DESIGN MANUAL

HFC-227ea
Extinguishing System
25bar

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1 Introduction

1.1 Scope and purpose of manual

This manual is a comprehensive guide containing all recommendations necessary to design and install the HFC-227ea Gas Extinguishing System.
In this manual “system” refers to the extinguishing equipment and does not include any electrical system which may initiate an agent release.
Furthermore the manual includes some information about HFC-227ea chemical and physical characteristics, and contains design technical specifications and safety requirements.
Working pressure of designed systems is 42 or 25 bar.
Users of this manual are assumed to be competent fire engineers with a basic knowledge of such systems.

1.2 Terminology and Definitions

For the purposes of this manual the following terms and definitions apply:

-A*pproved*: acceptable to a relevant authority.
NOTE in determining the acceptability of installation or procedures, equipment or materials, the authority may base acceptance on compliance with the appropriate standards.

-*Authority*: organisation, office or individual responsible for approving equipment, installation or procedures.

-*Automatic/Manual switch*: means of converting the system from automatic to manual actuation.
NOTE This may be in the form of manual switch on the control panel or other units, or a personnel door interlock. In all cases, this changes the actuation mode of the system from automatic and manual to manual only or vice versa.

-*Extinguishant*: electrically non-conducting gaseous fire extinguishant that does not leave a residue upon evaporation.

-*Extinguishing Concentration*: minimum concentration of extinguishant required to extinguish fire involving particular fuel under defined experimental conditions excluding any safety factor.

-*Engineered system*: system in which the supply of extinguishant stored centrally is discharged through a system of pipe and nozzles in which the size of each section of pipe and nozzle orifice has been calculated in accordance with relevant parts of ISO 14520.

-*Design Concentration*: concentration of extinguishant, including a safety factor, required for system design purpose.

-*Maximum Concentration*: concentration achieved from the actual extinguishant quantity at the maximum ambient temperature in the protected area.

-*Maximum Working Pressure*: equilibrium pressure within a container at the maximum working temperature.

-*Fill density:* mass of extinguishant per unit volume of container.

-*Liquefied gas*: gas or gas mixture (normally a halocarbon) which is liquid at the container pressurization level at room temperature (20 °C).

-*Non Liquefied Gas*: gas or gas mixture which, under service pressure and allowable service temperature conditions, is always present in the gaseous form.

-*Flooding Quantity*: mass or volume of extinguishant required to achieve the design concentration within the protected volume within the specified discharge time.

-*Protected Volume*: volume enclosed by the building elements around the protected enclosure , minus the volume of any permanent impermeable building elements within the enclosure.

-*Hold Time*: period of time during which a concentration of extinguishant greater than the fire extinguishing concentration surround the hazard

-*LOAEL (lowest observed adverse effect level)*: lowest concentration at which an adverse toxicological or physiological effect has been observed.

-*NOAEL (no observed adverse effect level):* highest concentration at which no adverse toxicological or physiological effect has been observed.

-*Normally Unoccupied Area*: area not normally occupied by people but which may entered occasionally for brief periods.

-*Selector Valve*: valve installed in the discharge piping downstream of the extinguishant containers, to direct the extinguishant to the appropriate hazard enclosure.

-*Total Flooding System*: system arranged to discharge extinguishant into an enclosed space to achieve the appropriate design concentration.

1.3 Contacts

Technical data of this manual are given for information only.
Bettati Antincendio S.r.l. ensures that information contained in this manual are careful and disclaims all responsibility about a not correct use of data here displayed.
If you cannot understand any part of this manual, or you have any queries concerning a system, please contact :

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1.4 Standards and Code of practice

Systems that use extinguishing agent HFC-227ea are designed according to these standards:
UNI 10877-9 (Italian Body Standard April 2000);
ISO 14520 part 1 “Gaseous media fire extinguishing systems – Physical properties and system design – Part 1: General requirements” First Edition.
ISO 14520 part 9 “ Gaseous fire extinguishing system physical properties and system design” First Edition.
ISO 14520 part 1 “Gaseous media fire extinguishing systems – Physical properties and system design – Part 1: General requirements” Next Edition.
ISO 14520 part 9 “ Gaseous fire extinguishing system physical properties and system design” First Edition.
2000 Edition NFPA 2001 “Clean agent fire extinguishing system”.

1.5 Approval / Certification of agent

HFC-227ea was approved as an extinguishing gas by :

EPA (Environmental Protection Agency – USA)
UL (Underwriters Laboratories)

2 Use and Limitations of extinguishing agent “HFC-227ea”

2.1 Introduction

The design, installation, service and maintenance of gaseous fire-extinguishing systems “HFC-227ea” shall be performed by competent person in fire extinguishing system technology. Total flooding fire-extinguishing systems are used primarily for protection against hazards that are in enclosures or equipment that, in itself, includes an enclosure to contain the extinguishant. The following are typical of such hazards, but the list is not exhaustive:
Electrical and electronic hazards;
Telecommunications facilities;
Flammable and combustible liquids and gases;
Other high-value assets.

2.2 Extinguishing agent “HFC-227ea” chemical and physical properties.

Heptafluoropropane (HFC-227ea) is the world’s most widely used in-kind replacement for Halon 1301 in total flooding applications. HFC-227ea effectively prevents or extinguishes all major classes of fires and is safe, clean, and electrically nonconductive. Its boiling point is –15,6°C making it useful for total flooding of enclosures at normal ambient temperatures.

HFC-227ea extinguishes fires by both physical and chemical means. Primarily, it raises the total heat capacity of the environment to the point that the atmosphere will not support combustion. In practice, however, extinguishment occurs at concentrations less than the theoretical heat capacity value. This is explained by assuming that the agent also removes the free radicals that serve to maintain the combustion process.

TABLE 2.1 – Chemical and Physical properties.

Property	Units	Value
Molecular mass	—	170
Boiling point at 1,013 bar (absolute)	°C	–16,4
Freezing point	°C	-127
Critical temperature	°C	101,7
Critical pressure	bar abs	29.26
Critical volume	cm^3/mol	274
Critical density	kg/m^3	573
Vapour pressure 20 °C	bar abs	3.90
Liquid density 20 °C	kg/m^3	1410
Saturated vapour density 20 °C	kg/m^3	31,035
Specific volume of superheated vapour at 1,013 bar and 20 °C	m^3/kg	0,1374
Chemical formula Chemical name	CF_3CHFCF_3 Heptafluoropropane	

2.3 Extinguishing Agent “HFC-227ea” applications

HFC-227ea has its greatest benefit when used as a total flooding agent to protect high-value critical equipment requiring a clean (leaves no residue), electrically nonconductive gaseous agent that is safe for people in the event of exposure.

Typical areas that can be protected by an HFC-227ea system are detailed below; the list is by no means exhaustive:

Bank Vaults
Libraries
Rare book stores
Archive Storage Rooms
Electronic Data Processing
Telephone Exchanges
Studios
Communication Centres
Transformer and Switchrooms
Control Rooms
Test Laboratories
Flammable Liquid Stores
Computer and Control Rooms
Tape Stores
Electrical Cabinets
Electrical Switchgear
Telecommunication Equipment

WARNING - HFC-227ea is not suitable for use with materials such as:

Reactive Metals, e.g. sodium, potassium, magnesium, titanium, metal hybrids
Chemicals capable of oxidation without air, e.g. cellulose nitrate, gun powder

2.4 Hazards to personnel (Reference: ISO-14520)

Potential hazards to be considered for individual systems are the following:

Agent Itself

The discharge of gaseous agent systems to extinguish a fire could create a hazard to personnel from the natural form of the agent itself 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.

