IS 15517 (2004): Gaseous Fire Extinguishing Systems - HFC 227ea (Hepta Fluoro Propane) Extinguishing Systems [CED 22: Fire Fighting]

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IS 15517: 2004

भारतीय मानक

गैसीय अग्नि शमन पद्धतियाँ — एचएफसी 227ईए शमन पद्धति

Indian Standard

GASEOUS FIRE EXTINGUISHING SYSTEMS — HFC 227ea (HEPTA FLUORO PROPANE) EXTINGUISHING SYSTEMS

ICS 13.220.10

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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AMENDMENT NO. 1 SEPTEMBER 2007
TO
IS 15517 : 2004 GASEOUS FIRE EXTINGUISHING SYSTEMS — HFC 227ea (HEPTA FLUORO PROPANE) EXTINGUISHING SYSTEMS

(*Page* 1, *Table* 1, *col* 2) — Substitute 'Hepta Fluoro Propane – ,1,1,2,3,3,3' *for* 'Hepta Fluoro Propane'.

[*Page* 2, *clause* 4.7, *Table* 4, *Sl No.* (iii), *col* 3] — Substitute '>80%' *for* >80'.

[*Page* 2, *clause* 4.8, *Table* 5, *Sl No.* (i), *col* 3 *and* 4] — Substitute '1 150 ;g/m^3' *for* '1.15 kg/m^2'.

[*Page* 3, *clause* 5.1(d)] — Insert the following matter at the end:

e) HFC 227ea system for spaces that are normally occupied and designed to concentrations above the NOAEL shall be permitted, if means are provided to limit exposure to the design concentrations shown in Table 8(b).'

(*Page* 3, *Fig.* 1) — Substitute 'S = 01269+0.0005' *for* 'S = 0.12632 +).000514'.

(*Page* 4, *clause* 6, *lines* 6 *and* 7) — Substitute 'IS 15493 : 2004' *for* 'relevant specifications'.

(*Page* 5 *Table* 8) — Renumber the existing Table 8 as '8A' and insert the following Table 8B:

Table 8B Time for Safe Human Exposure at Stated Concentration for HFC 227ea

[*Clause* 5.1(e)]

HFC 227ea Concentration		Human Exposure Time
Percent, *v/v*	ppm	(Min)
9.0	90 000	5.00
9.5	95 000	5.00
10.0	100 000	5.00
10.5	105 000	5.00
11.0	110 000	1.13
11.5	115 000	0.60
12.0	120 000	0.49

NOTE — Data derived from EPA approved and peer-reviewed PBPK model or its equipment.

[*Page* 7, *clause* 8(e)(1)] — Substitute 'Design concentration' *for* 'Minimum concentration'.

[*Page* 7, *clause* 8(e)(2), *line* 6] — Substitute safety factor '20 percent' *for* '10 percent'.

(*Page* 7, *Table* 10, *col* 3) — Substitute the following for the existing:

Percent by Volume (3)		
6.2	to	7.0
7.6	to	11.05
7.15	to	8.0
9.9	to	13.52
8.0	to	8.6
8.6	to	8.71

(CED 22)

Reprography Unit, BIS, New Delhi, India

Fire Fighting Sectional Committee, CED 22

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Fire Fighting Sectional Committee had been approved by the Civil Engineering Division Council.

It is important that the fire protection of a building or part be considered as a whole. HFC 227ea total flooding systems form only a part, though an important part, of the available facilities. However, it should not be assumed that their adoption necessarily removes the need to consider supplementary measures, such as provision of portable fire extinguishers or mobile appliances for first aid or emergency use, or measures to deal with special hazards.

HFC 227ea is recognized as effective for extinguishing Class A and Class B fires and fires where electrical risks are present. It does not cover the design of explosion suppression systems. Nevertheless, it should not be forgotten in the planning of comprehensive schemes that there may be hazards for which this technique is not suitable.

Agent dump/discharge test be replaced by enclosure integrity test unless required by legal requirement. Complete system should be approved by any recognized/independent authority.

Indian Standard

GASEOUS FIRE EXTINGUISHING SYSTEMS — HFC 227ea (HEPTA FLUORO PROPANE) EXTINGUISHING SYSTEMS

1 SCOPE

1.1 This standard sets out specific requirements for the design and installation of total flooding fire-extinguishing systems employing HFC 227ea (Hepta fluoro propane) gas extinguishant. This standard is applicable to single supply as well as distributed supply systems.

1.2 This standard complements various general requirements applicable to all types of gaseous fire-extinguishing systems (Halocarbon as well as Inert gas systems) listed in IS 15493. As such, both these standards should be read together before designing a system. Where requirements in both the standards differ, this standard shall take precedence.

1.3 This standard covers systems operating at nominal pressures of 2.5 MPa and 4.2 MPa only.

2 REFERENCES

The standards given below contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
7285 : 1988	Specification for seamless steel cylinders for permanent and high pressure liquefiable gases (*second revision*)
15493 : 2004	Gaseous fire extinguishing systems — General requirements

3 GENERAL INFORMATION

3.1 Application

3.1.1 HFC 227ea total flooding system is designed to develop a controlled atmosphere in an enclosed space and extinguishes the fires by physically cooling the fuel and by the production of free radicals which chemically interfere with the combustion process. The appropriate HFC 227ea concentration shall also be maintained until the temperature within the enclosure has fallen below the reignition point.

3.1.2 The minimum HFC 227ea concentration necessary to extinguish a flame has been determined by experiments for several surface-type fires particularly those involving liquids and gases. For deep-seated fires, longer soaking times may be necessary but are difficult to predict.

3.1.3 It is important that extinguishing concentrations are not only achieved but also 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 can lead to a recurrence of the initial event once the HFC 227ea has dissipated.

4 GAS CHARACTERISTICS AND PROPERTIES

4.1 HFC 227ea is a colourless, electrically non-conductive gas with a density approximately six times that of air.

4.2 HFC 227ea total flooding system can be used to extinguish all classes of fires except Class D fires. Information on use and limitations of HFC 227ea is available in IS 15493 (*see also* **1.2**).

4.3 The details of chemical formulae of HFC 227ea gas is as shown in Table 1.

Table 1 Composition of HFC 227ea Gas

Chemical Formula	Chemical Name
(1)	(2)
HFC-227ea (CF_3CHFCF_3)	Hepta Fluoro Propane

4.4 HFC 227ea is a gas that can be stored as a liquid in a suitable pressurized container. The pressure in the container depends upon the ambient temperature. At 20°C, the pressure is 4.2 MPa. At 30°C, the pressure is 4.54 MPa and at 0°C the pressure is 3.71 MPa.

4.5 HFC 227ea gas shall comply with the specification as shown in Table 2. The purity of HFCLea shall be determined in accordance with Annex A.

