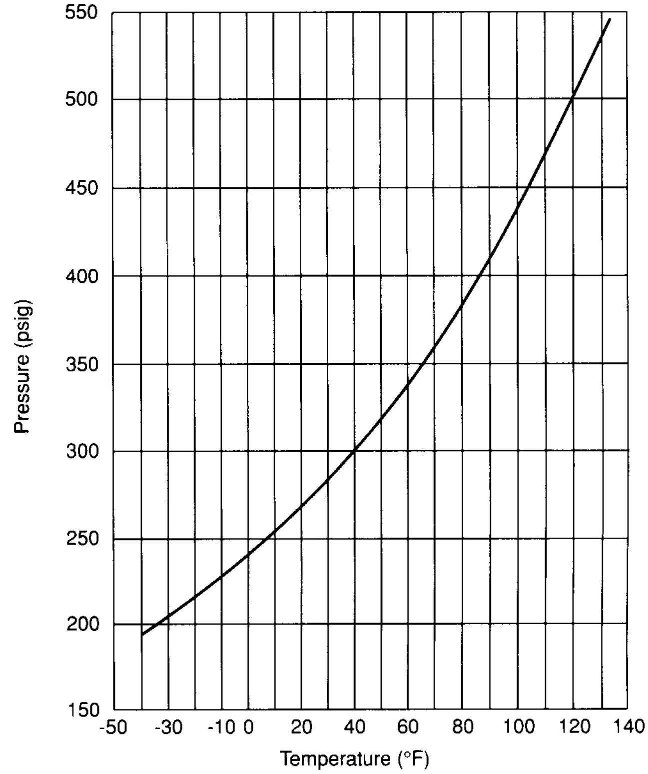

Figure A-2-1.4.1(c) Isometric diagram of HCFC Blend A, English.

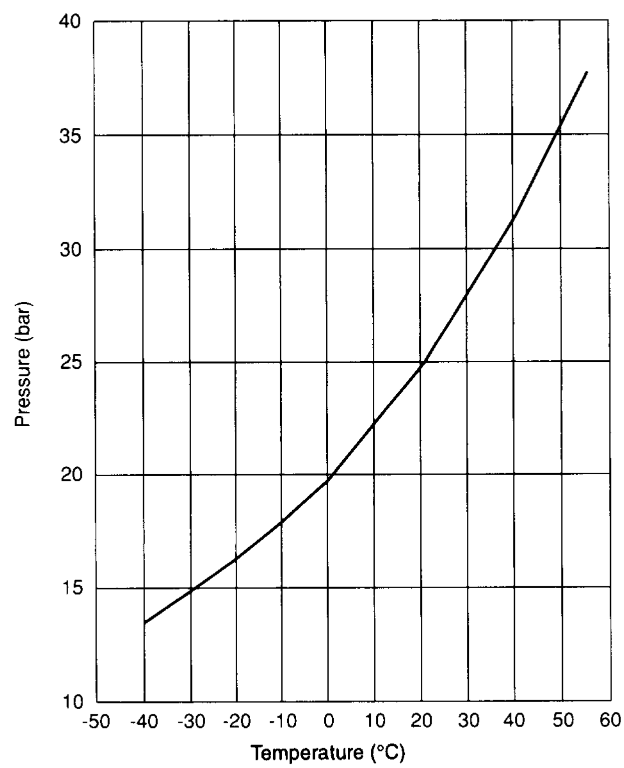

Figure A-2-1.4.1(d) Isometric diagram of HCFC Blend A, metric.

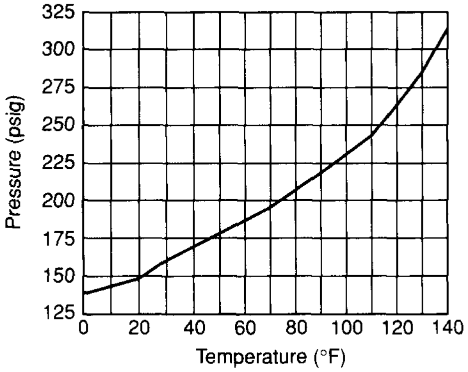

Figure A-2-1.4.1(e) Isometric diagram of HCFC-124 pressurized with nitrogen to 195 psig at 70°F and a loading density of 71.17 lb/ft³.

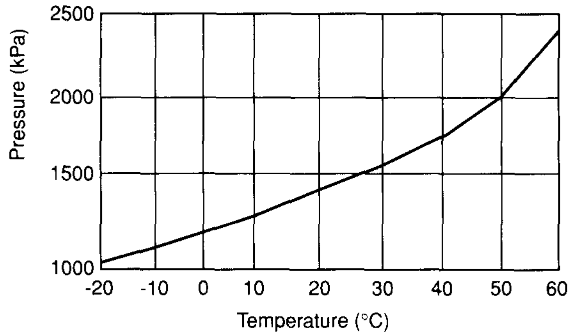

Figure A-2-1.4.1(f) Isometric diagram of HCFC-124 pressurized with nitrogen to 1340 kPa at 21°C and a loading density of 1140 kg/m³.

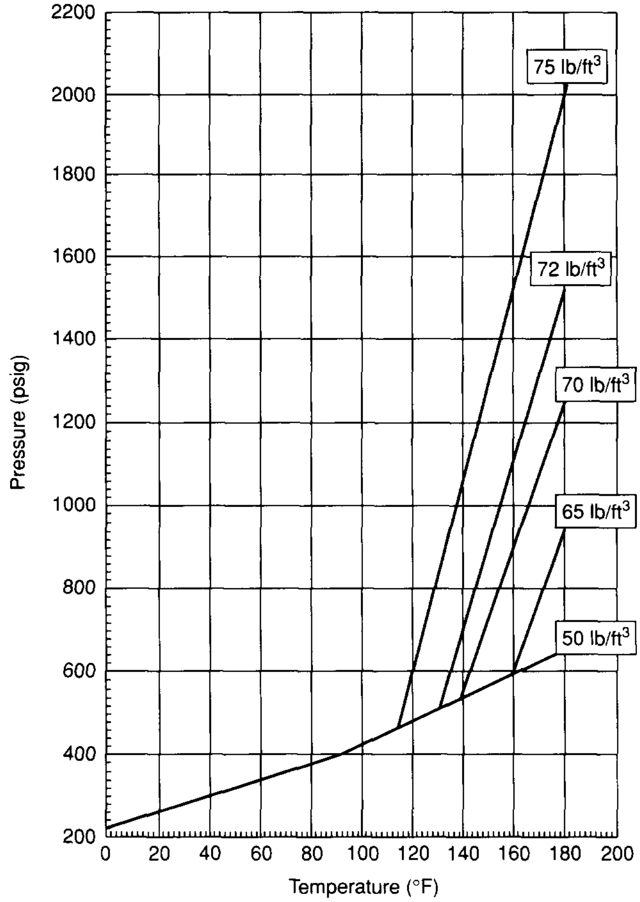

Figure A-2-1.4.1(g) Isometric diagram of HFC-227ea (pressurized with nitrogen to 360 psig at 70°F).

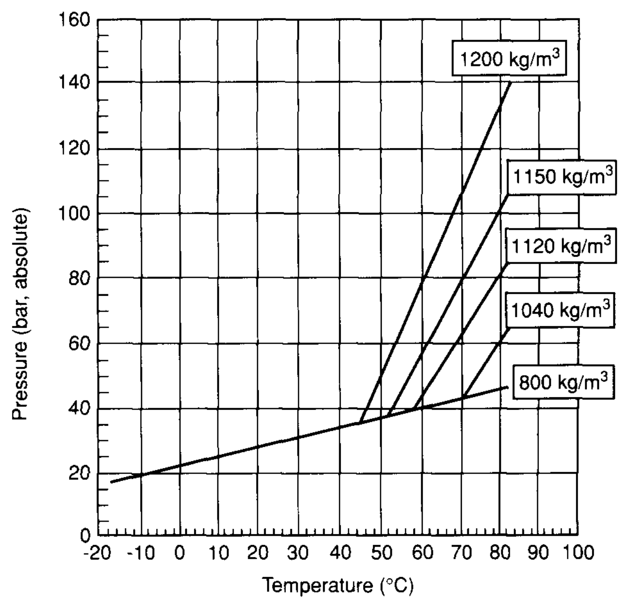

Figure A-2-1.4.1(h) Isometric diagram of HFC-227ea (pressurized with nitrogen at 2.5 MPa at 21°C).

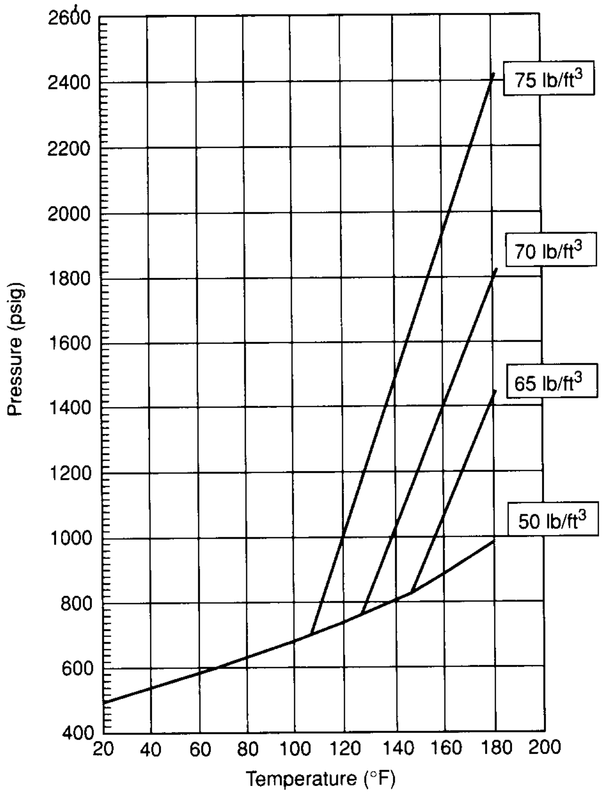

Figure A-2-1.4.1(i) Isometric diagram of HFC-227ea (pressurized with nitrogen to 600 psig at 70°F).

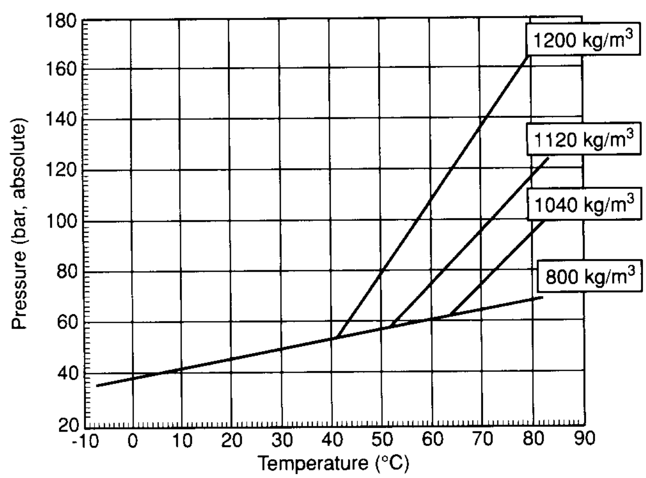

Figure A-2-1.4.1(j) Isometric diagram of HFC-227ea (pressurized with nitrogen at 4.1 MPa at 21°C).