Noise

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

Cold Temperature

Direct contact with liquefied extinguishants being discharged from a 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 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 vapour.

Turbulence

High-velocity discharge from nozzles could 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.

Physiological Effects of Halocarbon Agents

For halocarbons covered in this annex, the NOAEL and LOAEL are based on the toxicological effect known as cardiac sensitization. Cardiac sensitization occurs when a chemical causes an increased sensitivity of the heart to adrenaline, a naturally occurring substance produced by the body during times of stress, leading to the sudden onset of irregular heart beats and possibly heart attack.

Table 2.2 provides information on the toxicological effects of halocarbon agents covered by this standard. The NOAEL is the highest concentration at which no adverse physiological or toxicological effect has been observed. The LOAEL is the lowest concentration at which an adverse physiological or toxicological effect has been observed.

An appropriate protocol measures the effect in a stepwise manner such that the interval between the LOAEL and NOAEL is sufficiently small to be acceptable to the competent regulatory authority. The EPA includes in its SNAP evaluation this aspect (of the rigour) of the test protocol.

TABLE 2.2 - Toxicity Information for Halocarbon Clean Agents

Agent	LC_{50} or ALC (%)	NOAEL (%)	LOAEL (%)
HFC-227ea	>80	9.0	10.5

NOTE 1 LC50 is the concentration lethal to 50 percent 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 non-observance 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.

2.5 Safe Exposure Guidelines for Halocarbon Agents

Any unnecessary exposure to halocarbon clean agents, even at NOAEL concentrations, and halocarbon decomposition products shall be avoided. The requirements for pre-discharge alarms and time delays are intended to prevent human exposure to agents. The following additional provisions shall apply in order to account for failure of these safeguards:

Halocarbon systems for spaces that are **normally occupied** and designed to concentrations up to the **NOAEL** (see Table 2.2) shall be permitted provided that the maximum exposure time does not exceed five minutes (i.e. escape of all occupants must be achieved within 5 minutes).

Halocarbon systems for spaces that are **normally occupied** and designed to concentrations above the **NOAEL** and up to the **LOAEL** (see Table 2.2 and ISO 14520 Parts 2, 5, 6 and 8 through 14), shall be permitted, given that exposure is limited to no longer than the time specified in Table 2.3 corresponding to the given design concentration.

TABLE 2.3 – Human exposure time

HFC-227ea Concentration		
% v/v	**ppm**	**Human Exposure Time (minutes)**
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 1 Data derived from the EPA-approved and peer-reviewed PBPK model or its equivalent.

NOTE 2 Based on LOAEL of 10.5 percent in dogs.

In spaces that are **not normally occupied** and protected by a halocarbon system designed to concentrations above the **LOAEL** (see Table 2.2), and where personnel could possibly be exposed, exposure times are limited to those given in Table 2.3.

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2.6 Safety precautions for personnel

In areas which are protected by total flooding systems and which are capable of being occupied, the following shall be provided.

a) Time delay devices:

   1) for applications where a discharge delay does not significantly increase the threat from fire to life or property, extinguishing systems shall incorporate a pre-discharge alarm with a time delay sufficient to allow personnel evacuation prior to discharge;

   2) time delay devices shall be used only for personnel evacuation or to prepare the hazard area for discharge.

b) Automatic/manual switch, and lock-off devices where required in accordance with 2.4.

TABLE 2.4 - Minimum Safety Precautions.

Maximum concentration	Time delay device	Automatic/ manual switch	Lock-off device
Up to and including the NOAEL	Required	Not required	Not required
Above the NOAEL and up to the LOAEL	Required	Required	Not required
LOAEL and above	Required	Required	Required
NOTE The intent of this table is to avoid unnecessary exposure of occupants to the discharged extinguishant. Factors such as the time for egress and the risk to the occupants by the fire should be considered when determining the system discharge time delay. Where national standards require other precautions, these should be implemented.			

WARNING – Any change to the enclosure volume , or addition or removal of fixed contents that was not covered in the original design will affect the concentration of extinguishant. In such instances the system shall be recalculated to ensure that the required design concentration is achieved and the maximum concentration is consistent with maximum pipework spans.

NOTE - Although lock-off devices are not always required, they are essential in some situations, particularly for some specific maintenance functions.

c) Exit routes, which shall be kept clear at all times, and emergency lighting and adequate direction signs to minimize travel distances.

d) Outward-swinging self-closing doors which can be opened from the inside, including when locked from the outside.

e) Continuous visual and audible alarms at entrances and designated exits inside the protected area and continuous visual alarms outside the protected area which operate until the protected area has been made safe.

f) Appropriate warning and instructions signs.

g) Where required, pre-discharge alarms within such areas that are distinctive from all other alarm signals, that will operate immediately on commencement of time delay upon detection of the fire.

h) Means for prompt natural or forced-draft ventilation of such areas after any discharge of extinguishant. Forced-draft ventilation will often be necessary. Care shall be taken to completely dissipate hazardous atmospheres and not just move them to other locations.

i) Instructions and drills of all personnel within or in the vicinity of protected areas, including maintenance or construction personnel who may be brought into the area, to ensure their correct actions when the system operates.

In addition to the above requirements, the following are recommended:

— self-contained breathing apparatus should be supplied and personnel trained in its use;

— personnel should not enter the enclosure until it has been verified as being safe to do so.

2.7 Hazard to environment

HFC-227ea is environmentally acceptable with an ODP=0 (Ozone Depletion Potential) as it is shown in Table 2.5.

TABLE 2.5 – Environmental impact

	A.L.T. (years) Atmospheric Life Time	**G.W.P. Global Warming Potential**	**O.D.P. Ozone Depletion Potential**
HFC-227ea	37	2900	0

2.8 Hazard from electrostatic discharge in igniting flammable atmosphere

Care shall be taken discharging extinguishant into potentially explosive atmospheres.
Electrostatic charging of conductors not bonded to earth may occur during the discharge of extinguishant.
These conductors may discharge to other objects with sufficient energy to initiate an explosion.
Pipework shall be adequately bonded and earthed.

3 Basis of "HFC-227ea" Systems Design

This section of the manual will detail the steps necessary to design an HFC-227ea System.
The system designer must do a complete hazard analysis applying the guidelines from ISO-14520 Next Edition and consultation with all the authorities having jurisdiction.
The designer must carefully consider such items as room volume, room integrity, unclosable openings, fuel involved, concentration values, available cylinder storage, nozzle placement, etc.

3.1 Hazard Analysis

The system designer must first determine the hazard type. The hazard generally falls into one of the three following categories, and sometimes a combination thereof. The designer must be aware of the Hazard Type in order to determine the correct design concentration, agent quantity, etc. The three Hazard Types are:

Class B: flammable liquids

Surface Class A: wood, paper, plastic sheet (PMMA, PP, ABS)

Higher Hazard Class A:
cable bundles greater than 100 mm in diameter,
cable trays with a fill density greater than 20 percent of the tray cross-section;
horizontal or vertical stacks of cable trays (closer than 250 mm);
equipment energized during the extinguishment period where the collective power consumption exceeds 5 kW.

3.2 Design Concentration

The following is a guideline to be used in determining the Design Concentration for the hazard(s) being protected. Extinguishing concentration is the minimum concentration of extinguishant required to extinguish fire involving particular fuel under defined experimental conditions excluding any safety factor.
The Design Concentrations listed below are based on the extinguishing concentration value established by ISO-14520 Next Edition standard – Annex C. These values have been multiplied by a Safety Factor (1,3 for ISO-14520) as required by the applicable standard.