Table 2 Specification for HFC227ea Gas

Sl No.	Specification	Requirement
(1)	(2)	(3)
i)	Purity[1)]	99.6 percent by mass, *Min*
ii)	Moisture	10 × 10^{-6} by mass, *Max*
iii)	Acidity	3 × 10^{-6} by mass, *Max*
iv)	Non-volatile residue	0.01 percent by mass, *Max*
v)	Suspended matter or sediment	None visible

[1)] *See* Annex A.

4.6 Physical properties of HFC 227ea gas are shown in Table 3.

Table 3 Physical Properties of HFC 227ea Gas

Sl No.	Property	Value
(1)	(2)	(3)
i)	Molecular weight	170
ii)	Boiling point at 0.101 3 MPa (Absolute)	– 16.4°C
iii)	Freezing point	< 131.1°C
iv)	Vapour pressure at 20°C	0.391 MPa
v)	Specific volume of superheated vapour at 1.013 bar and 20°C (m^3/kg)	0.137 3
vi)	Critical temperature	101.7°C
vii)	Critical pressure	2.912 MPa
viii)	Critical volume	274 cm^3/mol
ix)	Critical density	621 kg/m^3
x)	Liquid density at 20°C	1 407 kg/m^3
xi)	Saturated vapour density at 20°C	31.176 kg/m^3

4.7 Toxicological information for HFC 227ea gas is shown in Table 4.

Table 4 Toxicological Information for HFC 227ea Gas

Sl No.	Property	Value
(1)	(2)	(3)
i)	No observed adverse effect level (NOAEL)	9 percent
ii)	Lowest observed adverse effect level (LOAEL)	10.5 percent
iii)	LC_{50}	> 80

4.8 Container Characteristics

The maximum fill density, container-working pressure of the HFC 227ea cylinders shall not exceed the values provided in Table 5 for systems operating at 2.5 MPa and 4.2 MPa respectively.

Table 5 2.5 MPa and 4.2 MPa Storage Container Characteristics for HFC 227ea

(*Clause* 4.8)

Sl No.	Property	Value	
		2.5 MPa	4.2 MPa
(1)	(2)	(3)	(4)
i)	Maximum fill density	1.15 kg/m^2	1.15 kg/m^2
ii)	Maximum container working pressure at 50°C	3.4 MPa	5.3 MPa
	Superpressurization at 21°C	2.5 MPa	4.2 MPa

NOTES

1 For further data on pressure/temperature relationship, Fig. 1 and Fig. 2 should be referred.

2 Exceeding the maximum fill density may result in the container becoming 'liquid full'. With the result that an extremely high rise in pressure occurs with small increases in temperature that could adversely affect the integrity of the container assembly.

4.9 Superpressurized Nitrogen

To allow faster flow through piping systems, the natural pressure of HFC 227ea is often supplemented with dry nitrogen. Commonly used pressures are respectively 2.5 MPa and 4.2 MPa measured at 20°C. The respective vapour pressures of HFC 227ea as well as dry nitrogen vary with temperature. Nitrogen is soluble in HFC 227ea. Thus when a storage cylinder is pressurized with nitrogen, some dissolves in the liquid HFC 227ea and the rest remains in the vapour phase and combines with the vapour pressure of HFC 227ea to produce the pressure necessary to propel the HFC 227ea through the pipeline. Details are given in Table 6 (*see also* Fig. 1 and Fig. 2).

Table 6 Nitrogen Pre-pressurization for HFC 227ea Containers at 20°C

Sl No.	Fill Density kg/m^3 (kg/litre)	Final Pressure 4.2 MPa Systems	Final Pressure 2.5 MPa Systems
(1)	(2)	(3)	(4)
i)	900 (0.9)	29.5	17.6
ii)	800 (0.8)	30.8	18.4
iii)	700 (0.7)	32.1	19.2
iv)	600 (0.6)	33.4	20.00
v)	500 (0.5)	34.8	20.80