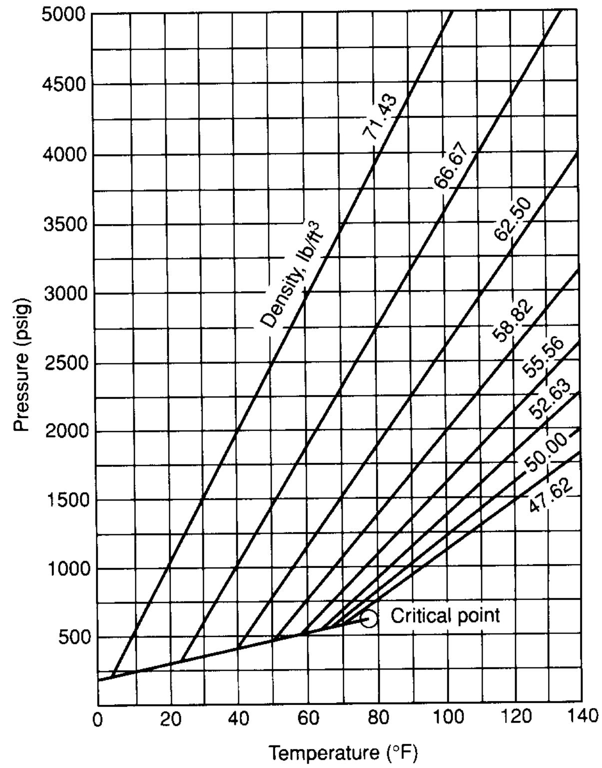

Figure A-2-1.4.1(k) Isometric diagram of HFC-23, English.

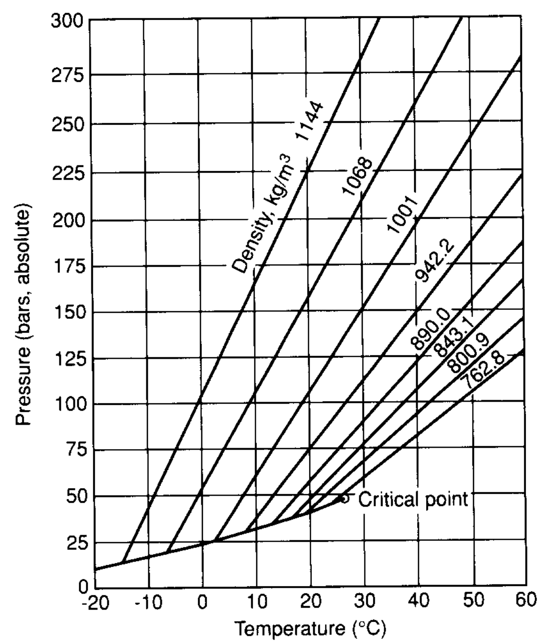

Figure A-2-1-4.1(l) Isometric diagram of HFC-23, metric.

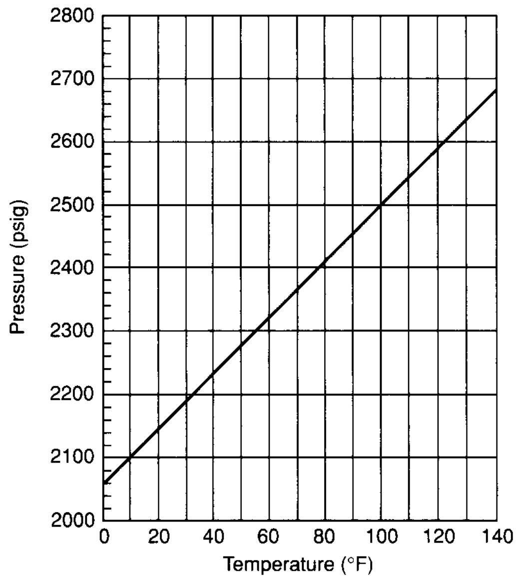

Figure A-2-1.4.1(m) Isometric diagram of IG-01 (2370 psi at 70°F).

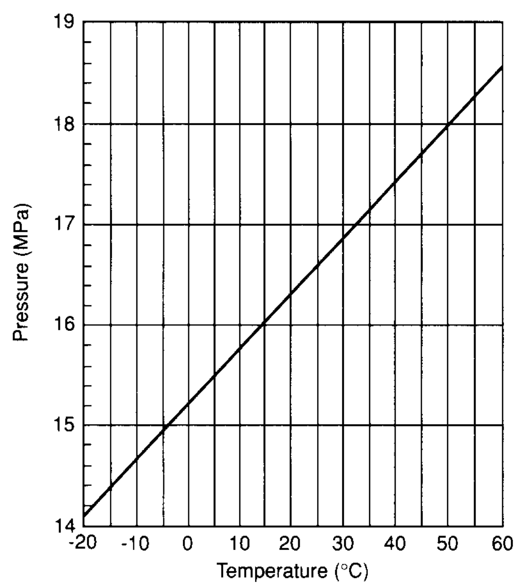

Figure A-2-1.4.1(n) Isometric diagram of IG-01 (160 bar at 15°C).

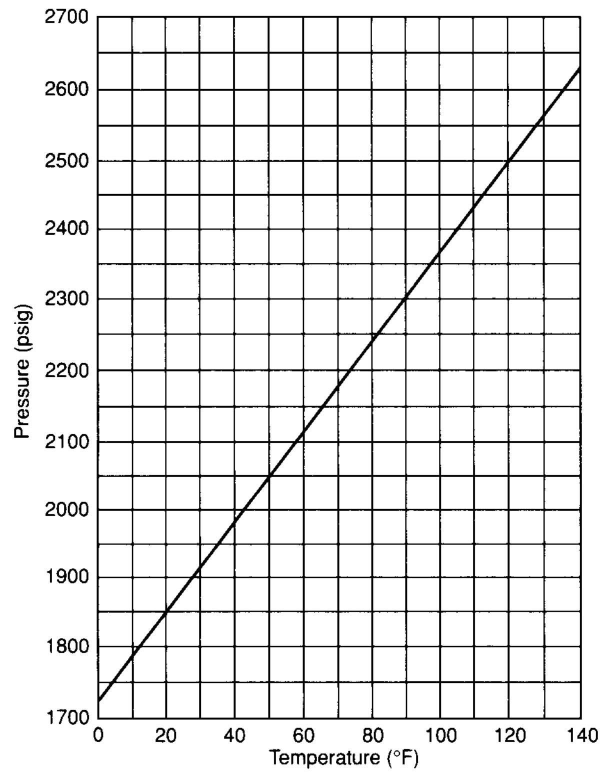

Figure A-2-1.4.1(o) Isometric diagram of IG-541 (2175 psig at 70°F).

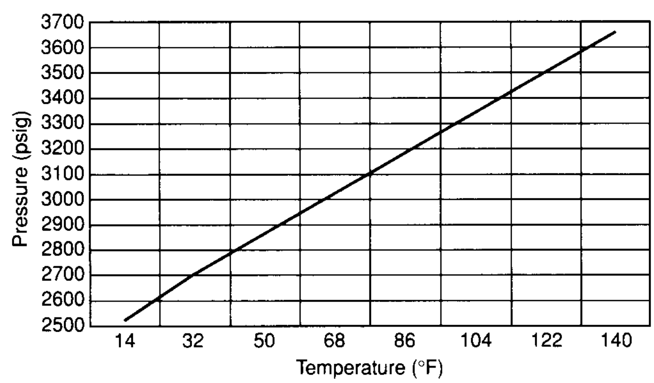

Figure A-2-1.4.1(p) Isometric diagram of IG-541 (2900 psig at 59°F).

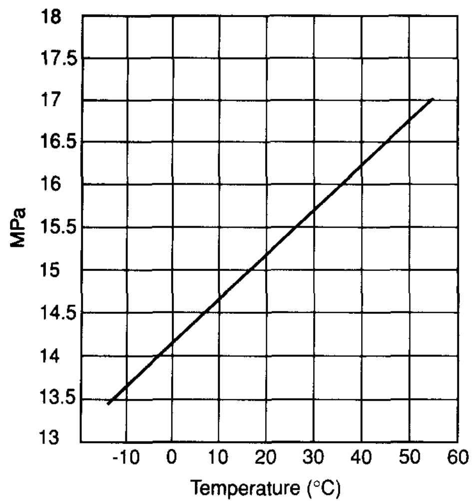

Figure A-2-1.4.1(q) Isometric diagram of IG-541 (15 MPa at 21°C).

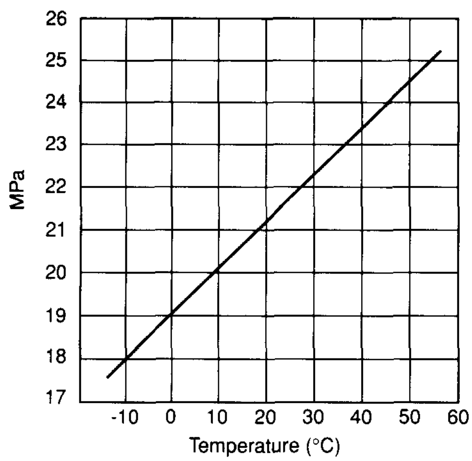

Figure A-2-1.4.1(r) Isometric diagram of IG-541 (20 MPa at 15°C).