TABLE 3.1 - HFC-227ea reference extinguishing and design concentrations ISO-14520-9 First Edition

Fuel	Extinguishment	Minimum design
	%	%
Heptane	6,9	9
Surface class A hazards [a]	5,8	7,5
a See 7.5.1.3 of ISO 14520-1:2000.		

NOTE 1 The heptane value is the greater of the cup burner or room agent concentrations tested in accordance with Annexes B and C
NOTE 2 This Class A surface fire extinguishing concentration is the value achieved when tested on a wood crib in accordance with Annex C
NOTE 3 Extinguishing concentrations were derived using the ISO 14520 Standard cup burner method.

TABLE 3.2 - HFC-227ea reference extinguishing and design concentrations ISO-14520-9 Next Edition

Fuel	Extinguishment %	Minimum design %
Class B		
Heptane (cup burner)	6,7	9,0
Heptane (room test)	6.9	
Surface Class A		
Wood Crib	4.9	
PMMA	6.1	
PP	6.1	7,9
ABS	6.1	
Higher Hazard Class A	See Note 4	8,5

NOTE 1 The extinguishment values for the Class B and the Surface Class A fuels are determined by testing in accordance with Annexes B and C of ISO 14520-1.

NOTE 2 The minimum design concentration for the Class B fuel is the higher value of the heptane cup burner or room test heptane extinguishment concentration multiplied by 1.3.

NOTE 3 The minimum design concentration for Surface Class A fuel is the highest value of the wood crib, PMMA, PP or ABS extinguishment concentrations multiplied by 1.3. In the absence of any of the 4 extinguishment values, the minimum design concentration for Surface Class A shall be that of Higher Hazard Class A.

NOTE 4 The minimum design concentration for Higher Hazard Class A fuels shall be the higher of the Surface Class A or 95% of the Class B minimum design concentration.

NOTE 5 See 7.5.1.3 of ISO 14520-1 for guidance on Class A fuels.

3.3 Required Agent quantity

The first step in designing the HFC-227ea system is to determine the volume of the space(s) being protected. The volume is calculated by multiplying the length x width x height of the space. Sometimes it is necessary to divide the protected space into smaller segments due to the configuration of the space. Each smaller segment is then added together to determine the total volume.

As a general rule, the volume used to calculate the quantity of HFC-227ea required should be based on the empty (gross) volume. Additional considerations include:

The volume taken by solid, non-permeable, and non-removable objects can be deducted from the protected volume

Any volume that is open to the space being protected must be added (i.e. non-dampered ductwork, unclosable openings, etc.)

HFC-227ea quantity per cubic meter of the protected area determination is obtained by the table 3.3.

TABLE 3.3 - HFC-227ea total flooding quantity (SI Units)

Temperature *T*	**Specific vapour volume** *S*	**HFC 227ea mass requirements per unit volume of protected space,** m/V (kg/m³) **Design concentration** (by volume)									
°C	**m³/kg**	**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	0,7967	0,8951	0,9957	1,0985	1,2038	1,3114	1,4216
0	0,1268	0,5034	0,5936	0,6858	0,7800	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	0,9550	1,0537	1,1546	1,2579	1,3636
10	0,1320	0,4834	0,5700	0,6585	0,7490	0,8414	0,9360	1,0327	1,1316	1,2328	1,3364
15	0,1347	0,4740	0,5589	0,6457	0,7344	0,8251	0,9178	1,0126	1,1096	1,2089	1,3105
20	0,1373	0,4650	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	0,9750	1,0684	1,1640	1,2618
30	0,1425	0,4481	0,5284	0,6104	0,6943	0,7800	0,8676	0,9573	1,0490	1,1428	1,2388
35	0,1450	0,4401	0,5190	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	0,9239	1,0124	1,1029	1,1956
45	0,1502	0,4250	0,5012	0,5790	0,6586	0,7399	0,8230	0,9080	0,9950	1,0840	1,1751
50	0,1527	0,4180	0,4929	0,5694	0,6476	0,7276	0,8093	0,8929	0,9784	1,0660	1,1555
55	0,1553	0,4111	0,4847	0,5600	0,6369	0,7156	0,7960	0,8782	0,9623	1,0484	1,1365
60	0,1578	0,4045	0,4770	0,5510	0,6267	0,7041	0,7832	0,8641	0,9469	1,0316	1,1183
65	0,1604	0,3980	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	0,4550	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	0,5890	0,6617	0,7360	0,8120	0,8898	0,9694	1,0509
85	0,1704	0,3745	0,4416	0,5102	0,5803	0,6519	0,7251	0,8000	0,8767	0,9551	1,0354
90	0,1730	0,3690	0,4351	0,5027	0,5717	0,6423	0,7145	0,7883	0,8638	0,9411	1,0202
95	0,1755	0,3638	0,4290	0,4956	0,5636	0,6332	0,7044	0,7771	0,8516	0,9277	1,0057
100	0,1780	0,3587	0,4229	0,4886	0,5557	0,6243	0,6945	0,7662	0,8396	0,9147	0,9916

Symbols:

m/V is the agent mass requirements (kg/m3); i.e. mass, m, in kilograms of agent required per cubic metre of protected volume V to produce the indicated concentration at the temperature specified;

V is the net volume of hazard (m3); i.e the enclosed volume minus the fixed structures impervious to extinguishant

$$m = \left(\frac{c}{100 - c} \right) \frac{V}{S}$$

T is the temperature (°C); i.e. the design temperature in the hazard area;

S is the specific volume (m3/kg); the specific volume of superheated HFC 227ea vapour at a pressure of 1,013 bar may be approximated by the formula:

$S = k_1 + k_2 T$

where

k_1 = 0,126 9

k_2 = 0,000 513

c is the concentration (%); i.e. the volumetric concentration of HFC 227ea in air at the temperature indicated, and a pressure of 1,013 bar absolute.

If concentration values wouldn't be in the table, HFC-227ea quantity per cubic meter of the protected area determination is obtained by the equation:

$$x = \left(\frac{c}{100 - c} \right) \frac{1}{S}$$

In this equation *x* represents the gaseous volume percent per unit of protected volume.
To obtain Design quantity (kg) to discharge in 10 seconds there is to multiply x, extinguishing agent density at 20°C, and the protected room's volume.

As an example follows the calculations for c = 7,9%.

$$S = k_1 + k_2 \cdot T = 0{,}1269 + 0{,}000513 \cdot 20 = 0{,}13716$$

$$m = \frac{V}{S} \cdot \left(\frac{c}{100 - c} \right) = \frac{100}{0{,}13716} \cdot \left(\frac{7{,}9}{100 - 7{,}9} \right) = 62{,}5374235$$

$$x = \frac{m}{V} = \frac{62{,}5374235}{100} = 0{,}625374235$$

NOTE – This value can be automatically calculated by using the Predimensioning.xls file.