5 SAFETY OF PERSONNEL

5.1 In addition to the provisions specified under IS 15493, the following requirements shall also apply:

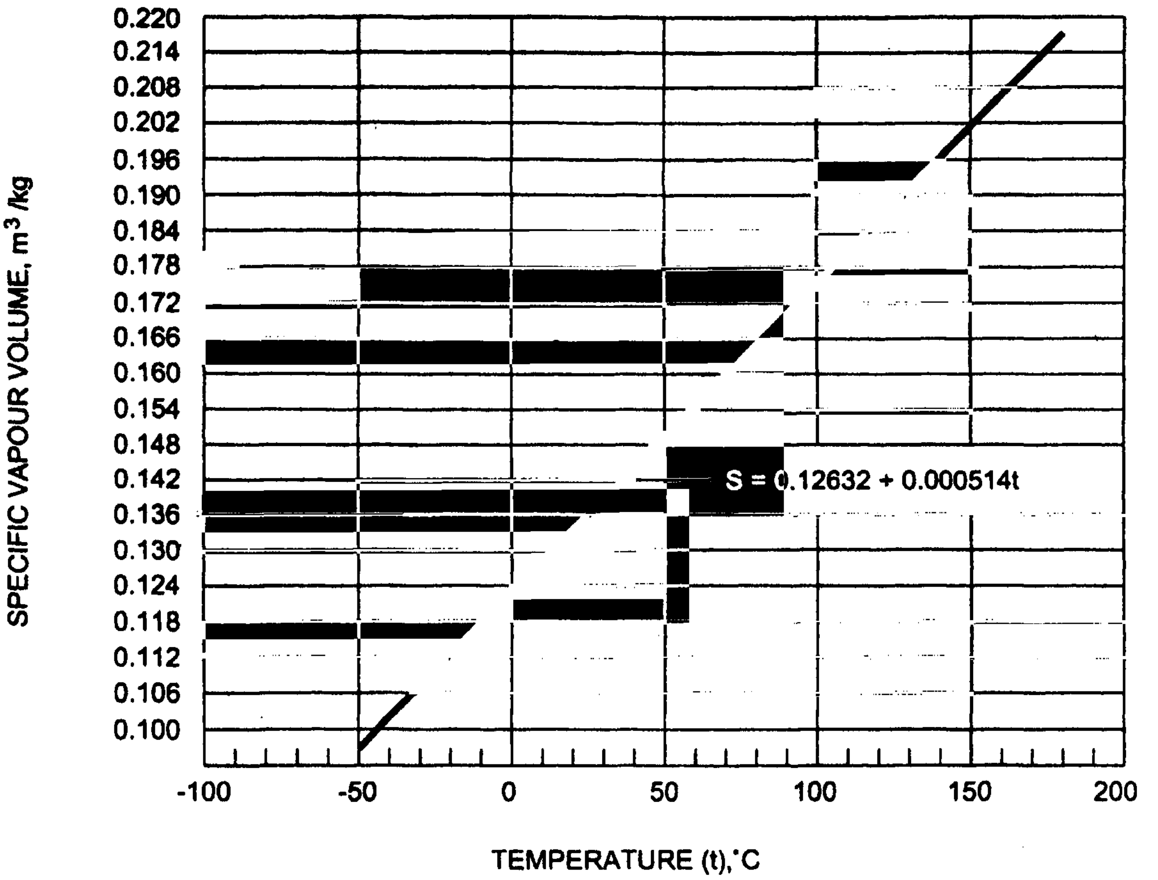

FIG. 1 SPECIFIC VAPOUR VOLUME OF SUPERHEATED HFC 227ea VAPOUR AT 100 kPa ABSOLUTE

a) Any hazard to personnel created by the discharge of HFC227ea shall be given due consideration in the design of the system. Potential hazard can arise from the following:
   1) Extinguishant itself,
   2) Combustion products of the fire, and
   3) Breakdown products of the extinguishant resulting from exposure to fire.
b) In areas, where there is a likelihood of significant difference between gross and net volumes of the enclosure, utmost care shall be exercised in proper system design to ensure that maximum concentrations as detailed in **5.1**(c) are not exceeded.
c) Where design concentration exceeds the LOAEL, HFC 227ea shall be used for total flooding only in normally unoccupied areas. For minimum safety requirements *see* **5** of IS 15493.
d) Safety limits and also minimum safety precautions that are associated with the use of HFC 227ea are as shown in the Tables 7 and 8.

5.2 Miscellaneous Hazards

Some of the additional hazards are as given below:

a) *Cold temperatures* — Direct contact with the vapourizing liquid being discharged from a HFC 227ea system will have a strong chilling effect on objects and can cause frostbite burns to the skin. The liquid phase vapourizes rapidly when mixed with air and thus limits the hazard to immediate vicinity of the discharge point.
b) *Visibility* — Discharge of HFC 227ea may create a light mist resulting from condensation of moisture in the air. However, the mist rarely persists after the discharge is completed. Thus little hazard is created from the standpoint of reduced visibility. Once HFC 227ea is discharged into an enclosure, its presence is easy to detect through the normal senses in concentrations above about 3 percent.
c) *Uneven distribution* — In total flooding systems, the high density of HFC 227ea vapour requires the use of discharge

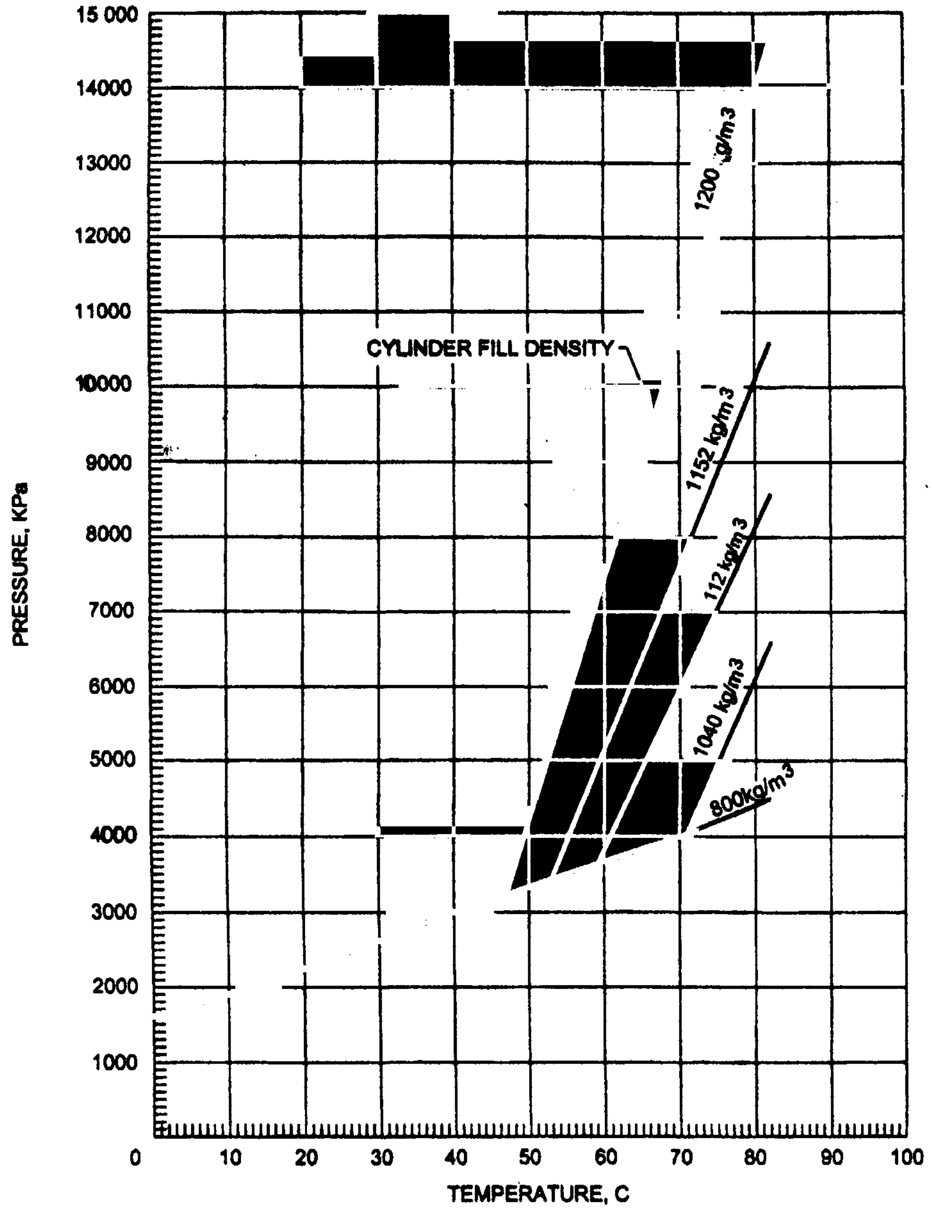

FIG. 2 TEMPERATURE/PRESSURE VARIATIONS FOR HFC 227ea STORAGE CONTAINERS

nozzles that will achieve a well-mixed atmosphere in order to prevent local pockets of higher concentration. HFC 227ea air mixtures are also more dense than air and will drift and accumulate in low spaces, such as cellars, pits and floor voids, and may be difficult to ventilate effectively.

5.3 Where egress takes longer than 30 s but less than a minute, HFC 227ea agent shall not be used in a concentration exceeding its LOAEL, that is, 10.5 percent.

5.4 HFC 227ea concentrations exceeding its LOAEL, that is, 10.5 percent are permitted only in areas normally not occupied by personnel.

6 ENCLOSURE STRENGTH AND VENTING FACILITIES

Venting may be provided at levels as high as possible in the enclosure. Strength and allowable pressures for average enclosures may be in conformity with the following guidelines. The building requirements for the type of enclosure and free venting required can also be calculated from the relevant specifications.