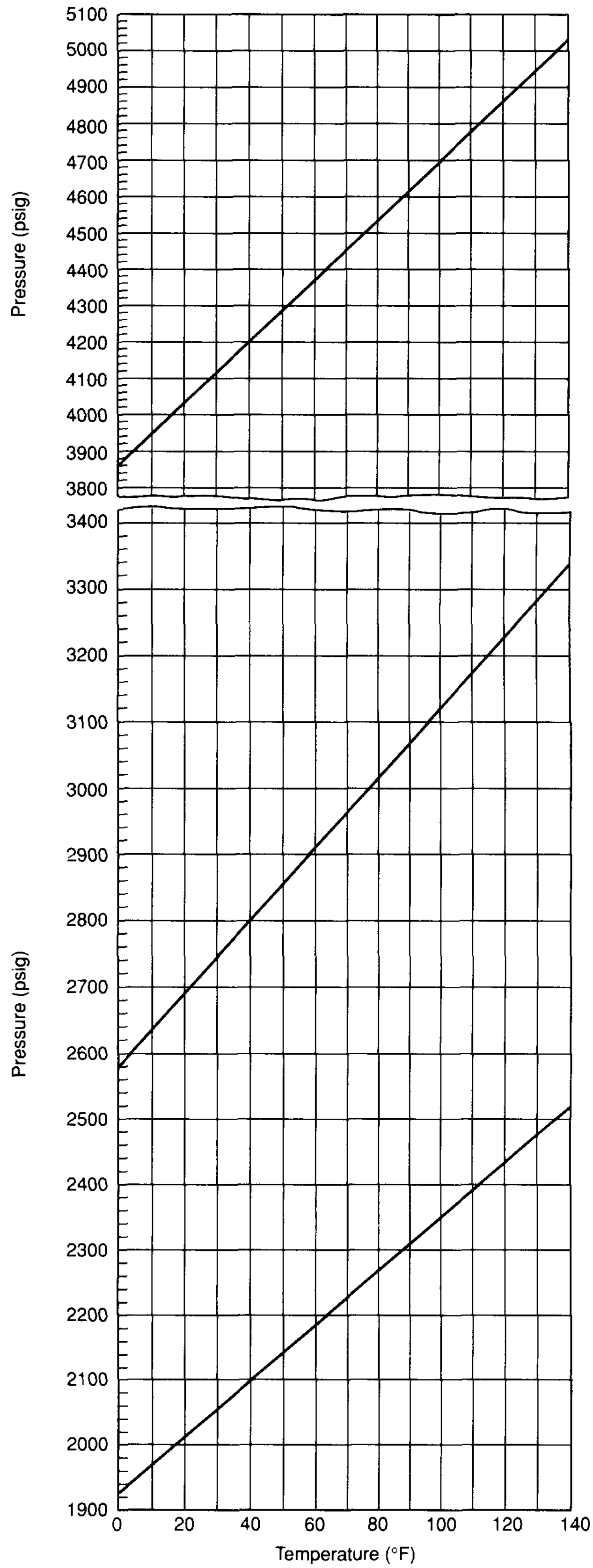

Figure A-2-1.4.1(s) Isometric diagram of IG-55, English.

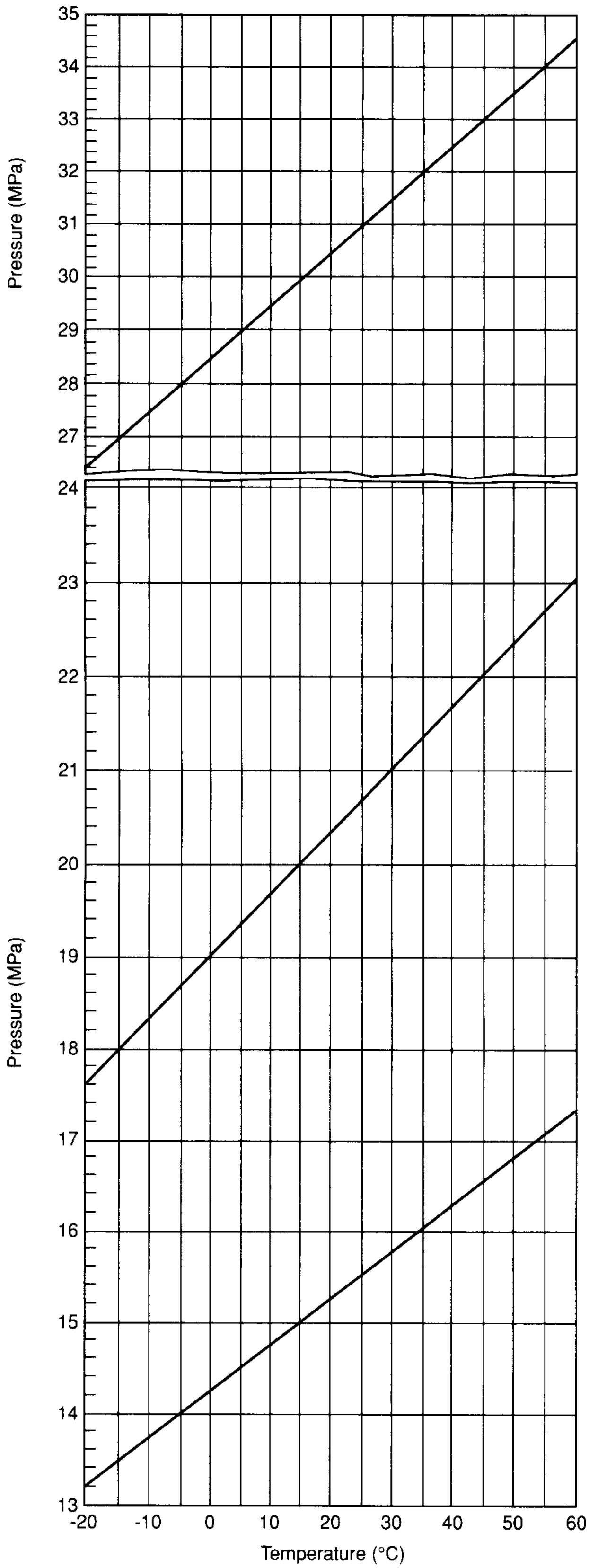

Figure A-2-1.4.1(t) Isometric diagram of IG-55, metric.

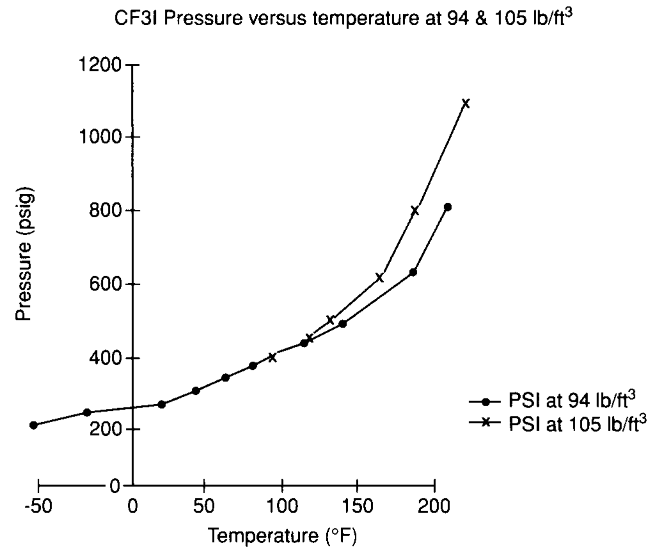

Figure A-2-1.4.1(u) Isometric diagram of FIC-13I1, English. (°F)

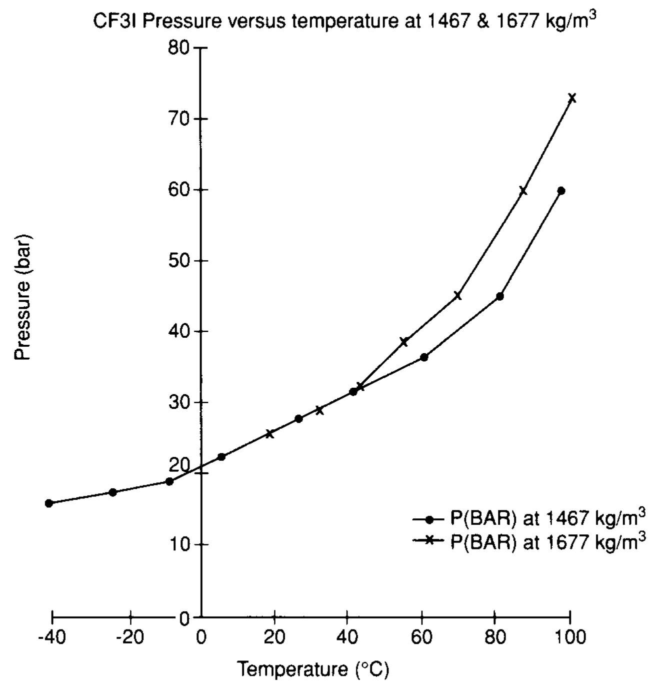

Figure A-2-1.4.1(v) Isometric diagram of FIC-13I1, metric. (°C)

A-2-2.1 Piping should be installed in accordance with good commercial practice. Care should be taken to avoid possible restrictions due to foreign matter, faulty fabrication, or improper installation.

The piping system should be securely supported with due allowance for agent thrust forces and thermal expansion and contraction and should not be subjected to mechanical, chemical, vibration, or other damage. ASME B31.1, *Power Piping Code*, should be consulted for guidance on this matter. Where explosions are likely, the piping should be attached to supports that are least likely to be displaced.

Although clean agent systems are not subjected to continuous pressurization, some provisions should be made to ensure that the type of piping installed can withstand the maximum stress at maximum storage temperatures. Maximum allowable stress levels for this condition should be established at values of 67 percent of the minimum yield strength or 25 percent of the minimum tensile strength, whichever is less. All joint factors should be applied after this value is determined.

Minimum Piping Requirements

The following table provides data on the maximum allowable pressure for which the most common types of steel pipe can be used. The pressures have been calculated using the formula and SE values shown in A-2-2.1.1(4) and A-2-2.1.1(7).

Tables A-2-2.1(a) and (b) provide pressure ratings for pipe sizes 1/2 in. through 8 in. NPS, in Schedule 40, Schedule 80, Schedule 120, and Schedule 160 wall thickness.

Halocarbon agent systems: For halocarbon agent systems, choose the proper piping where the pressure rating is equal to or greater than the pressure in the container at 130°F (55°C).

Inert gas agent system: For piping upstream of the pressure reducer, choose the proper piping where the pressure rating is equal to or greater than the pressure in the container at 130°F (55°C).

For piping downstream of the pressure reducer, choose the proper piping where the pressure rating is equal to or greater than the anticipated pressure in the piping at 130°F (55°C).