3.4 Additional Considerations

Additional quantities of HFC-227ea are required through the use of design factors to compensate for special conditions that may affect the ability of the system to extinguish the fire. The system designer MUST be aware of these criteria and make adjustments as necessary. Additional agent may be necessary for the following situation:

3.4.1 Altitude Correction Factors

The design quantity of HFC-227ea shall be adjusted to compensate for ambient pressures that vary more than eleven percent [equivalent to approximately 1000m of elevation change] from standard sea level pressures [1,013 bar absolute].
The amount of agent required must be adjusted using the correction factors shown below to compensate for these effects. (Reference: ISO 14520)

TABLE 3.4 - Altitude correction factors

Equivalent altitude m	Correction factor (for ideal gases)
-1000	1,130
0	1,000
1000	0,885
1500	0,830
2000	0,785
2500	0,735
3000	0,690
3500	0,650
4000	0,610
4500	0,565

3.5 Discharge Time

The liquefied extinguishant discharge shall be completed as quickly as possible to suppress the fire and limit the formation of decomposition products. In no case shall the discharge time required to achieve 95 % of the design concentration exceed 10 s at 20 °C, or as otherwise required by the authority.
The discharge time period is defined as the time required to discharge from the nozzles 95 % of the extinguishant mass required to achieve the design concentration at 20 °C. For liquefied extinguishants, this can be approximated as the interval between the first appearance of liquid at the nozzle and the time when the discharge becomes predominantly gaseous. Flow calculations shall be used to demonstrate compliance with this clause.

3.6 Duration of Protection (“Door Fan Test”)

It is important that an effective extinguishant concentration not only be achieved, but is maintained for a sufficient period of time to allow effective emergency action. 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 extinguishant has dissipated.
It is essential to determine the likely period during which the extinguishing concentration will be maintained within the protected enclosure. This is known as the hold time. The predicted hold time shall be determined by the door fan test specified in ISO 14520 annex E, or a full discharge test based on the following criteria.

At the start of the hold time, the concentration throughout the enclosure shall be the design concentration.
At the end of the hold time, the extinguishant concentration at 10%, 50% and 90% of the room height in the enclosure shall be not less than the fire extinguishing concentration.
The hold time shall be not less than 10 min, unless otherwise specified by the authority.

3.7 System Design Concept

The distribution of HFC-227ea agent to the protected area(s) may be accomplished through one, or more, of the following piping distribution methods:

- Pre-Engineered System
- Engineered System
- Modular System (Pre-Engineered or Engineered)
- Central Storage System (Pre-Engineered for Engineered)

The method used may depend on several factors including: installation time, the quantity of agent involved, economic factors, number of hazard areas, available space for placement of storage containers and customer preferences. Larger projects may require more than one method to address the challenges presented.
Therefore, the designer should be familiar with each of these methods, and the advantages and disadvantages of each for any particular application.

3.7.1 Pre-Engineered Systems Concept

Pre-Engineered Systems are simple, balanced-flow configurations that are simple to design and take less time to install. The Pre-Engineered concept minimizes the engineering effort required to design an effective system by utilizing a fixed series of nozzles and a tightly defined set of design criteria. As long as nozzle selection, pipe size, and pipe length limitations are adhered to.
Pre-Engineered Systems can be designed with the containers arranged in modular or central storage configurations as described below.

3.7.2 Engineered Systems Concept

Engineered Systems enable the designer to create a custom piping network to suit the individual needs of the project. The piping configurations can be balanced or unbalanced, and the flow splits within the system can vary from point to point. This requires a computerized hydraulic flow calculation to model the system. Therefore, this design concept gives the designer a great deal more flexibility to work with, but it will generally take longer to design these systems.
Engineered Systems can be designed with the containers arranged in modular, central storage or manifolded arrangements as described below.

3.7.3 Modular Systems

Modular Systems can be defined as a design concept where the containers are located throughout or around the protected area(s). This keeps the discharge piping requirements down to a minimum, but increases the electrical materials necessary to reach each individual container location.
A modular approach is often desirable (or necessary) for larger applications to reduce the amount of piping materials and installation labour necessary to complete the installation. In some instances, this approach will be necessary in order to make the system flow the agent required.

3.7.4 Central Storage Systems

Central Storage Systems can be defined as a design concept where the containers are located in one location, and piped to the protected space(s) from this location. This concept often requires more discharge piping, but it decreases the electrical materials necessary to reach the container location. This concept may be more difficult to design due to the increased piping runs involved, and the installation labour will tend to be more costly because of the additional piping. However, the installation may be more aesthetically desirable to the customer, and it is generally easier to maintain and service.

3.8 Container Locations

The type and location of the storage container is based on several considerations.

1. Agent Quantity – The agent storage container(s) selected must have the capacity to store the total quantity of agent required for the system.

2. System Type – An area might be protected by several smaller containers with independent nozzles, or it might be protected by a large capacity container that is discharged through a piping network of 2, 4, or more nozzles.

3. Extent of Piping – In systems having an unusually large piping system, the pressure drop may be too great for the location or configuration selected. In some cases, it may be necessary to relocate the container(s) closer to the hazard area(s) being protected. It may also be necessary to subdivide the piping network into smaller configurations with separate containers.

4. Container Type – Consideration should be given to the container type required for the installation. For example, a 480kg system could be stored in (4) 150 liter containers located on the floor.

5. Serviceability – In general, the larger the container, the more difficult it will be to remove it from the system for maintenance and service. However, smaller containers that are located in a subfloor space, under a computer bank, or above the ceiling over the same computer bank, can be difficult as well.

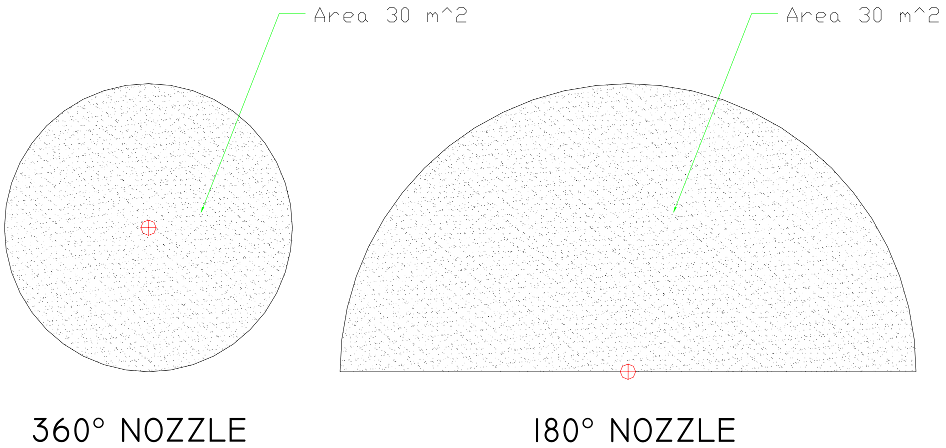
6. Floor Loading – This factor must be considered when selecting a container location. Excessive floor loading may require relocating the container(s) to a more suitable location.

7. Proximity – HFC-227ea Containers should be located as close as possible to, or within the hazard that they protect.

8. Environmental Effects – DO NOT locate containers where they would be subject to physical damage, exposure to corrosive chemicals, or harsh weather conditions.