7 EXTINGUISHING AGENT SUPPLY

7.1 Quantity

a) The amount of the HFC 227ea in the system shall be at least sufficient for the largest

Table 7 Minimum Safety Precautions for HFC 227ea

[*Clause* 5.1(d)]

Sl No.	HFC 227ea Design Concentration, Percent by Volume	Requirements			
		Inhibit Switch and Time Delay	Egress in 30 s Maximum	Safety Interlock	Lock-off Valve
(1)	(2)	(3)	(4)	(5)	(6)
i)	Below the NOAEL 9	√	Not required	Not required	Not required
ii)	Above the LOAEL 10.5	√	Not applicable[1] (*see* **4.5**)	√	√

[1] Injected concentration levels above LOAEL are not permitted in occupied area and question of egress does not arise.

Table 8 Minimum Safety Limits of HFC 227ea

[*Clause* 5.1(d)]

Sl No.	Property	Value
(1)	(2)	(3)
i)	No observed adverse effect level (NOAEL)	9 percent by volume
ii)	Lowest observed adverse effect level (LOAEL)	10.5 percent by volume
iii)	Lethal concentration LC_{50}	> 80

single hazard protected or group of communicating hazards that are to be protected simultaneously.

b) Where required, the reserve quantity shall be as many multiples of the main supply as the appropriate authority considers necessary. Normally, 100 percent of the largest one standby supply is recommended.

c) The quantity of the HFC 227ea required shall be further calculated to compensate for any special conditions, such as unclosable openings, forced ventilation, the free volume of air receivers that may discharge into the risk, altitude (substantially above or below sea level) or any other causes for the extinguishant loss.

7.2 Total Flooding Quantity

a) The amount of HFC 227ea required to achieve the design concentration shall be calculated from the following equations and this value shall need further adjustment as stated in **7.1**(c).

$$M = \frac{V \times C}{S(100 - C)}$$

where

M = total flooding quantity, kg;

C = design concentration, percent by volume;

V = net volume of the hazard, m^3;

S = $K_1 + K_2(T)$, where K_1 and K_2 are constants specific to the agent used and T is minimum temperature inside enclosure; and

V_S = specific volume of superheated HFC 227ea agent at 21°C, m^3/kg.

Specific volume constants for the HFC 227ea gas are $K_1 = 0.1269$ and $K_2 = 0.0005$. It may also be noted that this equation provides an allowance for the normal leakage from a tight enclosure to accomplish equalization of pressure.

b) The agent requirement per unit volume of protected space can also be calculated by using Table 9 for various levels of concentration corresponding to the temperature within the protected enclosure. (Flooding Factor obtained from Table 9, that is, temperature of the enclosure *versus* gas concentration, multiplied by net volume of the enclosure.)

NOTE — Quantity of the agent shall be the highest of the values calculated from the provisions contained in 7.2(a) and 7.2(b).

7.3 Enclosure Volumes

The net enclosure volumes are calculated using the following equations:

a) $V_{Max} = V_g - V_s$

b) $V_{Min} = V_{Max} - V_o$

where

V_{Max} = maximum net volume of the enclosure, m^3;

V_g = gross volume of enclosure, m^3;

V_s = volume of the structural/similar permanent objects in the enclosure that gas can not permeate, m^3;

V_{Min} = minimum net volume of enclosure considering the

Table 9 HFC 227ea Total Flooding Quantity of Protected Volume M/V (kg/m³)

[*Clause* 7.2(b)]

Sl No.	Temperature °C	Specific Vapour Volume, m³/kg	Design Concentration of HFC 227ea C (Percent by Volume)						
			6	7	8	9	10	11	12
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	– 10	0.121 8	0.524	0.618	0.714	0.812	0.912	1.015	1.120
ii)	– 5	0.124 3	0.513	0.605	0.699	0.795	0.894	0.994	1.097
iii)	0	0.126 9	0.503	0.593	0.685	0.779	0.876	0.974	1.075
iv)	5	0.129 5	0.493	0.581	0.672	0.764	0.858	0.955	1.053
v)	10	0.132 0	0.483	0.570	0.659	0.749	0.842	0.936	1.033
vi)	15	0.134 6	0.474	0.559	0.646	0.735	0.826	0.918	1.013
vii)	20	0.137 2	0.465	0.549	0.634	0.721	0.810	0.901	0.994
viii)	25	0.139 7	0.457	0.539	0.622	0.708	0.795	0.885	0.976
ix)	30	0.142 3	0.449	0.529	0.611	0.695	0.781	0.869	0.958
x)	35	0.144 9	0.441	0.520	0.600	0.683	0.767	0.853	0.941
xi)	40	0.147 4	0.433	0.511	0.590	0.671	0.754	0.838	0.925
xii)	45	0.150 0	0.426	0.502	0.580	0.659	0.741	0.824	0.909
xiii)	50	0.152 6	0.418	0.493	0.570	0.648	0.728	0.810	0.894
xiv)	55	0.155 1	0.411	0.485	0.561	0.638	0.716	0.797	0.879
xv)	60	0.157 7	0.405	0.477	0.551	0.627	0.705	0.784	0.865

maximum anticipated volume of the occupancy related to the objects in the enclosure, m³; and

V_o = volume of the occupancy related objects in the enclosure that gas can not permeate, for example, furniture fittings, etc, m³. (This value shall be ignored if the volume is less than 25 percent of the maximum net volume V_{Max}.)

8 DESIGN CONCENTRATION

a) Determination of design concentration of HFC 227ea shall include consideration of the type of combustibles involved, the conditions under which it normally exists in the enclosure, and any special conditions in the enclosure. The HFC 227ea system shall be capable of establishing uniform design concentration throughout the protected volume.

b) The distribution system for applying HFC 227ea to enclosed fire hazards shall be designed with due consideration of the materials involved, the type of fire expected and the nature of the enclosure, any one of which may affect the discharge times and rates of application.

c) The minimum design concentration of HFC 227ea for involving surface Class A fires, and also fires involving flammable liquids and gases shall be as follows:

1) The minimum design concentration of the HFC 227ea agent for Class A surface fire hazards shall be the extinguishing concentration with a loading of 20 percent as a safety factor of 1.2.

2) The minimum design concentration of the HFC 227ea agent for Class B fuel hazards shall be the extinguishing concentration with a loading of 30 percent as a safety factor of 1.3 (*see* Table 10 and Table 11, which includes 20 percent loading).

d) *Requirements for flame extinguishment*:

1) The design concentration shall be as shown in Table 11 for the fuel. Where range of separate fuels is present, the design concentration shall be as shown in Table 11 for the fuel requiring the greatest concentration.

2) For other fuels of Class B not listed in the Table 11, tests shall be conducted in independent recognized laboratories for the determination of extinguishing concentration. This value as determined shall be loaded by a safety

factor of 30 percent. In no case, shall the design concentration be less than 7.5 percent or such higher figure, determined by test as indicated above.

e) *Requirements for inerting*:

1) Minimum concentration requirements for inerting atmospheres within the enclosure involving flammable liquids and gases shall be as shown in Table12. Where range of separate fuels is present, the inerting concentration shall be as shown in Table 12 for the fuel requiring the greatest concentration.