Table A-2-2.1(a) Piping with Threaded Connections
Maximum Allowable Pressure (psig)

Schedule 40 Steel Pipe

NPS	Grade: Type: SE:	A-106C Seamless 21000	A-53B A-106B Seamless 18000	A-53B ERW 15360	A-53A A-106A Seamless 14400	A-53A ERW 12240	A-53F Furnace 8160
1/2		2593	2222	1896	1778	1511	1008
3/4		2234	1915	1634	1532	1302	868
1		2026	1736	1482	1390	1181	787
1 1/4		1782	1528	1304	1222	1038	692
1 1/2		1667	1429	1220	1144	972	648
2		1494	1280	1093	1025	871	581
2 1/2		1505	1290	1100	1032	877	584
3		1392	1193	1018	954	811	541
4		1278	1096	935	876	745	497
5		1193	1022	872	818	693	463
6		1141	978	834	782	664	443
8		1081	926	790	740	630	420

Schedule 80 Steel Pipe

NPS	Grade: Type:	A-106C Seamless	A-53B A-106B Seamless	A-53B ERW	A-53A A-106A Seamless	A-53A ERW	A-53F Furnace
1/2		4493	3851	3286	3080	2618	1746
3/4		3874	3320	2833	2657	2258	1505
1		3495	2996	2556	2397	2037	1358
1 1/4		3073	2634	2248	2107	1792	1194
1 1/2		2883	2472	2110	1978	1681	1121
2		2625	2250	1920	1800	1530	1020
2 1/2		2571	2204	1882	1764	1499	1000
3		2400	2057	1756	1645	1399	932
4		2212	1896	1618	1517	1289	859
5		2076	1780	1518	1423	1210	806
6		2105	1804	1540	1442	1226	817
8		1948	1669	1424	1336	1135	757

Table A-2-2.1(b) Piping with Rolled Groove or Welded Connections Maximum Allowable Pressure

Schedule 40 Steel Pipe

NPS	Grade: Type:	A-106C Seamless	A-53B A-106B Seamless	A-53B ERW	A-53A A-106A Seamless	A-53A ERW	A-53F Furnace
1/2		5450	4672	3986	3737	3176	2118
3/4		4520	3875	3306	3100	2634	1757
1		4248	3641	3107	2912	2475	1650
1 1/4		3542	3036	2591	2429	2064	1376
1 1/2		3205	2747	2344	2197	1868	1246
2		2723	2334	1992	1867	1588	1058
2 1/2		2965	2542	2168	2033	1728	1152
3		2592	2221	1896	1777	1511	1007
4		2212	1896	1618	1516	1289	859
5		1948	1669	1424	1336	1135	757
6		1775	1522	1298	1217	1034	690
8		1568	1344	1147	1075	914	609

Schedule 80 Steel Pipe

NPS	Grade: Type:	A-106C Seamless	A-53B A-106B Seamless	A-53B ERW	A-53A A-106A Seamless	A-53A ERW	A-53F Furnace
1/2		7350	6300	5376	5040	4284	2856
3/4		6160	5280	4506	4224	3590	2394
1		5717	4900	4182	3920	3332	2221
1 1/4		4833	4142	3535	3314	2816	1878
1 1/2		4421	3789	3234	3032	2576	1718
2		3855	3304	2820	2644	2248	1498
2 1/2		4032	3456	2949	2765	2350	1567
3		3600	3086	2633	2469	2098	1339
4		3145	2696	2301	2157	1834	1223
5		2831	2427	2071	1941	1650	1100
6		2739	2347	2003	1878	1596	1064
8		2435	2087	1781	1670	1420	946

Table A-2-2.1(c) Minimum Piping Requirements

Clean Agent Systems — with Charging Pressures up to and Including 360 psi (2482 kPa)	
Steel Pipe—Threaded Connections	
ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—1/8 in. through 1 1/2 in. NPS Schedule 80—2 in. through 8 in. NPS
Steel Pipe—Welded or Rolled Groove Connections	
ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—1/8 in. through 6 in. NPS Schedule 80—8 in. NPS
Steel Pipe—Cut Groove Connections	
ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—1/8 in. through 5 in. NPS Schedule 80—6 in. through 8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—1/8 in. through 3 in. NPS Schedule 80—4 in. through 8 in. NPS
Copper Tubing—Compression Fittings	
ASTM B-88 Seamless, Drawn	Type K 1/4 in. through 8 in.
ASTM B-88 Seamless, Drawn	Type L 1/4 in. through 3 in.
ASTM B-88 Seamless, Drawn	Type M 1/4 in. through 1 1/2 in.
ASTM B-88 Seamless, Annealed	Type K 1/4 in. through 1 in.
ASTM B-88 Seamless, Annealed	Type L 1/4 in. through 3/4 in.
ASTM B-88 Seamless, Annealed	Type M 1/4 in. ONLY

Table A-2-2.1(d) Minimum Piping Requirements

Clean Agent Systems — 600 psi Charging Pressure	
Steel Pipe—Threaded Connections	
ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—1/8 in. through 5 in. NPS Schedule 80—6 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—1/8 in. through 2½ in. NPS Schedule 80—3 in. through 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—1/8 in. through 3 in. NPS Schedule 80—4 in. through 8 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—1/8 in. through 1¼ in. NPS Schedule 80—1½ in. through 8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—1/8 in. through ½ in. NPS Schedule 80—¾ in. through 2½ in. NPS Schedule 120—3 in. through 8 in. NPS
Steel Pipe—Welded Connections	
ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—1/8 in. through 6 in. NPS Schedule 80—8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—1/8 in. through 3 in. NPS Schedule 80—4 in. through 6 in. NPS Schedule 120—8 in. NPS
Copper Tubing—Compression Fittings	
ASTM B-88 Seamless, Drawn	Type K ¼ in. through 1¼ in.
ASTM B-88 Seamless, Drawn	Type L ¼ in. through ¾ in.
ASTM B-88 Seamless, Drawn	Type M ¼ in. through 3/8 in.
ASTM B-88 Seamless, Annealed	Type K ¼ in. through 3/8 in.
ASTM B-88 Seamless, Annealed	Type L DO NOT USE
ASTM B-88 Seamless, Annealed	Type M DO NOT USE

Table A-2-2.1(e) Minimum Piping Requirements

IG-541 Systems — Upstream of Pressure Reducer	
Steel Pipe—Threaded Connections	
ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. through ½ in. NPS Schedule 80—¾ in. through 2½ in. NPS
ASTM A-106/A-53 Seamless Grade B	Schedule 40—DO NOT USE Schedule 80—1/8 through 1¼ NPS
ASTM A-106/A-53 Seamless Grade A	Schedule 40—DO NOT USE Schedule 80—1/8 through ¾ in. NPS
ASTM A-53 ERW Grade B	Schedule 40—DO NOT USE Schedule 80—1/8 through 1 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—DO NOT USE Schedule 80—1/8 in. through ½ in. NPS
ASTM A-53 Furnace Weld Class F	DO NOT USE
Steel Pipe—Welded	
ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. through 3 in. NPS Schedule 80—4 in. through 6 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—1/8 through 1½ in. NPS Schedule 80—2 in. through 4 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—1/8 through 1 in. NPS Schedule 80—1¼ through 2½ NPS
ASTM A-53 ERW Grade B	Schedule 40—1/8 in. through 1¼ in. NPS Schedule 80—1½ in. through 3 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—1/8 in. through ¾ NPS Schedule 80—1 in. through 1½ NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—DO NOT USE Schedule 80—1/8 in. through ½ in.
Copper Tubing—Compression Fittings	
ASTM B-88 Seamless, Drawn	Type K, L, M—DO NOT USE
ASTM B-88 Seamless, Annealed	Type K, L, M—DO NOT USE

Table A-2-2.1(f) Minimum Piping Requirements

IG-541 Systems — Downstream of Pressure Reducer	
Steel Pipe—Threaded Connections	
ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—1/8 in. through 5 in. NPS Schedule 80—6 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—1/8 in. through 2 1/2 in. NPS Schedule 80—3 in. through 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—1/2 in. through 3 in. NPS Schedule 80—4 in. through 8 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—1/8 in. through 1 1/4 in. NPS Schedule 80—1 1/2 in. through 8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—1/8 in. through 1/2 in. NPS Schedule 80—3/4 in. through 2 1/2 in. NPS Schedule 120—3 in. through 8 in. NPS
Steel Pipe—Welded	
ASTM A-106 Seamless, Grade C	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade B	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-106/A-53 Seamless, Grade A	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 ERW Grade B	Schedule 40—1/8 in. through 8 in. NPS
ASTM A-53 ERW Grade A	Schedule 40—1/8 in. through 6 in. NPS Schedule 80—8 in. NPS
ASTM A-53 Furnace Weld Class F	Schedule 40—1/8 in. through 3 in. NPS Schedule 80—4 in. through 6 in. NPS Schedule 120—8 in. NPS
Copper Tubing—Compression Fittings	
ASTM B-88 Seamless, Drawn	Type K—1/4 in. through 1 1/4 in.
ASTM B-88 Seamless, Drawn	Type L—1/4 in. through 3/4 in.
ASTM B-88 Seamless, Drawn	Type M—1/4 in. through 3/8 in.
ASTM B-88 Seamless, Annealed	Type K—1/4 in. through 3/8 in.
ASTM B-88 Seamless, Annealed	Type L—DO NOT USE
ASTM B-88 Seamless, Annealed	Type M—DO NOT USE

Table A-2-2.1.1(a) Maximum Pressure Schedule 120, Threaded

GRADE TYPE SE				A-106C SMLS 21000	A-53B A-106B SMLS 18000	A-53B ERW 15360	A-53A A-106A SMLS 14400	A-53A ERW 12240	A-53F FURN. 8160
NOM. DIA.	O.D.	WALL = t	A						
4	4.5	0.437	0.1	3145	2696	2301	2157	1833	1222
5	5.563	0.5	0.1	3020	2589	2209	2071	1760	1173
6	6.625	0.562	0.1	2929	2510	2142	2008	1707	1138
8	8.625	0.718	0.1	3009	2579	2201	2064	1754	1169

Table A-2-2.1.1(b) Maximum Pressure Schedule 120, Welded

GRADE TYPE SE			A-106C SMLS 21000	A-53B A-106B SMLS 18000	A-53B ERW 15360	A-53A A-106A SMLS 14400	A-53A ERW 12240	A-53F FURN. 8160
NOM. DIA.	O.D.	WALL = t						
4	4.5	0.437	4079	3496	2983	2797	2377	1585
5	5.563	0.5	3775	3236	2761	2589	2200	1467
6	6.625	0.562	3563	3054	2606	2443	2077	1384
8	8.625	0.718	3496	2997	2557	2397	2038	1359

Table A-2-2.1.1(c) Maximum Pressure Schedule 160, Threaded

GRADE TYPE SE				A-106C SMLS 21000	A-53B A-106B SMLS 18000	A-53B ERW 15360	A-53A A-106A SMLS 14400	A-53A ERW 12240	A-53F FURN. 8160
NOM. DIA.	O.D.	WALL = t	A						
0.5	0.84	0.187	0.057	6500	5571	4754	4457	3789	2526
0.75	1.05	0.218	0.057	6440	5520	4710	4416	3754	2502
1	1.315	0.25	0.07	5749	4928	4205	3942	3351	2234
1.25	1.66	0.25	0.07	4554	3904	3331	3123	2654	1770
1.5	1.9	0.281	0.07	4664	3998	3412	3198	2719	1812
2	2.375	0.343	0.07	4828	4138	3531	3310	2814	1876
2.5	2.875	0.375	0.1	4017	3443	2938	2755	2342	1561
3	3.5	0.437	0.1	4044	3466	2958	2773	2357	1571
4	4.5	0.531	0.1	4023	3448	2942	2758	2345	1563
5	5.563	0.625	0.1	3964	3397	2899	2718	2310	1540
6	6.625	0.718	0.1	3918	3358	2866	2687	2284	1522
8	8.625	0.906	0.1	3925	3364	2871	2691	2288	1525