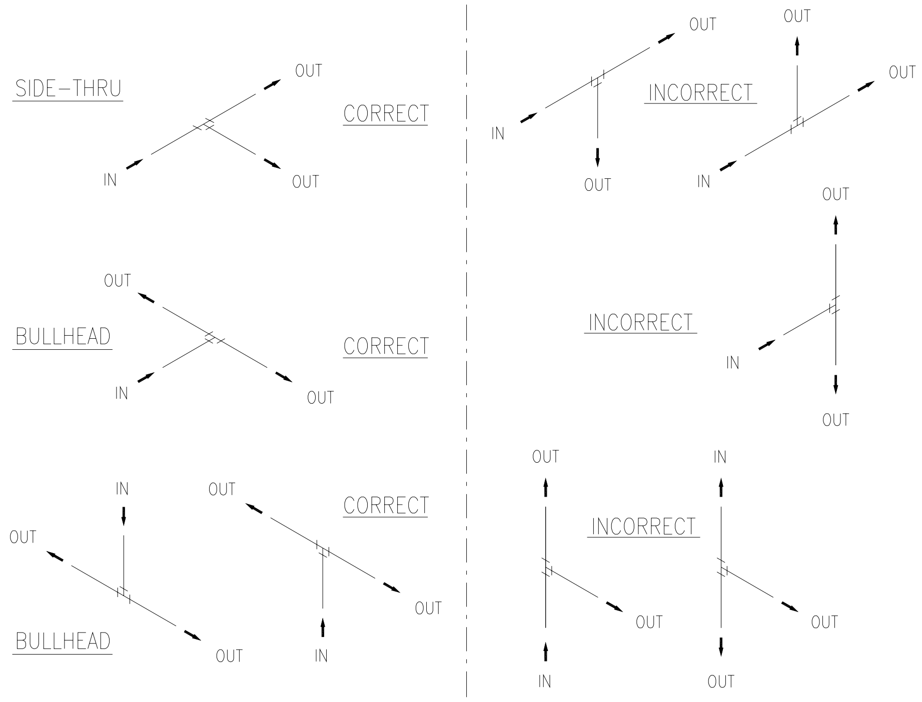
3.9 Nozzle selection and location

The number of nozzles required is based on the hazard size and configuration and the coverage provided by the nozzle.
Nozzles are available in multi-port versions with calibrated plate to provide 180 or 360 degree discharge patterns respectively. The orifice plate hole diameter is determined by a flow programme.
When considering the optimum nozzle location, the following factors should be taken into account.
Nozzle location is effected by the shape of the hazard area.
Design concentration has to be achieved in all parts of protected volume by a correct nozzle location.
The maximum discharge area for a 360° and a 180° nozzle is 30m² (normative CEA).
Nozzle orifices must be not placed where they may discharge into nearby objects.
For 360° nozzles, nozzles must be installed within 300 mm of the ceiling.
4.5 m maximum protection height for single 360° and 180° nozzle
180 degree nozzles must be mounted adjacent to a wall and must be located to cover the entire area.



3.10 Tee Orientation

The Tee orientation is an important characteristic in maintaining consistency of flow split percentages. Therefore, a simple rule MUST be observed concerning tee orientation: EVERY OUTLET of every tee MUST be orientated in the horizontal plane.



3.11 Pipework and Fitting

The most important considerations about pipework distribution are:

Room shape.
Nozzles location

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

Pipe and pipeline specifics are the following:

TABLE 3.5 - Pipeline

	Pipe	Schedule	Diameter (inches)	Material	Thread
Manifold	API 5LGRB	40	2"1/2 3"		NPT
Pipeline	API 5LGRB	40	1/2" 3/4" 1" 1"1/4 1"1/2 2" 2"1/2 3"	ASTM A-106 Zinc plated without welding	NPT

TABLE 3.6 - Pipe fittings

	Type	Material	Screw thread
Pipe fittings	ASA 3000	ASTM A-105 Zinc plated	NPT

3.12 Estimating Pipe Sizes

The following are approximate flow rate for estimating pipe sizes:

TABLE 3.7 – Flow rate

HFC-227ea Sch40	
inches	**Kg/sec x 10sec**
1/2"	0-14
3/4"	15-24
1"	25-40
1"1/4	41-60
1"1/2	61-90
2"	91-150
2"1/2	151-210
3"	211-270
4"	271-400

NOTE – A flow calculation programme must be used to verify exact pipe sizes, nozzles orifices and restrictors sizes for all systems designs and installations.

3.13 Pipes Hangers and Support

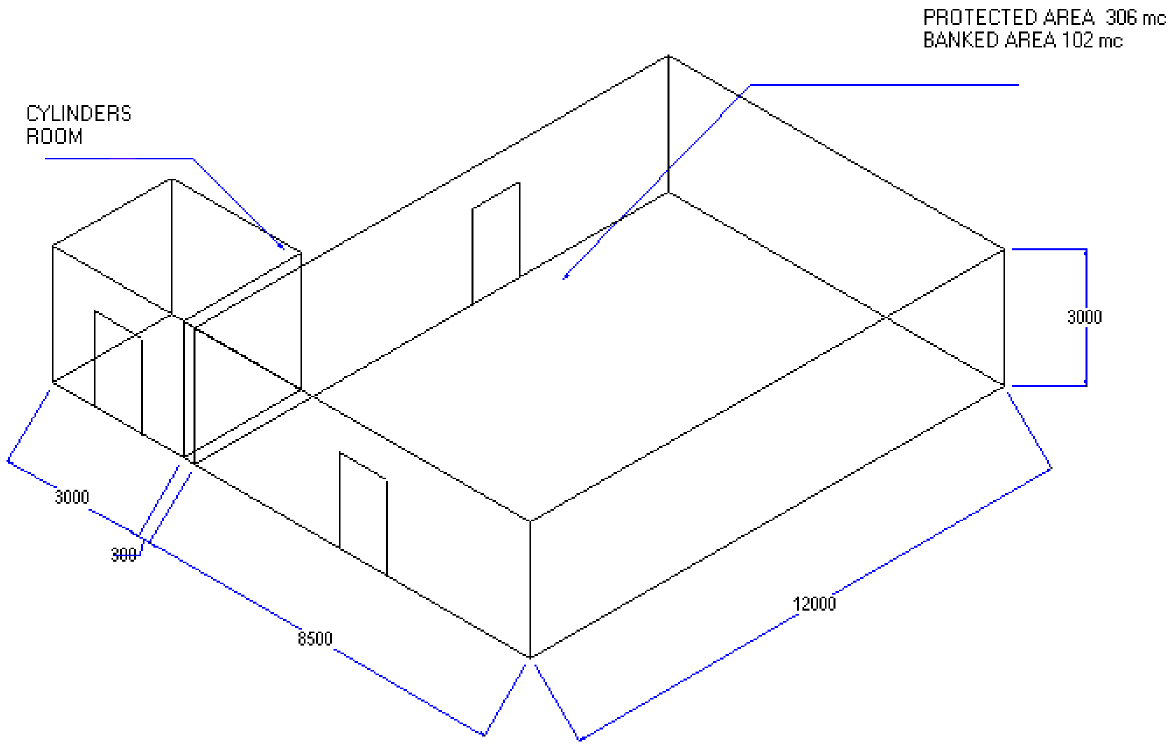
All support and parts thereof shall conform to the requirements for ISO-14520.

TABLE 3.8 - Maximum pipework spans

Nominal diameter of pipe DN	**Maximum pipework span** m
6	0,5
10	1,0
15	1,5
20	1,8
25	2,1
32	2,4
40	2,7
50	3,4
65	3,5
80	3,7
100	4,3
125	4,8
150	5,2
200	5,8

3.14 Design example calculation according to ISO 14520 part 9 Next Edition

The risk is represented by an archives with storage paper.