2) For other fuels not listed in Table 12, tests shall be conducted in independent recognized laboratories for the determination of inerting concentration. This value as determined from Table 12 shall be loaded by a safety factor of 10 percent. In no case, shall the inerting concentration be less than 7.5 percent or such higher figure, determined by test as indicated above.

f) Lastly, it is required to adjust the number of HFC 227ea agent containers, where necessary, by compensating for ambient pressure change due to location elevation as per 8(g) and round off the number as before. The equation in such cases shall be as follows:

$N_1 = N \times$ Atmospheric correction factor

where

N_1 = adjusted number of containers, and

N = initial number of containers.

g) *Atmospheric correction factors*:

It shall be necessary to adjust the actual HFC 227ea agent quantity for altitude effects. Depending upon the altitude, atmospheric correction factor shall be applied as per the Table 13. The adjusted HFC 227ea agent quantity is determined by multiplying the number of HFC 227ea containers by the ratio of average ambient enclosure pressure to standard sea level pressure.

9 POST DISCHARGE SCENARIO

The HFC 227ea system, when tested for discharge test as per Annex B, shall be in accordance with the following requirements:

a) Within 1 min of commencement of discharge, the concentrations at not more than 1 m above the floor of the enclosure or at the top of the highest hazard shall not vary from the design concentration by more than one percent by volume.

b) At 10 min of the discharge or other period (as required, if necessary), the concentrations at the levels given in 8(a) shall be not less than 80 percent of the design concentration (Retention time).

Table 10 Minimum HFC 227ea Design Concentration for Flame Extinguishment (In Air at 0.1 MPa and at 20°C)

[*Clause* 8(c) *and* (d)]

Sl No.	Material	Percent by Volume	Weight kg/m^3
(1)	(2)	(3)	(4)
i)	Minimum (including surface Class A hazards) combustible solids	7.0	0.6
ii)	Ethanol	7.6	0.419
iii)	Methane	8.0	0.360
iv)	Methanol	9.9	0.707
v)	*n*-Heptane	8.6	0.360
vi)	Propane	8.6	0.360

10 APPLICATION RATE, DURATION OF DISCHARGE AND DISCHARGE TIME

10.1 Design Application Rate

The design application rate shall be based on the quantity of HFC 227ea (*M*) as per 7 and the duration of discharge required under **10.2**.

10.2 Duration of HFC 227ea Discharge

The minimum theoretical concentration shall be achieved within 10 s and the actual injected concentration [that is the above plus a suitable safety factor adjusted for rounding off container] shall be achieved within two min.

10.3 Discharge Time for the HFC 227ea Gas

The discharge time shall be the time for actuation of the first HFC 227ea container valve to the achievement of the required design concentration or the discharge time is the interval from the first appearance of liquid at the nozzle to the time when the discharge becomes predominantly gaseous, recognized by a change in the appearance and sound of the discharge as follows:

a) The discharge time period is defined as the time required to discharge from the nozzles 90 percent of the agent mass at 21°C, necessary to achieve the minimum design concentration based on a 20 percent safety factor for flame extinguishment.

Table 11 HFC 227ea Flame Extinguishing Design Concentrations (Cup Burner)

[*Clause* 8(c)]

Sl No.	Material	Percent by Volume	Sl No.	Material	Percent by Volume
(1)	(2)	(3)	(1)	(2)	(3)
1.	Methyl acetate	8.60	45.	Cyclohexane	8.60
2.	Vinyl acetate	10.00	46.	Decahydronaphthalene	8.60
3.	Acetic acid (Glacial)	8.60	47.	Decalin	8.60
4.	Acetonitrile	8.60	48.	Diesel fuel 250	8.60
5.	Aceto Nitryl	8.60	49.	Diethyl ether	8.60
6.	Acetyl acetone	8.60	50.	I, I-Drifluoroethane	8.60
7.	Acetyl acetylene	8.60	51.	Dimethyl ether	14.50
8.	Acetyl ester	8.60	52.	*n, n*-Dimenthylformamide	10.40
9.	Acetylene	17.80	53.	Dioxane	12.70
10.	Acetic anhydride	8.60	54.	202 Dimethylpropanedo	8.60
11.	Acrylic acid	9.10	55.	Dowtherm A	8.60
12.	Acrylic alcohol	10.00	56.	Energol HLP-65	8.60
13.	Acrylo nirile	9.30	57.	Energol OEM-30	8.60
14.	Alcohol comm denatured	9.80	58.	Epichlorohydrin	11.20
15.	Ethyl alcohol	9.80	59.	Ethane	10.32
16.	Methyl alcohol	15.48	60.	Ethyl acetate	8.60
17.	*Iso*-Propyl alcohol	9.50	61.	Ethyl ether	8.60
18.	*n*-Propyl alcohol	9.50	62.	Wax	8.60
19.	Amyl acetate	8.60	63.	Surface type Class A fires	8.60
20.	*Iso*-Amyl acetate	8.60	64.	Ethyl benzene	8.6
21.	Acroleine	17.00	65.	Ethyl chloride	8.60
22.	Amylic alcohol	10.00	66.	Ethyl formiatic	9.80
23.	Auryl acetate	8.60	67.	Ethylene glycol	11.70
24.	Avgas	8.60	68.	Ethylene oxide	20.30
25.	Avtag	8.60	69.	Butyl formate	9.30
26.	Avtur	8.60	70.	Formic acid	8.60
27.	Benzol	9.20	71.	Fuel oil — JP4	8.60
28.	Benzyl alcohol	9.80	72.	Fuel oil — JP5	8.60
29.	Bunker C	8.60	73.	Gasoline (98 Octane)	8.60
30.	2-Butanone	8.80	74.	Gasoline (94 Octane)	8.60
31.	Butyraldehyde	10.40	75.	Butyl glycol	8.60
32.	Butylene oxide	13.30	76.	Ethyl benzene	8.60
33.	1, 3-Butadiene	9.30	77.	Methyl glycol	10.35
34.	*i*-Butane	8.60	78.	Gas oil	8.60
35.	*n*-Butane	8.60	79.	*i*-Hexanol	9.80
36.	*i*-Butanol	8.60	80.	*n*-Hexanol	8.90
37.	Butanol	8.60	81.	Hydraulic jack oil	8.60
38.	*i*-Butene	8.60	82.	Hydrogen	48.16
39.	Butyl acetate	8.60	83.	Jet A	8.60
40.	Butyl alcohol	9.50	84.	Kerosene	8.60
41.	Carbon disulfide	8.60	85.	Methyl isobutyl ketone	8.60
42.	Carbon monoxide	8.60	86.	Methylated spirits	9.50
43.	Chlorobenzene	8.60	87.	Methyl amine	12.00
44.	Cyclopentane	8.60	88.	Methyl benzoate	8.60