Table A-2-2.1.1(d) Maximum Pressure Schedule 160, Welded

GRADE TYPE SE			A-106C SMLS 21000	A-53B A-106B SMLS 18000	A-53B ERW 15360	A-53A A-106A SMLS 14400	A-53A ERW 12240	A-53F FURN. 8160
NOM. DIA.	O.D.	WALL = t						
0.5	0.84	0.187	9350	8014	6839	6411	5450	3633
0.75	1.05	0.218	8720	7474	6378	5979	5083	3388
1	1.315	0.25	7985	6844	5840	5475	4654	3103
1.25	1.66	0.25	6325	5422	4627	4337	3687	2458
1.5	1.9	0.281	6212	5324	4543	4259	3620	2414
2	2.375	0.343	6066	5199	4437	4159	3535	2357
2.5	2.875	0.375	5478	4696	4007	3757	3193	2129
3	3.5	0.437	5244	4495	3836	3596	3057	2038
4	4.5	0.531	4956	4248	3625	3398	2889	1926
5	5.563	0.625	4719	4045	3451	3236	2750	1834
6	6.625	0.718	4552	3902	3329	3121	2653	1769
8	8.625	0.906	4412	3782	3227	3025	2571	1714

Table A-2-2.1.1(e) Piping Requirements for IG-541 @ 2900 psig (3433 psig)

Threaded	Sch. 40	Sch. 80	Sch. 120	Sch. 160
A-106C, SMLS	Do Not Use	1/2 in - 1 in., NPS	Do Not Use	1/2 in. - 8 in., NPS
A-53B/A-106B, SMLS	Do Not Use	1/2 in., NPS	Do Not Use	1/2 in. - 4 in., NPS
A-53B, ERW	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 2 in., NPS
A-53A/A-106A, SMLS	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 1 in., NPS
A-53A, ERW	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 3/4 in., NPS
A-53F, FW	Do Not Use	Do Not Use	Do Not Use	Do Not Use
Welded				
A-106C, SMLS	Do Not Use	1/2 in., NPS	4 in. - 8 in., NPS	1/2 in. - 8 in., NPS
A-53B/A-106B, SMLS	Do Not Use	1/2 in., NPS	4 in., NPS	1/2 in. - 8 in., NPS
A-53B, ERW	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 5 in., NPS
A-53A/A-106A, SMLS	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 3 in., NPS
A-53A, ERW	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 2 in., NPS
A-53F, FW	Do Not Use	Do Not Use	Do Not Use	1/2 in., NPS

Table A-2-2.1.1(f) Piping Requirements for IG-01 @ 2370 psig (2650 psig)

Threaded	Sch. 40	Sch. 80	Sch. 120	Sch. 160
A-106C, SMLS	Do Not Use	1/2 in. - 1 1/2 in., NPS	4 in. - 8 in., NPS	1/2 in. - 8 in., NPS
A-53B/A-106B, SMLS	Do Not Use	1/2 in. - 1 in., NPS	4 in., NPS	1/2 in. - 8 in., NPS
A-53B, ERW	Do Not Use	1/2 in. - 3/4 in., NPS	Do Not Use	1/2 in. - 8 in., NPS
A-53A/A-106A, SMLS	Do Not Use	1/2 in. - 3/4 in., NPS	Do Not Use	1/2 in. - 8 in., NPS
A-53A, ERW	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 2 in., NPS
A-53F, FW	Do Not Use	Do Not Use	Do Not Use	Do Not Use
Welded				
A-106C, SMLS	Do Not Use	1/2 in. - 1 1/2 in., NPS	4 in. - 8 in., NPS	1/2 in. - 8 in., NPS
A-53B/A-106B, SMLS	Do Not Use	1/2 in. - 1 in., NPS	4 in. - 8 in., NPS	1/2 in. - 8 in., NPS
A-53B, ERW	Do Not Use	1/2 in. - 3/4 in., NPS	4 in. - 5 in., NPS	1/2 in. - 8 in., NPS
A-53A/A-106A, SMLS	Do Not Use	1/2 in. - 3/4 in., NPS	4 in., NPS	1/2 in. - 8 in., NPS
A-53A, ERW	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 6 in., NPS
A-53F, FW	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 1 in., NPS

Table A-2-2.1.1(g) Piping Requirements for IG-55 @ 2222 psig (2475 psig)

Threaded	Sch. 40	Sch. 80	Sch. 120	Sch. 160
A-106C, SMLS	1/2 in., NPS	1/2 in. - 2 1/2 in., NPS	4 in. - 8 in., NPS	1/2 in. - 8 in., NPS
A-53B/A-106B, SMLS	Do Not Use	1/2 in. - 1 1/4 in., NPS	4 in. - 8 in., NPS	1/2 in. - 8 in., NPS
A-53B, ERW	Do Not Use	1/2 in. - 1 in., NPS	Do Not Use	1/2 in. - 8 in., NPS
A-53A/A-106A, SMLS	Do Not Use	1/2 in. - 3/4 in., NPS	Do Not Use	1/2 in. - 8 in., NPS
A-53A, ERW	Do Not Use	1/2 in., NPS	Do Not Use	1/2 in. - 8 in., NPS
A-53F, FW	Do Not Use	Do Not Use	Do Not Use	1/2 in., NPS
Welded				
A-106C, SMLS	1/2 in. - 3 in., NPS	1/2 in. - 6 in., NPS	4 in. - 8 in., NPS	1/2 in. - 8 in., NPS
A-53B/A-106B, SMLS	1/2 in. - 1 1/2 in., NPS	1/2 in. - 4 in., NPS	4 in. - 8 in., NPS	1/2 in. - 8 in., NPS
A-53B, ERW	1/2 in. - 1 1/4 in., NPS	1/2 in. - 3 in., NPS	4 in. - 8 in., NPS	1/2 in. - 8 in., NPS
A-53A/A-106A, SMLS	1/2 in. - 1 in., NPS	1/2 in. - 2 1/2 in., NPS	4 in. - 5 in., NPS	1/2 in. - 8 in., NPS
A-53A, ERW	1/2 in. - 1 in., NPS	1/2 in. - 1 1/2 in., NPS	Do Not Use	1/2 in. - 2 in., NPS
A-53F, FW	Do Not Use	1/2 in., NPS	Do Not Use	1/2 in. - 3/4 in., NPS

Table A-2-2.1.1(h) Piping Requirements for IG-55 @ 2962 psig (3300 psig)

Threaded	Sch. 40	Sch. 80	Sch. 120	Sch. 160
A-106C, SMLS	Do Not Use	1/2 in. - 1 in., NPS	Do Not Use	1/2 in. - 8 in., NPS
A-53B/A-106B, SMLS	Do Not Use	1/2 in. - 3/4 in., NPS	Do Not Use	1/2 in. - 8 in., NPS
A-53B, ERW	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 6 in., NPS
A-53A/A-106A, SMLS	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 4 in., NPS
A-53A, ERW	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 2 in., NPS
A-53F, FW	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 1 in., NPS
Welded				
A-106C, SMLS	1/2 in. - 1 1/4 in., NPS	1/2 in. - 3 in., NPS	4 in. - 8 in., NPS	1/2 in. - 8 in., NPS
A-53B/A-106B, SMLS	1/2 in. - 1 in., NPS	1/2 in. - 2 1/2 in., NPS	4 in., NPS	1/2 in. - 8 in., NPS
A-53B, ERW	1/2 in. - 3/4 in., NPS	1/2 in. - 1 1/4 in., NPS	Do Not Use	1/2 in. - 8 in., NPS
A-53A/A-106A, SMLS	1/2 in., NPS	1/2 in. - 1 1/4 in., NPS	Do Not Use	1/2 in. - 8 in., NPS
A-53A, ERW	Do Not Use	1/2 in. - 1 in., NPS	Do Not Use	1/2 in. - 8 in., NPS
A-53F, FW	Do Not Use	1/2 in. - 1 in., NPS	Do Not Use	1/2 in. - 1 in., NPS

Table A-2-2.1.1(i) Piping Requirements for IG-55 @ 4443 psig (4950 psig)

Threaded	Sch. 40	Sch. 80	Sch. 120	Sch. 160
A-106C, SMLS	Do Not Use	1/2 in., NPS	Do Not Use	1/2 in. - 1 1/2 in., NPS
A-53B/A-106B, SMLS	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 1 in., NPS
A-53B, ERW	Do Not Use	Do Not Use	Do Not Use	Do Not Use
A-53A/A-106A, SMLS	Do Not Use	Do Not Use	Do Not Use	Do Not Use
A-53A, ERW	Do Not Use	Do Not Use	Do Not Use	Do Not Use
A-53F, FW	Do Not Use	Do Not Use	Do Not Use	Do Not Use
Welded				
A-106C, SMLS	1/2 in. - 1 in., NPS	1/2 in. - 1 in., NPS	Do Not Use	1/2 in. - 4 in., NPS
A-53B/A-106B, SMLS	1/2 in. - 3/4 in., NPS	1/2 in. - 3/4 in., NPS	Do Not Use	1/2 in. - 2 in., NPS
A-53B, ERW	1/2 in., NPS	1/2 in., NPS	Do Not Use	1/2 in. - 1 in., NPS
A-53A/A-106A, SMLS	1/2 in., NPS	1/2 in., NPS	Do Not Use	1/2 in. - 1 in., NPS
A-53A, ERW	Do Not Use	Do Not Use	Do Not Use	1/2 in. - 3/4 in., NPS
A-53F, FW	Do Not Use	Do Not Use	Do Not Use	Do Not Use

A-2-2.1.1 The following presents calculations to provide minimum pipe schedules (wall thickness) for use with clean agent fire extinguishing systems in accordance with this standard. Paragraph 2-2.1.1 requires that "the piping wall shall be calculated in accordance with ASME B31.1, *Power Piping Code*."

Minimum Piping Requirements for Clean Agent Systems

1. Limitations on piping to be used for clean agent systems (or any pressurized fluid) are set by:

(a) Maximum pressure expected within the pipe;

(b) Material of construction of the pipe, tensile strength of the material, yield strength of the material, and temperature limitations of the material;

(c) Joining methods, e.g., threaded, welded, grooved, etc.;

(d) Pipe construction method, e.g., seamless, ERW (electric resistance welded), furnace welded, etc.;

(e) Pipe diameter; and

(f) Wall thickness of the pipe.

2. The calculations are based on the following:

(a) The calculations contained herein apply only to steel pipe conforming to ASTM A 53 or ASTM A 106, and copper tubing conforming to ASTM B 88;

(b) The calculations cover threaded, welded, and grooved joints for steel pipe; and compression fittings for copper tubing; and

(c) Other materials, such as stainless steel pipe or tubings, can be used provided that the appropriate SE values, wall thicknesses, and end connection factors are substituted.

3. The basic equation to determine the minimum wall thickness for piping under internal pressure is:

$$t = [PD/2SE] + A$$

where:

t = required wall thickness (inches)
D = outside pipe diameter (inches)
P = maximum allowable pressure (psi)
SE = maximum allowable stress [including joint efficiency] (psi)
A = allowance for threading, grooving, etc. (inches).

NOTE: For these calculations:

A = depth of thread for threaded connections
A = depth of groove for cut groove connections
A = zero for welded or rolled groove connections
A = zero for joints in copper tubing using compression fittings.

The term SE is defined as $\frac{1}{4}$ of the tensile strength of the piping material or $\frac{2}{3}$ of the yield strength (whichever is lower) multiplied by a joint efficiency factor.