Volume = 306 m³
Room temperature = 20°C
Class A minimum design concentration according to ISO 14520.9
c = 6,1%+30% = 7,9%
Then according with the equation (that is located in ISO 14520 part 9):

$$S = k_1 + k_2 \cdot T = 0{,}1269 + 0{,}000513 \cdot 20 = 0{,}13716$$

$$m = \frac{V}{S} \cdot \left(\frac{c}{100 - c} \right) = \frac{306}{0{,}13716} \cdot \left(\frac{7{,}9}{100 - 7{,}9} \right) = 191{,}3645159 kg$$

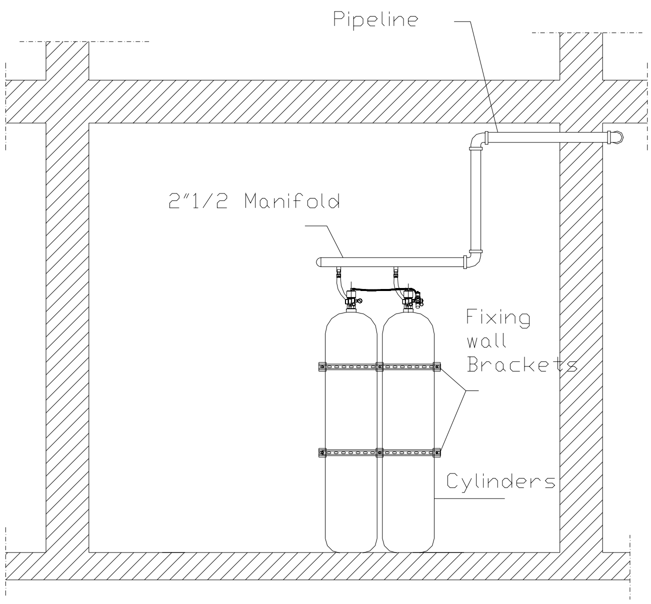
$$x = \frac{m}{V} = \frac{191{,}3645159}{306} = 0{,}625374235 kg / m^3$$

Value was obtained by the formula because 7,9% isn't listed in the table 3.2.

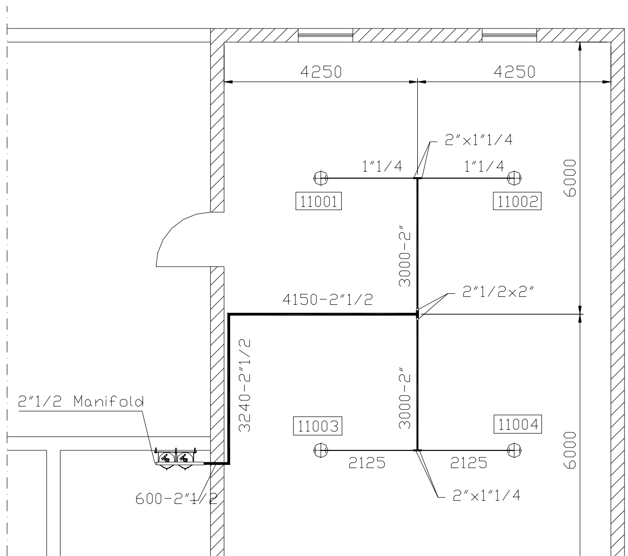
HFC-227ea design quantity in kg is : 191,3645159 [kg]

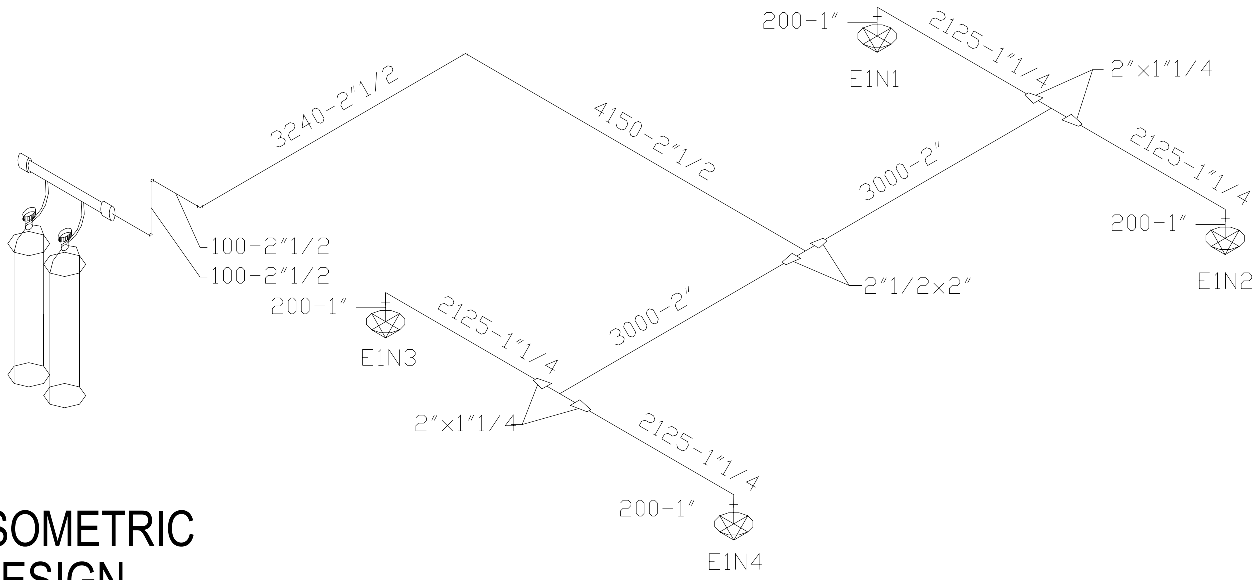
$Q_{real} = Q_{design} + 0{,}1354841 = 191{,}5$ [kg]

Number of cylinders : $N = \frac{Q_{real} \cdot 1{,}15}{120} = 1{,}83521 \Rightarrow 2$ x 120lt Cylinders



CYLINDERS LAYOUT





ISOMETRIC
DESIGN

Pipeline network axonometric view with diameters and nozzles connected to a two cylinders HFC-227ea system.

3.15 Calculations with spreadsheet

Formula taken from ISO 14520 – 9 Next Edition.

DATA	
MINIMUM DESIGN CONCENTRATION BY VOLUME	7,9
TEMPERATURE [°C]	20
NET VOLUME OF THE ENCLOSURE [m^3]	306
NOAEL	9
SPECIFIC VOLUME AT 20°C [m^3/KG]	0,1373
MAX FILL DENSITY kg/l	1,12
MINIMUM FILL DENSITY kg/l	0,5
NUMBER OF NOZZLES	4
DISCHARGE TIME[s]	10
RESULTS	
QUANTITY BY WEIGHT [Kg/m^3]	0,62
DESIGN QUANTITY OF FM200 IN Kg	191,17
MANIFOLD'S SIZE	21/2 inch
FLOW RATE OF NOZZLE	47,79
SIZE OF NOZZLE	1

TABLE 3.9 – Cylinder's filling capacity

CYLINDER:	Lt	Kg min.	Kg max			number of cylinders
	14	7	15,68		12,2	13
	27	13,5	30,24		6,3	7
	50	25	56		3,4	4
	75	37,5	84		2,3	3
	120	60	134,4		1,4	2
	150	75	168		1,1	2

TABLE 3.10 – Fill density

FILL DENSITY OF CYLINDERS	Lt	Kg/l
	14	1,050
	27	1,011
	50	0,956
	75	0,850
	120	0,797
	150	0,637

3.16 Flow Calculations with Hughes Associates Inc.

BETTATI ANTINCENDIO

Via Cilea 1
Reggio Emilia
scadenza taratura 10/06/05
Phone: 0522-300705
AgentCalcs for HFC-227ea
File Name: C:\Programmi\Hughes Associates\AgentCalcs for HFC-227ea GEN300\Projects\esempio.FLC
Calculation Date/Time: giovedì 19 maggio 2005, 11.20.18