Table 11 *(Concluded)*

Sl No.	Material	Percent by Volume	Sl No.	Material	Percent by Volume
(1)	(2)	(3)	(1)	(2)	(3)
89.	Methyl ether ketone	8.60	108.	Propalactene	
90.	Methyl formiate	10.00	109.	*n*-Propanol	9.10
91.	Methyl methacrylate	12.80	110.	*Iso*-Propyl amine	8.60
92.	Naptha	13.80	111.	*Iso*-Propyl nitrate	17.70
93.	Natural gas	10.30	112.	*Iso*-Propyl oxide	8.60
94.	Navy distillate	8.60	113.	Propylene	8.90
95.	Nitromethane	15.80	114.	Propylene oxide	22.20
96.	Octane	8.60	115.	Pyridine	8.60
97.	Cyclo-Pentane	8.60	116.	Shell thermia	8.60
98.	*Iso*-Pentane	8.60	117.	Stoddart solvent	8.60
99.	Neo-Pentane	8.60	118.	Styrene	8.60
100.	Nor-Pentane	8.60	119.	Styrolene	8.60
101.	Petroleum ether	8.60	120.	Sulphur	8.60
102.	Polyester	8.60	121.	Tetrahydrofuran	56.70
103.	Polyether	8.60	122.	Transformer oil	9.80
104.	Polyethylene	8.60	123.	Triethylamine	8.60
105.	Polystyrene	8.60	124.	2-2-5 Trimethylthexane	9.46
106.	Polyurethane	8.60	125.	White spirit	9.80
107.	Polyvinyl chloride	8.60	126.	Zinc octoate	9.10

Table 12 HFC 227ea Design Concentration for Inerting

[*Clause* 8(e)]

Sl No.	Material	Percent by Volume
(1)	(2)	(3)
i)	Acetone	8.5
ii)	Benzene	12.5
iii)	Methane	8.8
iv)	*n*-Heptane	8.6
v)	Propane	12.8
vi)	Methyl ethyl ketone	15.0

b) The discharge time required to achieve 95 percent of the minimum design concentration for flame extinguishment based on a 20 percent safety factor shall not exceed 10 s.

c) Flow calculations performed in accordance with **12**, or in accordance with the approved pre-engineered systems, shall be used to demonstrate the discharge time requirements stated above.

11 STORAGE CONTAINERS

The HFC 227ea storage containers conforming to IS 7285 shall comply with the following in addition to various requirements contained in IS 15493:

Table 13 Atmospheric Correction Factors

[*Clause* 8(g)]

Sl No.	Equivalent Altitude m	Enclosure Pressure mm Hg	Atmospheric Correction Factor
(1)	(2)	(3)	(4)
i)	– 920	840	1.11
ii)	– 610	812	1.07
iii)	– 300	787	1.04
iv)	0	760	1.00
v)	300	733	0.96
vi)	610	705	0.93
vii)	910	678.9	0.89
viii)	1 220	650	0.86
ix)	1 520	622	0.82
x)	1 830	596	0.78
xi)	2 130	570	0.75
xii)	2 440	550	0.72
xiii)	2 740	528	0.69
xiv)	3 050	505	0.66

a) The containers used in HFC 227ea systems shall be seamless cylinders designed, fabricated, inspected and certified in accordance with the requirements of Chief Controller of Explosives, Nagpur.

b) The design pressure shall be suitable for the maximum pressure developed at 65°C or at the maximum controlled temperature limit.

c) The containers shall be charged to a filling ratio (fill density) not greater than 1 150 kg/m^3 (1.15 kg/l) and not less than 500 kg/m^3 (0.5 kg/l).

d) The containers shall be superpressurized with nitrogen (moisture content not greater than 0.006 percent by volume) to a total pressure of either 2.5 MPa ± 5 percent or at 4.2 MPa ± 5 percent measured at 21 ± 1°C.

e) The storage containers shall have reliable means of indicating their pressure. The storage containers shall have reliable means of indicating the variation of container pressure with temperature. A pressure/temperature chart (*see* Fig. 1 and Fig. 2) attached to the container, is acceptable

12 DISTRIBUTION SYSTEM

The HFC 227ea distribution system shall comply with the following in addition to various requirements contained in IS 15493.

12.1 Piping Network

a) The piping shall withstand the maximum expected pressure at the maximum storage temperature, as follows:

1) 2.5 MPa systems : 4.19 MPa at 55°C
2) 4.2 MPa systems : 6.58 MPa at 55°C

b) Carbon steel pipes and fittings shall be galvanized inside and outside or otherwise suitably protected against corrosion. Stainless steel pipes and fittings may be used without corrosion protection.

c) The piping shall withstand the maximum developed pressure at 55°C and shall be in accordance with IS 15493.

NOTE — Stainless steel pipes may be used in all applications subject to appropriate design strength calculations.

12.2 Piping Fittings

a) Pipe fittings shall comply with the requirements given in IS 15493.

b) Fittings shall be selected according to the wall thickness or schedule number of the pipe to which they are intended to be fitted.

12.3 Pipe Sizing

Pipe sizing is a complex issue, particularly in view of the two-phase flow within the pipe lines. Too small a bore results in excessive pressure losses while too large a bore reduces the liquid flow velocity. This also may result in excess pressure drops and lower flow rates. Table 14 may be used as a guide to estimate pipe sizes. The sizes can be checked using an approved computer flow calculation programme.

Table 14 Pipe Sizes *versus* Flow Rate
(Informative)

Sl No.	Nominal Pipe Size mm	Nominal Design Flow Rate, kg	
		Minimum	Maximum
(1)	(2)	(3)	(4)
i)	10	1.2	4.4
ii)	15	2.2	6.6
iii)	20	4.4	12.1
iv)	25	7.8	18.7
v)	32	13.3	27.5
vi)	40	19.9	44.1
vii)	50	31.0	66.1
viii)	65	44.1	121.3
ix)	80	66.2	198.5
x)	100	121.3	275.5
xi)	125	198.5	440.9
xii)	150	254.6	661.3

12.4 Nozzle Placement

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

b) Selecting the number of nozzles in a system shall take into account, the shape of the enclosure (Area and volume), shape of the void (Raised floor, suspended ceiling). Installed equipment in the enclosure/void (Chimney effect), allowed pressure at the restrictor, (Pipe quality), obstructions, which may affect the distribution of the discharged agent and architectural considerations.

c) Nozzles shall be selected and located to protect an area less than its area of coverage. The area of coverage to the type of nozzle shall be so listed for the purpose.

d) In hazards having suspended ceiling, consideration shall be given for having nozzles installed in the ceiling void

(simultaneous discharge) in order to equalize the pressure during discharge, thus reducing the risk of unnecessary damaging ceiling tiles, etc.

e) In hazards having raised floor (not gas-tight) consideration shall be given for having nozzles installed in the floor void (simultaneous discharge) in order to equalize the pressure and obtain extinguishing concentration below the floor.

f) In hazards having suspended ceiling, nozzles for protecting rooms void shall be installed in such a way that the jets from the nozzles do not damage the ceiling plated excessively during discharge, that is, the nozzles to be positioned vertically with the discharge holes free of the ceiling tiles and/or Escutcheon plates. For light weight ceiling tiles, it may be recommended to securely anchor tiles for a minimum of 1.5 m from each discharge nozzle.

g) Maximum nozzle height above floor level for a single row of nozzles is 3.5 m. Where ceiling height (of the protected enclosure) exceeds 3.5 m, an additional row of nozzles shall be provided for uniform and faster distribution of the agent within the enclosure.

h) Minimum nozzle height above the floor void level of the hazard shall be adequately provided.

j) The maximum distance between nozzles should not exceed 6 m and the maximum distance to wall/partition should not exceed 3 m.

k) In case of enclosures having no false ceiling, nozzles can be located on the ceiling anywhere within 0.5 to 5 m from the walls. In case of enclosures having false ceilings, deflector shields shall be used with each nozzle and also nozzles shall be so located (with an anticipation of dislodgement of false ceiling materials or any movable objects in the path of discharge) to prevent any damage thereto.

m) Nozzles shall be provided in all the concealed spaces, floor voids, ceiling voids, etc, besides the main area within the protected enclosure.