Joint efficiency factors are:

1.0 for seamless

0.85 for ERW (electric resistance welded)

0.60 for furnace butt weld (continuous weld) (Class F).

4. The basic equation can be rewritten to solve for P so as to determine the maximum allowable pressure for which a pipe having a nominal wall thickness, t, can be used:

$$P = 2SE\,(t - A)/D$$

as required by 2-2.1.1 of this standard.

The maximum allowable pressure P must exceed the minimum calculated pressure provided in the following table:

Clean Agent	Initial Charging Pressure	Minimum Calculated Pressure (up to and Including)
All	360 psig (2482 kPa)	620 psig (4275 kPa)
	600 psig (4137 kPa)	1000 psig (6895 kPa)
HFC-23		2250 psig (15514 kPa)
IG-541	2175 psig (14,997 kPa)	
	Upstream of the pressure reducer	2575 psig (17,755 kPa)
	Downstream of the pressure reducer	1000 psig (6895 kPa)
	2900 psig (19,996 kPa)	
	Upstream of the pressure reducer	3433 psig (23,671 kPa)
	Downstream of the pressure reducer	1000 psig (6895 kPa)
IG-01	2370 psig (16,341 kPa)	
	Upstream of the pressure reducer	2650 psig (18,972 kPa)
	Downstream of the pressure reducer	975 psig (6723 kPa)
IG-55	2222 psig (15,521 kPa)	
	Upstream of the pressure reducer	2475 psig (15,318 kPa)
	Downstream of the pressure reducer	950 psig (6550 kPa)
	2962 psig (20,424 kPa)	
	Upstream of the pressure reducer	3300 psig (22,754 kPa)
	Downstream of the pressure reducer	950 psig (6,550 kPa)
	4443 psig (30,636 kPa)	
	Upstream of the pressure reducer	4950 psig (34,130 kPa)
	Downstream of the pressure reducer	950 psig (6550 kPa)

NOTE: The calculated pressure values, P, are based on a maximum agent storage temperature of 130°F (55°C).

5. If higher storage temperatures are approved for a given system, the internal pressure should be adjusted to the maximum internal pressure at maximum temperature. In performing this calculation, all joint factors and threading, grooving, or welding allowances should be taken into account.

6. The following list gives values for SE as taken from Appendix A of ASME B31, *Code for Pressure Piping*. Identical values are given in ASME B31.1, *Power Piping Code*, and ASME B31.9, *Building Services Piping Code*.

		SE Value
Grade C Seamless Pipe	ASTM A 106	17500 psi
Grade B Seamless Pipe	ASTM A 53	15000 psi
Grade B Seamless Pipe	ASTM A 106	15000 psi
Grade A Seamless Pipe	ASTM A 53	12000 psi
Grade A Seamless Pipe	ASTM A 106	12000 psi
Grade B ERW Pipe	ASTM A 53	12800 psi
Grade A ERW Pipe	ASTM A 53	10200 psi
Grade F Furnace Welded Pipe	ASTM A 53	6800 psi
Seamless Copper Tubing (Annealed)	ASTM B 88	5100 psi
Seamless Copper Tubing (Drawn)	ASTM B 88	9000 psi

For SI units: 1 psi = 6.895 kPa.

7. Paragraph 102.2.4(B) of ASME B31.1, *Power Piping Code*, allows the maximum allowable stress (SE) to be exceeded by 20 percent if the duration of the pressure (or temperature) increase is limited to less than 1 percent of any 24-hr period. Since the clean agent piping is normally unpressurized, the system discharge period satisfies this criteria. Therefore, the piping calculations set out in this paragraph are based on values of SE that are 20 percent greater than those outlined above in Paragraph 6 (per Appendix A of ASME B31.1, *Power Piping Code*). The specific values for maximum allowable stress used in these calculations are as follows:

		SE Value
Grade C Seamless Pipe	ASTM A 106	21000 psi
Grade B Seamless Pipe	ASTM A 53	18000 psi
Grade B Seamless Pipe	ASTM A 106	18000 psi
Grade A Seamless Pipe	ASTM A 53	14400 psi
Grade A Seamless Pipe	ASTM A 106	14400 psi
Grade B Seamless Pipe	ASTM A 53	15360 psi
Grade A ERW Pipe	ASTM A 53	12240 psi
Grade F Furnace Welded Pipe	ASTM A 53	8160 psi
Seamless Copper Tubing (Annealed)	ASTM B 88	6120 psi
Seamless Copper Tubing (Drawn)	ASTM B 88	10800 psi

For SI units: 1 psi = 6.895 kPa.

NOTE 1: When using rolled groove connections or welded connections with internal projections (backup rings, etc.), the hydraulic calculations should consider these factors.

NOTE 2: Pipe supplied as dual stenciled A 120/A 53 Class F meets the requirements of Class F furnace welded pipe ASTM A 53 as listed above. Ordinary cast-iron pipe, steel pipe conforming to ASTM A 120, or nonmetallic pipe should not be used.

NOTE 3: All grooved couplings/fittings should be listed/approved for use with clean agent extinguishing systems.

NOTE 4: The above calculations do not apply to extended discharge exceeding 14.4 min.

NOTE 5: For compression or flare-type tubing fittings, the maximum allowable working pressure specified by the fitting manufacturer should be used.

A-2-2.3.1 Fittings that are acceptable for use in clean agent systems can be found in Table A-2-2.3.1.

Pressure-temperature ratings have been established for certain types of fittings. A list of ANSI standards covering the different types of fittings is given in Table 126.1 of ASME B31.1, *Power Piping Code*. Where fittings not covered by one of these standards are used, the design recommendations of the manufacturer of the fittings should not be exceeded.

A-2-2.4.2 Some of the new clean agents might not be compatible with the elastomers used in Halon 1301 system valves. Before charging a system container with some of the clean agents, it might be necessary to disassemble the discharge valve and completely replace the o-rings and other sealing surfaces with components that will not react to that agent. Make certain that this evaluation has been completed. Also make certain that the change results in the valve, container, and system complying with the appropriate listings or approvals.

A-2-3.2.1 The detection system selection process should evaluate the ambient environmental condition in determining the appropriate device and sensitivity in order to prevent unwanted discharges while still providing the necessary earliest actuation. In high air flow environments, air sampling detection devices should be considered.

A-2-3.5.3 A telephone should be located near the abort switch.

A-2-3.6 Accidental discharge can be a significant factor in unwanted clean agent emissions. Equipment lockout or service disconnects can be instrumental in preventing false discharges when the clean agent system is being tested or serviced. In addition, servicing of air conditioning systems with the release of refrigerant aerosols, soldering, or turning electric plenum heaters on for the first time after a long period of idleness might trip the clean agent system. Where used, an equipment service disconnect switch should be of the keyed-access type if external of the control panel or can be of the toggle type if within the locked control panel. Either type should annunciate at the panel when in the out-of-service mode. Written procedures should be established for taking the clean agent system out of service.

A-3-2.1 A listed or approved calculation method should predict nozzle pressure, agent discharged per nozzle, and discharge time within the following minimum limits of accuracy:

(a) The weight of agent predicted by flow calculation to discharge from the nozzle should agree with the total weight of agent actually discharged from each nozzle in the system within a range of -5 percent to +10 percent (predicted to actual).

(b) The discharge time predicted by the flow calculation method should agree with the actual discharge time from each nozzle in the system within a range of ± 10 percent or ± 1 second, whichever is greater (predicted to actual).

(c) The accuracy of calculated nozzle pressures versus actual pressures at each nozzle should be such that actual nozzle pressures in an installation will not fall outside the range required for acceptable nozzle performance.

(d) The nozzle pressure should not fall below the minimum or above the maximum nozzle pressure required for the nozzle to uniformly distribute the agent throughout the volume which that nozzle's discharge is to protect.

A-3-3.4 Examples of ventilation systems necessary to ensure safety include cooling of vital equipment required for process safety and ventilation systems required for containment of hazardous materials.

A-3-4.2.1 This appendix section provides a summary of a method of evaluating inerting concentration of a fire extinguishing vapor.

Table A-2-2.3.1 Piping System Fittings

Clean Agent	Initial Charging Pressure (*up to and Including*)	Acceptable Fittings	Maximum Pipe Size
All Halocarbon Agents	360 psig (2482 kPa)	Class 300 malleable or ductile iron fittings	3 in. NPS
		1000-lb rated ductile iron or forged steel fittings	>3 in. NPS
		Class 300 flanged joints	All
	600 psig (4137 kPa)	Class 300 malleable or ductile iron fittings	3 in. NPS
		1000-lb rated ductile iron or forged steel fittings	>3 in. NPS
		Class 600 flanged joints	All
HFC-23	609 psig (4199 kPa)	Class 300 malleable or ductile iron fittings	2 in. NPS
		1000-lb rated ductile iron or forged steel fittings	>3 in. NPS
		Class 300 flanged joints	All - Downstream of any stop valve or in systems with no stop valve
		Class 600 flanged joints	All - Upstream of any stop valve.
IG-541	2175 psig (14,997 kPa)	2000-lb forged steel	All
	Upstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
	Downstream of the pressure reducer	1000-lb rated ductile iron or forged steel	>3 in. NPS
		Class 600 flanged joints	All
	2900 psig (19,996 Pa)	3000-lb forged steel	All
	Upstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
	Downstream of the pressure reducer	1000-lb rated ductile iron or forged steel	>3 in. NPS
		Class 600 flanged joints	All
IG-01	2370 psig (16,341 kPa)	3000-lb forged steel	All
	Upstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
	Downstream of the pressure reducer	1000-lb rated ductile iron or forged steel	>3 in. NPS
		Class 600 flanged joints	All
IG-55	2222 psig (15,521 kPa)	3000-lb forged steel	All
	Upstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
	Downstream of the pressure reducer	1000-lb rated ductile iron or forged steel	>3 in. NPS
		Class 600 flanged joints	All
	2962 psig (20,424 kPa)	3000-lb forged steel	All
	Upstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
	Downstream of the pressure reducer	1000-lb rated ductile iron or forged steel	>3 in. NPS
		Class 600 flanged joints	All
	4443 psig (30,636 kPa)	3000-lb forged steel	1 in. NPS
	Upstream of the pressure reducer	6000-lb forged steel	>1 in. NPS
	Downstream of the pressure reducer	Class 300 malleable iron or ductile iron	3 in. NPS
		1000-lb rated ductile iron or forged steel	>3 in. NPS
		Class 600 flanged joints	All

NOTE: The materials itemized above do not preclude the use of other materials and type and/or style of fittings that satify the requirements of 2-2.3.1.

One characteristic of halons and replacement agents is frequently referred to as the inerting, or inhibiting, concentration. Related to this, flammability diagram data (Dalzell, W., 1975 and Coll., J.P., 1976) on ternary systems was published in NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*. The procedures used previously have been used more recently to evaluate inerting concentrations of halons and replacement chemicals against various fuel-air systems. Differences between the earlier studies and the recent work are that the test vessel volume used was 7.9 L (2.1 gal) vs 5.6 L (1.5 gal) previously; the igniter type was the same, i.e. carbon rod corona discharge spark, but the capacitor stored energy levels were higher, approximately 68 J (16.2 cal) vs 6 or 11 J (1.4 or 2.6 cal) on the earlier work. The basic procedure, employing a gap spark, has been adopted to develop additional data.