Consolidated Report

Customer Information

Company Name:	Bettati Antincendio srl
Address:	
Phone:	
Contact:	
Title:	

Project Data

Project Name:	
Designer:	Massimo Bettati
Number:	
Account:	
Location:	
Description:	

Consolidated Report
Enclosure Information

Elevation:	0 m (relative to sea level)
Atmospheric Correction Factor:	1
Enclosure Number:	1
Name:	No Name Entered
Enclosure Temperature...	
Minimum:	20,0 C
Maximum:	20,0 C
Maximum Concentration:	7,910 %
Design Concentration...	
Adjusted:	7,910 %
Minimum:	7,900 %
Minimum Agent Required:	191,8 kg
Width:	0,00 m
Length:	0,00 m
Height:	0,00 m
Volume:	306,00 cubic m
Non-permeable:	0,00 cubic m
Total Volume:	306,00 cubic m

Agent Information

Adjusted Agent Required:	192,0 kg
Number of Nozzles:	4
Agent:	HFC-227ea / Propellant N2

Adjusted Agent Required:	192,0 kg
Container Name:	120lt
Container Part Number:	
Number of Main Containers:	2
Number of Reserve Containers:	0
Manifold:	Baseline1 End, 2 Cyls, Up
Pipe Take Off Direction:	Horizontal
Agent Per Container:	96,0 kg
Fill Density:	0,800 kg / l
Container Empty Weight:	0,0 kg
Weight, All Containers + Agent:	192,0 kg
Floor Area Per Container:	0,00 square m
Floor Loading Per Container:	0 kg /square m

Pipe Network

Consolidated Report

Part 1 - Pipe

Description	Start	End	Type	Diameter	Pipe Length	Elevation
Main Cyl. X 2	0	1			1,50 m	1,50 m
Manifold X 2	1	2	40T	50 mm	0,61 m	0,30 m
Manifold X 1	2	3	40T	65 mm	1,52 m	0,00 m
Pipe	3	4	40T	65 mm	0,10 m	0,10 m
Pipe	4	5	40T	65 mm	0,10 m	0,00 m
Pipe	5	6	40T	65 mm	3,24 m	0,00 m
Pipe	6	7	40T	65 mm	4,15 m	0,00 m
Pipe	7	8	40T	50 mm	3,00 m	0,00 m
Pipe	8	9	40T	32 mm	2,12 m	0,00 m
Pipe/E1-N1	9	10	40T	32 mm	0,20 m	-0,20 m
Pipe	8	11	40T	32 mm	2,12 m	0,00 m
Pipe/E1-N2	11	12	40T	32 mm	0,20 m	-0,20 m
Pipe	7	13	40T	50 mm	3,00 m	0,00 m
Pipe	13	14	40T	32 mm	2,12 m	0,00 m
Pipe/E1-N4	14	15	40T	32 mm	0,20 m	-0,20 m
Pipe	13	16	40T	32 mm	2,12 m	0,00 m
Pipe/E1-N3	16	17	40T	32 mm	0,20 m	-0,20 m

Part 2 - Equivalent Length

Start	End	90	45	Thru	Side	Union	Other	Added	Total
0	1	0	0	0	0	0		0,00 m	3,00 m
1	2	0	0	0	0	0		0,00 m	0,61 m
2	3	1	0	0	3	0		0,00 m	15,79 m
3	4	1	0	0	0	0		0,00 m	2,10 m
4	5	1	0	0	0	0		0,00 m	2,10 m
5	6	1	0	0	0	0		0,00 m	5,24 m
6	7	1	0	0	0	0		0,00 m	6,16 m
7	8	0	0	0	1	0		0,00 m	6,40 m
8	9	0	0	0	1	0		0,00 m	4,42 m
9	10	1	0	0	0	0		0,00 m	1,34 m
8	11	0	0	0	1	0		0,00 m	4,42 m
11	12	1	0	0	0	0		0,00 m	1,34 m
7	13	0	0	0	1	0		0,00 m	6,40 m
13	14	0	0	0	1	0		0,00 m	4,42 m
14	15	1	0	0	0	0		0,00 m	1,34 m
13	16	0	0	0	1	0		0,00 m	4,42 m

Consolidated Report

Part 2 - Equivalent Length

Start	End	90	45	Thru	Side	Union	Other	Added	Total
16	17	1	0	0	0	0		0,00 m	1,34 m

Part 3 - Nozzles

Start	End	Flow	Name	Size	Type	Nozzle Area
0	1	96,0 kg				
1	2	96,0 kg				
2	3	192,0 kg				
3	4	192,0 kg				
4	5	192,0 kg				
5	6	192,0 kg				
6	7	192,0 kg				
7	8	96,0 kg				
8	9	48,0 kg				
9	10	48,0 kg	E1-N1	32 mm	Metric	538,84 square mm
8	11	48,0 kg				
11	12	48,0 kg	E1-N2	32 mm	Metric	538,84 square mm
7	13	96,0 kg				
13	14	48,0 kg				
14	15	48,0 kg	E1-N4	32 mm	Metric	538,84 square mm
13	16	48,0 kg				
16	17	48,0 kg	E1-N3	32 mm	Metric	538,84 square mm

Parts Information

Total Agent Required: 192,0 kg
Container Name: 120lt
Number Of Containers: 2
Manifold: Baseline1 End, 2 Cyls, Up

Nozzle	Type	Diameter	Nozzle Area	Part Number
E1-N1	Metric	32 mm	538,84 square mm	
E1-N2	Metric	32 mm	538,84 square mm	
E1-N3	Metric	32 mm	538,84 square mm	
E1-N4	Metric	32 mm	538,84 square mm	

Nozzle	Drill Diameter	Drill Size
E1-N1	26,2000 mm	1-1/32

Consolidated Report

Nozzle	Drill Diameter	Drill Size
E1-N2	26,2000 mm	1-1/32
E1-N3	26,2000 mm	1-1/32
E1-N4	26,2000 mm	1-1/32

Pipe:	Type	Diameter	Length
	40T	32 mm	9,28 m
	40T	50 mm	7,22 m
	40T	65 mm	9,11 m

List of 90 degree elbows:
4 - 32 mm
5 - 65 mm

List of Tees:
2 - 50 mm
1 - 65 mm

System Acceptance

System Discharge Time: 9,2 seconds
Percent Agent In Pipe: 38,6%
Percent Agent Before First Tee: 22,5%

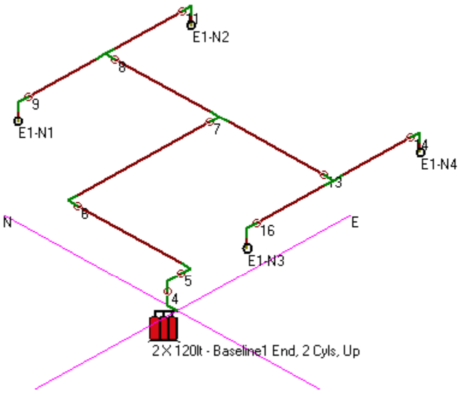
Enclosure Number: 1
Enclosure Name: No Name Entered

Minimum Design Concentration: 7,900%
Adjusted Design Concentration: 7,910%
Predicted Concentration: 7,910%
Maximum Expected Agent Concentration: 7,910% (At 20,0 C)