13 HYDRAULICS OF THE SYSTEM

13.1 General

a) An approved hydraulic calculation method shall be employed to predict pipe sizes, nozzle pressure, agent flow rate, discharge per nozzle and the discharge time.

b) The various parameters as stated below shall be considered to determine the following minimum limits of accuracy:

   1) 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 of actual prediction.

   2) The discharge time predicted by the flow calculation method should agree with the actual discharge time from each nozzle in the system.

   3) The accuracy of the 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.

   4) 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 from which nozzle's discharge is to protect.

13.2 HFC 227ea Agent in Pipe Work

The HFC 227ea flows through the distribution system in both liquid and vapour phase. As the liquid phase flows through the distribution system the pressure continues to drop, causing the liquid to boil. The volume of the vapour phase increases with the decreasing pressure and hence the density of the mixture drops. To maintain a constant flow rate, the speed through the distribution system must continuously increase down the pipe work. The pressure drop for a given flow rate is not linear, as it is with water, but is variable along the pipe.

13.3 Density of HFC 227ea in Distribution System

Using the thermodynamic properties of the HFC 227ea, including the nitrogen used for super-pressurization, the density of the two-phase mixture in the distribution system can be calculated. The density of the HFC 227ea leaving the storage container varies over the course of the discharge. The density is lowest at the start of discharge and increases until the last of the liquid leaves the container.

13.4 Temperature

The drop in container pressure as the HFC 227ea flows from the container causes remaining HFC 227ea in the container to cool. As a result, liquid, that is, below ambient temperature is introduced to the distribution system. During a system discharge the temperature of the HFC 227ea leaving the storage container recedes as a function of instantaneous container pressure.

13.5 Initial Vapour Time

At the start of discharge virtually all the liquid phase HFC 227ea entering the distribution system is vapourized before it reaches the nozzles, due to heating by the pipe work and the initial low pressure in the system. The initial vapourization limits the flow of HFC 227ea through the distribution system because the mass flow of vapour is much lower than that of liquid.

13.6 Liquid Flow

There is a significant delay between the opening of the discharge valve and the first appearance of liquid at the nozzles. Some of the delay is due to the flow restriction presented by the container and distribution system, however much of delay is due to the initial vapour phase flow of the HFC 227ea.

13.7 Phase Separation

The flow of HFC 227ea in the distribution system is a two-phase flow (containing both liquid and vapour). In a properly sized distribution system the flow will be highly turbulent throughout the system and the two phases will mix homogeneously. If the pipes are too big the phases may tend to separate, which can cause a variety of flow problems and can in some cases result in a reduced flow rate.

13.8 Average Pressure Conditions

Pressure at the nozzle is not constant throughout discharge because the pressure in the storage container is constantly decreasing. If one were to attempt manual calculation it would be desirable to use an average pressure condition. It is difficult to arrive at an average as the volume of piping has a marked effect on the average nozzle (pressure, density and velocity conditions), all of which have a marked effect on discharge quantities and times.

13.9 Average Nozzle Pressure

The nozzle pressure used for calculations is the pressure when half the liquid phase has been discharged from the nozzle. The timing of this is used to calculate an average pressure drop in the distribution system. To calculate the correct storage container pressure, allowance must be made for the amount of liquid in the piping system.

13.10 Percent in Distribution System

The points outlined above are taken into consideration to calculate the average container pressure during discharge. Figure 3 shows how the ratio of the pipe volume to the volume of HFC 227ea supply expanded under flowing conditions varies with average container pressure. The former quantity shall be referred to as percent-in-the-pipe.

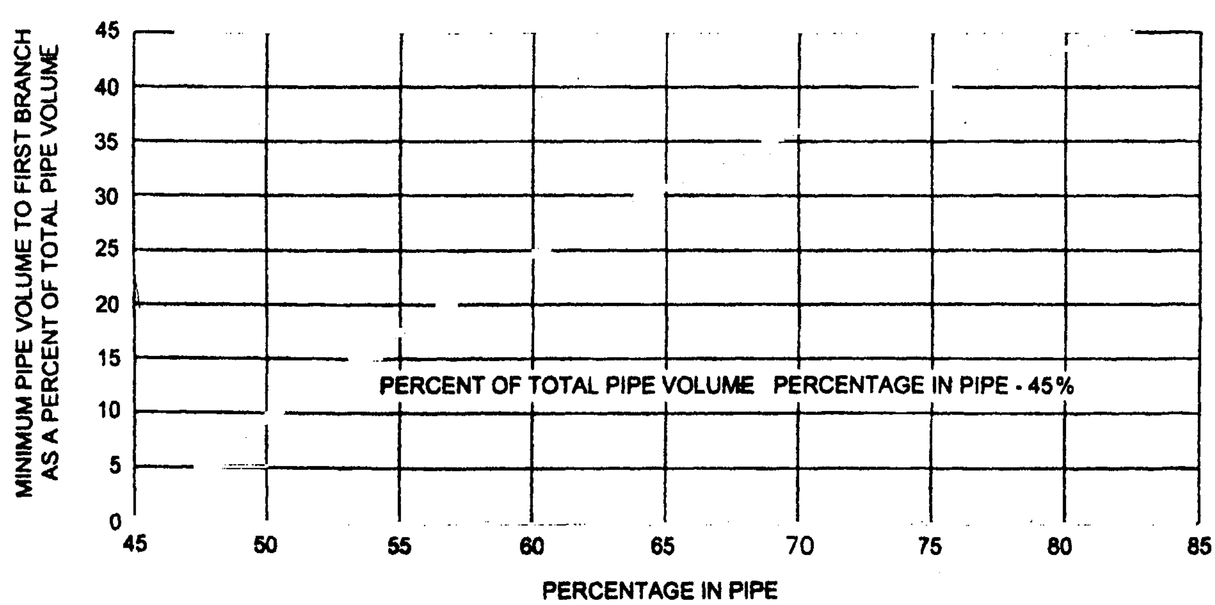

FIG. 3 PERCENT IN HFC 227ea IN PIPE

13.11 Engineered and Pre-engineered Systems

a) *General* — HFC 227ea is suitable for use in both engineered (central storage) systems and pre-engineered (modular or packaged) systems, as described in **13.3**(b) and **13.3**(c).

b) *Engineered* — An engineered system uses large storage containers installed in a central location. The containers are manifold together and a single pipe feeds the nozzle located inside the hazard area. Predicting pipe pressure losses and designing nozzle orifice sizes require complex flow calculations for both HFC 227ea and nitrogen phases, which takes into account the minimum and maximum volumes or the enclosure.

c) *Pre-engineered* — A pre-engineered system involves a single container with a maximum of two nozzles and a small piping network. This system can be multiplied to cover larger volume areas. The larger area is viewed as a number of smaller areas each protected by a single modular unit.