Ternary fuel-air agent mixtures were prepared at a test pressure of 1 atmosphere and at room temperature in a 7.9-L (2.1-gal) spherical test vessel by the partial pressure method. The vessel was fitted with inlet and vent ports, a thermocouple, and a pressure transducer. The test vessel was first evacuated. Agent was then admitted, and if a liquid, sufficient time was allowed for evaporation to occur. Fuel vapor and finally air were admitted, raising the vessel pressure to 1 atmosphere. An internal flapper allowed the mixtures to be agitated by rocking the vessel back and forth. The pressure transducer was connected to a suitable recording device to measure pressure rise that might occur on actuation of the igniter.

The igniter employed consisted of a bundle of four graphite rods ("H" pencil leads) held together by two wire or metal brand wraps on either end of the bundle leaving a gap between the wraps of about 3 mm (0.12 in.). The igniter was wired in series with two 525 mF 450-volt capacitors. The capacitors were charged to a potential of 720 to 730 VDC. The stored energy was, therefore, 68 to 70 J (16.2 to 16.7 cal). The nominal resistance of the rod assemble was about 1 ohm. On switch closure the capacitor discharge current resulted in ionization at the graphite rod surface. A corona spark jumped across the connector gap. The spark energy content was taken as the stored capacitor energy though, in principle, it must be somewhat less than this amount due to line resistance losses.

The pressure rise, if any, resulting from ignition of the test mixture was recorded. The interior of the test vessel was wiped clean with a cloth damp with either water or a solvent between tests to avoid buildup of decomposition residues that might influence the results.

The definition of the flammable boundary was taken as that composition that just produces a pressure rise of 0.07 times the initial pressure, or 1 psi (6.9 kPa) when the initial pressure is 1 atmosphere. Tests were conducted at fixed fuel-air ratios and varying amounts of agent vapor until conditions were found to give rise to pressure increases that bracket 0.07 times the initial pressure. Tests were conducted at several fuel-air ratios to establish that condition requiring the highest agent vapor concentration to inert.

Data obtained on several chemicals that can serve as fire protection agents are given below.

Table A-3-4.2.1 Inerting Concentrations for Various Agents

Fuel	Agent	Vol % Inerting Concentration	Reference
i-Butane	H-1301	6.7	Senecal
	HFC-227ea	11.3	Robin
1-Chloro-1, 1-difluoroethane (HCFC-142b)	HFC-227ea	2.6	Robin
1,1-Difluoroethane (HFC-152a)	HFC-227ea	8.6	Robin
Difluoromethane (HFC-32)	HFC-227ea	3.5	Robin
Ethylene Oxide	HFC-227ea	13.6	Robin
Methane	HFC-227ea	8.0	Robin
	HFC-23	20.2	Senecal
	HFC-125	14.7	Senecal
	IG-541	43.0	Tamanini
	Halon 1301	4.9	Skaggs
Pentane	HFC-227ea	11.6	Robin
Propane	H-1301	7.7	Senecal
	H-1301	6.0	Senecal
	H-1301	6.2	Moore
	HFC-227ea	11.6	Robin
	HFC-227ea	11.7	Moore
	HFC-23	20.2	Senecal
	HFC-23	20.2	Moore
	HFC-23	20.4	Skaggs
	HFC-125	15.7	Senecal
	IG-541	49.0	Tamanini
	FC-3-1-10	10.3	Senecal
	FC-3-1-10	9.9	Skaggs
	FC-3-1-10	9.6	Moore
	FC-5114	7.3	Senecal
	HCFC Blend A	18.5	Moore
	FIC-1311	6.5	Moore
	Halon 1301	6.2	Skaggs
Propane*	HFC-227ea	11.7	Skaggs

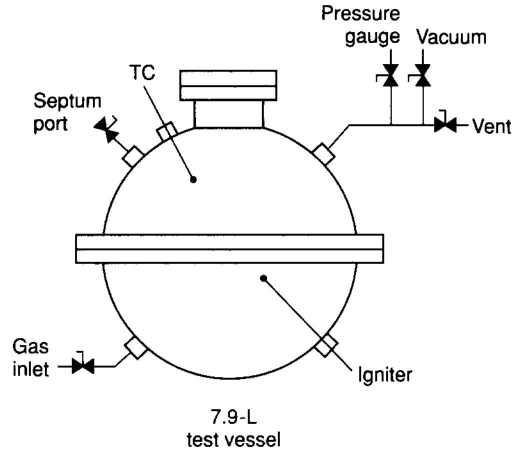

Figure A-3-4.2.1 Spherical test vessel.

A-3-4.2.2 This appendix section provides a summary of the cup burner method for determining extinguishing concentrations.

One apparatus, shown schematically in Figure A-3-4.2.2, consists of an 8.5-cm (3.35-in.) I.D. by 53-cm (20.87-in.) tall outer chimney through which air is passed at 40 L/min (10.6 gal/min) from a glass bead distributor at its base, and an inner fuel cup burner with a 3.1-cm (1.22-in.) O.D. and a 2.15-cm (0.84-in.) I.D. positioned 30.5 cm (12.01 in.) below the top edge of the outer chimney. Extinguishing agent is added to the air stream prior to entering the glass bead distributor. The air flow rate is maintained at 40 L/min (10.6 gal/min) for all trials. Air and agent flow rates are measured using calibrated rotameters.

Each trial is conducted by adjusting the extended fuel reservoir (*see Figure A-3-4.2.2*) to bring the liquid level in the cup burner to just even with the base of a ground glass lip on the burner cup. With the air flow maintained at 40 L/min (10.6 gal/min), the fuel in the cup burner is ignited. Agent is gradually added to the air stream until the flame is extinguished. The agent rotameter reading is then recorded.

Several extinguishing trials are conducted with each agent-fuel combination to ensure that repeatability is obtained.

The extinguishment concentration is computed as follows:

$$\text{Ext. Conc.} = \frac{F_1}{F_1 + F_2} \times 100\%$$

where F_1 = Agent flow rate, L/min
F_2 = Air flow rate, L/min.

The average of the several values of agent flow rate at extinguishment is used in the above calculation.

A number of investigators using different test methods and procedures have published flame extinguishing data. Reported cup burner flame extinguishing concentrations often vary between investigators, and variations in equipment and techniques exist. Despite this, however, agreement between different laboratories is relatively good. Table A-3-4.2.2 presents cup burner flame extinguishing concentrations for halocarbon agents in this standard from various investigators.

A-3-4.2.2.2 Deep-seated fires involving Class A fuels may require substantially higher design concentrations and extended holding times than the design concentrations

Table A-3-4.2.2 Cup-Burner Heptane Flame Extinguishing Data

Agent	NRL	3M	NMERI	Investigator Fenwal	GLCC	Ansul	NIST
FC-3-1-10	5.2	5.9	5.0	5.5	—	—	—
HCFC-124	—	—	—	6.4	—	—	7.0
HFC-227ea	6.6	—	6.3	5.8	5.9	—	6.2
HFC-236fa	—	—	5.6	5.3	—	—	6.5
HCFC Blend A	11	—	9.9	—	—	—	—
HFC-23	12	—	12.6	12	12.7	—	12
HFC-125	9	—	9.4	8.1	—	—	8.7
410	—	—	—	—	—	—	5.3
CF_3I	—	—	—	—	—	—	3.2
FIC-1311	3.241	—	3.0	—	—	—	—
IG-541	—	—	—	—	—	29.1	—
IG-55	—	—	28	—	—	—	—
IG-01	—	—	38	—	—	—	—
Halon 1301	3.1	3.9	2.9	3	3.5	—	3.1

NOTES:
(a) NRL—Naval Research Laboratory, 3M—3M Company, NMERI—New Mexico Engineering Research Institute, Fenwal—Fenwal Safety Systems Company, GLCC—Great Lakes Chemical Company, Ansul—Ansul Fire Protection Company, NIST—National Institute For Standards and Technology.
(b) Sheinson, R.S., Maranghides, A., "Halon Replacement n-Heptane Cup Burner Values," Naval Research Laboratory Ltr Rpt 6180/0222, April 1995, in progress.
(c) Sheinson, R.S., Penner-Hahn, J.E., and Indritz, D. "The Physical and Chemical Action of Fire Suppressants," Fire Safety Journal, Vol. 15, pp. 437-450, 1989.

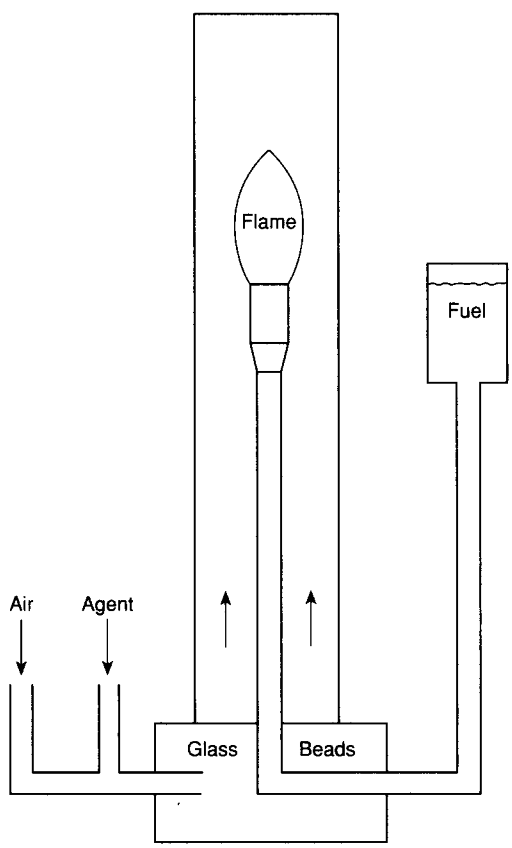

Figure A-3-4.2.2 Cup burner apparatus.

and holding times required for surface-type fires involving Class A fuels. Hazards containing both Class A and Class B fuels should be evaluated on the basis of the fuel requiring the highest design concentration.

A-3-4.2.2.3 Fire Extinguishment/Area Coverage Fire Test Procedure for Engineered and Preengineered Clean Agent Extinguishing System Units.

(a) General Requirements.

1. An engineered or preengineered extinguishing system should mix and distribute its extinguishing agent and should totally flood an enclosure when tested in accordance with the recommendations of 3. through 17. under the maximum design limitations and most severe installation instructions. See also 2.

2. When tested as described in 4. through 11., an extinguishing system unit should extinguish all fires within 30 sec after the end of system discharge. When tested as described in 4. through 8. and 12. through 17., an extinguishing system should prevent reignition of the wood crib after a 10-minute soak period.