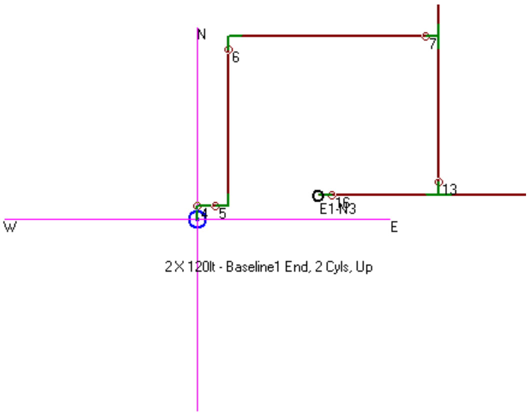
Nozzle	Minimum Agent Required	Adjusted Agent Required	Predicted Agent Delivered	Nozzle Pressure (Average)
E1-N1	48,0 kg	48,0 kg	48,0 kg	7,174 bar
E1-N2	48,0 kg	48,0 kg	48,0 kg	7,174 bar
E1-N3	48,0 kg	48,0 kg	48,0 kg	7,174 bar
E1-N4	48,0 kg	48,0 kg	48,0 kg	7,174 bar

Consolidated Report

Standard Isometric View

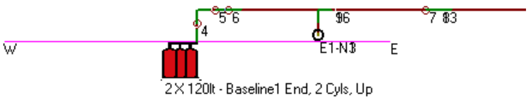


Standard Plan View



Consolidated Report

Standard Elevation View



4 System Components

This section describes the individual components that comprise a complete system. Some items are optional depending on the application, and are indicated as such.

4.1 HFC-227ea Container

HFC-227ea is stored in a solid-draw, seamless cylinder of a nominal volume of either 14,27,50,75,120 0r 150 litres.
Containers sharing the same manifold shall be equal in size and fill density.
Containers are finished in two-pack polyurethane red.
A label is affixed to the container displaying the: cylinder capacity, fills pressure, HFC-227ea weight, tare weight, gross weight.
Technical info about HFC-227ea container:

TABLE 4.1 – Cylinder's filling capacity

CYLINDER:	Lt	Kg min.	Kg max
	14	7	15,68
	27	13,5	30,24
	50	25	56
	75	37,5	84
	120	60	134,4
	150	75	168

TABLE 4.2 – Cylinder's technical info

Cylinder capacity	**14lt**	**27lt**	**50lt**	**75lt**	**120lt**	**150lt**
Length (mm)	800	1020	1030	1245	1480	1485
Internal Cylinder Thread	1" NPT G	1" NPT G	2"1/2 NPT G	2"1/2 NPT G	2"1/2 NPT G	3" NPT G
Maximum Filling Pressure	25 bar at 15°C					
Test Pressure	100 bar					
Cylinder Approval	CE-TPED					
Marking and Location of Equipment	π					
Diameter (mm)	168	203	267	316	356	403
Weight without gas (kg)	17	25	43	65	112	145

4.2 Fixing Brackets

The bracket assembly consists of a nut and bolt, four bracket straps and two back channels.
To hold the container securely in position during the system discharge, four bracket assemblies are required per container.
Each strap is notched for insertion into the back channel allowing the container to be properly aligned.
The bracket assembly is designed to be mounted on a rigid surface with the container assembly resting on the floor.

4.3 Halocarbon agents valve

A pressure operated cylinder valve having a forged brass body and cap. It is activated through an operating piston at the top.
The valve incorporates the following parts:

- Device for refill on site
- Safety fusible plug 90°C
- Safety Disc
- Treated port for the connection of: manual solenoid actuator, pressure gauge and pressure switch assembly.

The valve incorporates the following features:

TABLE 4.3 – Valve's info

Halocarbon Agent	Working pressure at 22°C	PS 60°C	Test pressure 1,5 PS	Working temperature	Safety Disc	Safety Plug	Cylinder capacity	Valve Outlet
HFC-227ea	25bar	57bar	86bar	-20°C/+60°C	60bar	90°C	14/27lt	3/4”
							50/75/120lt	1”1/2
							120/150lt	2”

4.4 Halocarbon Valve with manual solenoid actuator

It is fitted on a pilot cylinder.
This manual solenoid actuator assembly includes pressure gauge, low pressure switch, bleeder valve and adapter with swivel nut.
The manual solenoid actuator is used to actuate the cylinder's valve via pilot flexible hose.

The valve incorporates the following parts:

- Low pressure switch
- Pressure gauge (0-100bar)
- Solenoid (24Vcc –11 W)
- Manual swivel actuator
- Safety pin
- Swivel nut (connection to valve)
- Pilot flexible hose

4.5 Pressure switch and gauge removable device

This unit is required for the slave cylinders to provide a local visual means to determine the pressure within the slave cylinder. The pressure gauge assembly includes a low pressure switch that changes state upon loss of cylinder's pressure.
Mounting and dismounting can be carried out on site without losses of gas.

4.6 Discharge flexible hose

Multiple container installations are connected to the system by means of a discharge flexible hose.
A swivel fitting at the inlet of the hose enables the container to be readily coupled to the distribution system through a check valve.

4.7 Manifold

A manifold is a fabricated section of steel pipework (type sch40).
It enables multiple containers to be connected to a common pipe network.
This manifold can be used in conjunction with directional valves to provide protection for multiple risk areas and in situations where main/reserve container arrangements are required.

4.8 Manifold bracket assembly

A manifold bracket assembly consist of two lengths of unirax, mounted vertically on a wall or bulkhead to enable height adjustment of the manifold assembly.
Cantilever brackets are located over the unirax and each is held in position using a uninut long spring, washer and hex head screw.
Manifold brackets slot into the cantilever and are clamped using a hexagonal head screw and plain nut.

4.9 Halocarbon agents manifold check valve

They are used to avoid a flow-back of the gas into the cylinder during the discharge or a leakage in case one or more cylinder have been removed from the multiple cylinders system.
All check valves are supplied ready fitted to the manifold assembly.

4.10 Directional valve

The directional valve is installed directly into the agent pipe network.
The directional valve assembly consist of:

- A normally closed ball valve
- A pneumatic piston
- A manual solenoid actuator
- A non return valve
- A pilot flexible hose

The manual solenoid actuator, connected to the piston, allows the pressure coming from the pilot cylinder to open the ball valve.
From the piston outlet the same pressure is used to open the required number of cylinders.

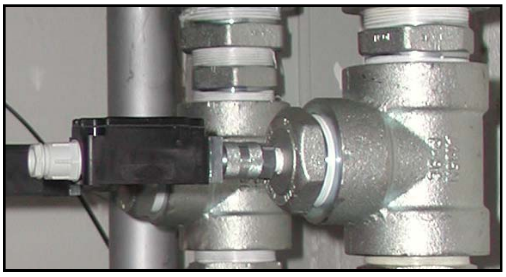
4.11 Flexible Pilot Hose

The flexible pilot hose is used to connect pressure-activated devices to the system, e.g. slave container.

4.12 Male Tee

The male tee is used primarily to open the slave cylinder and to connect pilot lines from one slave container to the next.

4.13 Discharge Pressure Switch



The pressure switch is activated by pressure from the agent during discharge and can be used to signal to control panel that the system has actually discharged.
The pressure switch incorporates a reset button that has to be depressed following a discharge.

4.14 Halocarbon agents Discharge Nozzle

The discharge nozzles are available in four basic sizes: 1/2”, 3/4”, 1”, and 1-1/2”.
Each is fitted with a drilled orifice to assure proper flow rates, agent quality and proper discharge timing as determined by flow calculations.
Maximum nozzle spacing for room mounted nozzles should not exceed 30 square meter.