14 COMMISSIONING AND ACCEPTANCE TESTING

14.1 Criteria for Acceptance

The completed HFC 227ea total flooding system shall be commissioned in accordance with IS 15493.

14.2 Cross-check various observed parameters with the respective operating clause to ensure conformity.

14.3 Recommissioning

Restore all systems to a fully operational status.

14.4 Reporting

The following shall be reported:

a) Information identifying the system shall include:
   1) Installation, designer and contractor;
   2) Enclosure identifications;
   3) Enclosure temperature prior to discharge;
   4) Oxygen and carbon dioxide residual concentrations; and
   5) Position of sampling points.

b) Date and time of test.

c) Discharge time.

d) Concentration levels at each sampling point at 1 and 10 min from the commencement of discharge.

e) System deficiencies.

ANNEX A

(*Table* 2)

DETERMINATION OF PURITY OF HFC 227ea

A-1 Percent purity of HFC 227ea is determined by gas chromatograph

A-2 APPARATUS REQUIRED

The following special apparatus is required to determine the percent purity of HFC 227ea:

a) *Gas chromatograph* — Capable of programmed temperature operation and equipped with a Thermal Conductivity Detector (TCD).

b) *Column* — 3.1 m by 5 mm outside diameter (2.6 mm inner diameter) glass tubing, packed with 80-120 mesh Carbopack B or equivalent.

c) *Gas sampling valve* — 10 ml volume or a volume sufficient to achieve proper separation in the specified column.

d) *Sample containers with luer lock fittings* — To connect the sample container with automatic gas valve.

A-3 REAGENTS

A-3.1 The carrier gas shall be chromatographic grade of helium. The column packing shall consist of a standard solution, for example, 3 percent (weight/weight) methyl silicone on 80 - 120 mesh Carbopack B (or equivalent).

A-4 PROCEDURE

A-4.1 Install the column and adjust the temperature of the column oven to 30°C, injection port to 100°C, and detector block to 150°C. The temperature should be programmed to rise 10 to 15°C/min (from an initial temperature of 30°C), to a maximum of 100°C.

A-4.2 Adjust the helium flow to 25 ml/min.

A-4.3 Adjust the detector voltage to 8 V or to a mid-range of the TCD instrument being used and allow the instrument to stabilize.

A-4.4 Evacuate the sampling cylinder completely with no air inside and take the sample from the vapour phase with the help of hose from a given source and connect the sample cylinder to GC and ensure that there is no leakage. Allow the sample to go the chromatograph system after opening the knob to the sample cylinder. Allow the sample to elute for 20 min attenuating as necessary to make the peak heights a convenient size. Under proper instrument settings the HFC 227ea should elute after 5 min.

A-5 CALCULATION

A-5.1 Calculate percent HFC 227ea as follows:

$$\text{Percent HFC 227ea} = \frac{A(CF_3CHFCF_3) \times 100}{A_s}$$

where

$A(CF_3CHFCF_3)$ = area of the HFC 227ea peak, and

A_s = sum of the area of all peaks, excluding nitrogen peak.

A-5.2 The percentage of HFC 227ea shall be determined from the resulting chromatograph by comparison with the standard graph (*see* Fig. 4).

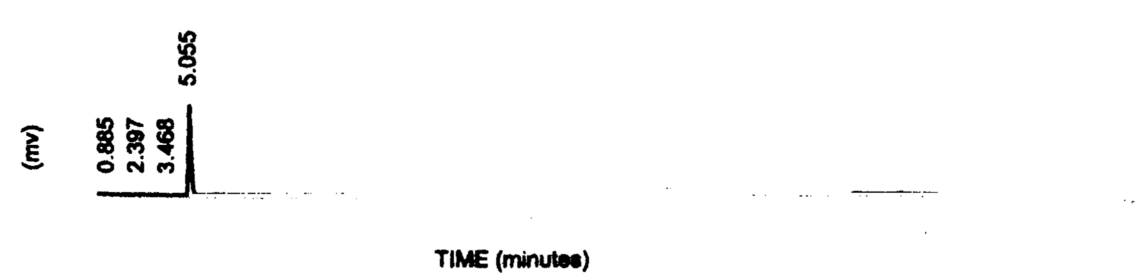

FIG. 4 STANDARD GAS CROTMATOGRAPH OF HFC 227ea

ANNEX B

(*Clause* 9)

DISCHARGE TEST

B-1 Discharge test be limited to only where it is legal requirement otherwise enclosure integrity test be done. This sets out a proceduce to determine compliance of the HFC 227ea total flooding system with the requirements for discharge time, concentration and holding time.

B-2 PRINCIPLE

The system is operated, discharge time is measured and concentration readings are taken at a specified height at nominated periods.

B-2.1 Test Medium

The test medium shall be HFC 227ea gas.

B-2.2 Apparatus

The following apparatus is required:

a) A chart recorder type concentration meter calibrated in strict accordance with the manufacturer's instructions.

b) A suitable time-measuring device.

c) Temperature-measuring equipment.

B-3 PROCEDURE

The procedure shall be as follows:

a) Ensure that the preliminary checks, in accordance with IS 15493 have been completed.

b) Electrically isolate all HFC 227ea systems serving adjacent enclosures.

c) Locate sampling points in the enclosure at the specified heights (*see* **8**). Do not locate sampling points nearer than 200 mm to ceiling unless the combustibles being protected extend within that area, in which case special design considerations may be necessary.

NOTE — If more than one space or compartment is being simultaneously protected, locate a sampling point in each space in accordance with the above criteria. Additional sampling points may be required by the appropriate authority. Where the geometry of the enclosure does not lend itself to sampling in the above manner, take a minimum of three samples at locations agreed upon by the appropriate authority.

d) Set the continuous chart recorder type concentration meter for HFC 227ea and check that meter is calibrated in accordance with the manufacturer's instructions so that it will record concentration levels at each sampling point for 10 min from commencement of discharge.

e) Record temperature in enclosure.

f) Ensure that plant which is capable of affecting system performance, for example, air-handling plant in its normal operating mode.

g) Activate the system and record the discharge time (*see* **8**).

h) Record concentration readings and holding times (*see* **9**).

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