3. The tests described in 4. through 17. consider the intended use and limitations of the extinguishing system, with specific reference to (1) the area coverage for each type of nozzle; (2) the operating temperature range of the system; (3) location of the nozzles in the protected area; (4) either maximum length and size of piping and number of fittings to each nozzle, or minimum nozzle pressure; (5) maximum discharge time; and (6) maximum fill density.

(b) Test Enclosure.

4. The enclosure for the test should be constructed of either indoor or outdoor grade minimum 3/8 in. (9.5 mm) thick plywood or equivalent material.

5. An enclosure(s) is to be constructed having (1) the maximum area coverage for the extinguishing system unit or nozzle being tested, and (2) the minimum and maximum protected area height limitations.

Exception: The test enclosure(s) for the maximum height, flammable liquid and wood crib fire extinguishment tests need not have the maximum coverage area but should be at least 10 ft (3.0 m) wide by 10 ft (3.0 m) long.

(c) Extinguishing System.

6. A preengineered-type extinguishing system unit is to be assembled using its maximum piping limitations with respect to number of fittings and length of pipe to the discharge nozzles and nozzle configuration(s) as specified in the manufacturer's design and installation instructions.

7. An engineered-type extinguishing system unit is to be assembled using a piping arrangement that results in the minimum nozzle design pressure at 70°F (21°C).

8. Except for the flammable liquid fire test using the $2\frac{1}{2}$-ft^2 (0.23-m^2) square pan and the wood crib extinguishment test, the cylinders are to be conditioned to the minimum operating temperature specified in the manufacturer's installation instructions.

(d) Extinguishing Concentration.

9. The extinguishing agent concentration for each test is to be 83.34 percent of the intended end use design concentration specified in the manufacturer's design and installation instructions at the ambient temperature of approximately 70°F (21°C) within the enclosure. The concentration for inert gas clean agents may be adjusted to take into consideration actual leakage measured from the test enclosure. The concentration within the enclosure for halocarbon clean agents should be calculated using the following formula unless it is demonstrated that the test enclosure exhibits significant leakage. If significant test enclosure leakage does exist, the formula used to determine the test enclosure concentration of halocarbon clean agents can be modified to account for the leakage measured.

Halocarbon Clean Agents

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

Where:

W = Weight of clean agents, lb
V = Volume of test enclosure, ft^3
s = Specific volume of clean agent at test temperature (ft^3/lb)
C = Concentration, percent.

(e) Flammable Liquid Extinguishment Tests.

10. Test cans, 3.0 to 3.5 in. (76.2 mm to 88.9 mm) in diameter and at least 4 in. (102 mm) high, containing either heptane or heptane and water, are to be placed within 2 in. (50.8 mm) of the corners of the test enclosure(s) and directly behind the baffle (see below), and located vertically within 12 in. (305 mm) of the top or bottom of the enclosure, or both top and bottom if the enclosure permits such placement. If the cans contain heptane and water, the heptane is to be at least 2 in. (50.8 mm) deep. The level of heptane in the cans should be at least 2 in. (50.8 mm) below the top of the can. For the minimum room height area coverage test, closeable openings shall be provided directly above the cans to allow for venting prior to system installation. In addition, for the minimum height limitation area coverage test, a baffle is to be installed between the floor and ceiling in the center of the enclosure. The baffle is to be perpendicular to the direction of nozzle discharge, and to be 20 percent of the length or width of the enclosure, whichever is applicable with respect to nozzle location. For the maximum room height extinguishment test, an additional test shall be conducted using a $2\frac{1}{2}$-ft^2 (0.23-m^2) square pan located in the center of the room and the storage cylinder conditioned to 70°F (21°C). The test pan is to contain at least 2 in. (50.8 mm) of heptane with the heptane level at least 2 in. (50.8 mm) below the top of the pan. For all tests the heptane is to be ignited and allowed to burn for 30 sec, upon which time all openings are to be closed and the extinguishing system is to be manually actuated. At the time of actuation, the percent of oxygen within the enclosure should be at least 20.0 percent.

11. The heptane is to be commercial grade having the following characteristics:

Distillation -	
Initial boiling point	90°C (194°F)
50 percent	93°C (199°F)
Dry point	96.5°C (208°F)
Specific gravity (60°F/60°F) (15.6°C/15.6°C)	0.719
Reid vapor pressure	2.0 psi
Research octane rating	60
Motor octane rating	50

(f) Wood Crib Extinguishment Tests.

12. The storage cylinder is to be conditioned to 70°F (21°C). The test enclosure is to have the maximum ceiling height as specified in the manufacturer's installation instructions.

13. The wood crib is to consist of four layers of six, trade size 2 by 2 ($1\frac{1}{2}$ by $1\frac{1}{2}$ in.) by 18 in. long, kiln spruce or fir lumber having a moisture content between 9 and 13 percent. The alternate layers of the wood members are to be placed at right angles to one another. The individual wood members in each layer are to be evenly spaced, forming a square determined by the specified length of the wood members. The wood members forming the outside edges of the crib are to be stapled or nailed together.

14. Ignition of the crib is to be achieved by the burning of commercial grade heptane in a square steel pan $2\frac{1}{2}$ ft^2 (0.23 m^2) in area and not less than 4 in. (101.6 mm) in height. The crib is to be centered with the bottom of the crib 12 to 24 in. (304 to 609.6 mm) above the top of the pan and the test stand constructed so as to allow for the bottom of the crib to be exposed to the atmosphere.

15. The heptane is to be ignited and the crib is to be allowed to burn freely for approximately 6 minutes outside the test enclosure. The heptane fire is to burn for 3 to $3\frac{1}{2}$ minutes. Approximately $\frac{1}{4}$ gal (0.95 L) of heptane will provide a 3 to $3\frac{1}{2}$ minutes burn time. Just prior to the end of the preburn period, the crib is to be moved into the test enclosure and placed on a stand such that the bottom of the crib is between 20 and 28 in. (508 and 711 mm) above the floor. The closure is then to be sealed.

16. After the crib is allowed to burn for a period of 6 minutes, the system is to be actuated. At the time of actuation, the percent of oxygen within the enclosure at the level of the crib shall be at least 20.0 percent.

17. After the end of system discharge, the enclosure is to remain sealed for a total of 10 minutes. After the 10-minute soak period, the crib is to be removed from the

enclosure and observed to determine whether sufficient fuel remains to sustain combustion and to detect signs of reignition.

A-3-5.1 The amount of clean agent required to develop a given concentration will be greater than the final amount of agent in the same enclosure.

In most cases, the clean agent must be applied in a manner that promotes progressive mixing of the atmosphere. As the clean agent is injected, the displaced atmosphere is exhausted freely from the enclosure through small openings or through special vents. Some clean agent is therefore lost with the vented atmosphere, and the higher the concentration, the greater the loss of clean agent.

For the purposes of this standard, it is assumed that the clean agent/air mixture lost in this manner contains the final design concentration of the clean agent. This represents the worst case from a theoretical standpoint and provides a built-in safety factor to compensate for non-ideal discharge arrangements.

A-3-5.2 The volume of inert gas clean agent required to develop a given concentration will be greater than the final volume remaining in the same enclosure.

In most cases the inert gas clean agent must be applied in a manner that promotes progressive mixing of the atmosphere. As the clean agent is injected, the displaced atmosphere is exhausted freely from the enclosure through small openings or through special vents. Some inert gas clean agent is therefore lost with the vented atmosphere. This loss becomes greater at high concentrations. This method of application is called "free efflux" flooding.

Under the above conditions the volume of inert gas clean agent required to develop a given concentration in the atmosphere is expressed by the following equations:

$$e_x = \frac{100}{100 - \% \text{ IG}}$$

or

$$X = 2.303 \text{ Log}_{10} \frac{100}{100 - \% \text{ IG}}$$

Where: % IG = Volume % of inert gas
X = Volume of inert gas added per volume of space.

A-3-6 Some areas affected by pressures other than sea level include hyperbaric enclosures, facilities where ventilation fans are used to create artificially higher or lower pressures such as test chambers, and facilities at altitudes above or below sea level. Although mines are usually below normal ground levels, they occasionally have to be ventilated so that personnel can work in that environment. Ambient pressures in that situation can be considerably different from those expected by a pure altitude correction.

Although adjustments are required for barometric pressures equivalent to 3000 ft (915 m) or more above or below sea level, adjustments can be made for any ambient pressure condition.

The atmospheric correction factor is not linear. However, in the moderate range discussed it can be closely approximated with two lines:

For −3000 ft to 5500 ft of equivalent altitude:
$Y = (-0.000036 * X) + 1$

For 5501 ft to 10000 ft of equivalent altitude:
$Y = (-0.00003 * X) + 0.96$
Where:
Y = Correction Factor
X = Altitude (ft).

For SI units: 1 ft = 0.305 m.

A-3-7 Energized electrical equipment that might provide a prolonged ignition source should be de-energized prior to or during agent discharge. If electrical equipment cannot be de-energized, consideration should be given to the use of extended discharge, the use of higher initial concentration, and the possibility of the formation of combustion and decomposition products.

A-3-8.1.2 The optimum discharge time is a function of many variables. Five variables are very important:

(a) Limitation of decomposition products;
(b) Limitation of fire damage and its effects;
(c) Enhanced agent mixing;
(d) Limitation of compartment overpressure; and
(e) Secondary nozzle flow effects.

The halogenated hydrocarbon fire extinguishing agents described in this standard will break down into their decomposition products as they are exposed to a fire. It is essential that the end user understand this process as the selection of the discharge time, and other design factors, will be impacted by the amount of decomposition products the protected hazard can tolerate.

The quantity of decomposition products generated for a particular agent is proportional to the size of the fire, the actual agent concentration, and the speed at which the extinguishing concentration is applied to the fire. The larger the flame size, the greater the quantity of decomposition products that would be expected. Likewise, the decomposition products will be greater if the agent discharges slowly. This is due to the fact that it takes longer for the minimum extinguishing concentration to be achieved. Until it is achieved, the flame will continue to decompose agent rather than be suppressed. Additionally, studies by Ferreira et al (1992) demonstrated a 50 percent reduction in decomposition products when cup burner plus 20 percent concentrations of FC-3-1-10 were used in a comparison to cup burner concentrations only.

This decomposition issue is not unique to these agents. Halon 1301 decomposed into limited quantities of HBr and HF. In a properly designed Halon 1301 system, the quantity of these products would be very small and of little consequence to the end user. After decades of experience, the quantity of decomposition products generated as Halon 1301 suppressed a fire was not known to have caused any damage.

The agents described in this standard also will decompose into various chemicals. The most common decomposition product is HF. HF can be a very hazardous substance. Therefore, the system designer should make every effort to limit the generation of HF to the least possible amount. This is especially critical in areas where people or sensitive equipment might be present.

People would be aware of excessive HF in an area as it generates a very objectionable odor. Excessive HF can be damaging to sensitive equipment as it can mix with the water vapor in the air to form diluted hydrofluoric acids that can cause corrosion and accelerated aging of contact points.