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DESIGN MANUAL

FOR HALOCARBON GAS SYSTEM

HFC 227EA – HFC 125 – HFC 23

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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 "HFC125", "HFC227ea" e "HFC23" Gas Extinguishing Systems. 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 "HFC125", "HFC227ea" e "HFC23" chemical and physical characteristics, and contains design technical specifications and safety requirements.
Users of this manual are assumed to be competent fire engineers with a basic knowledge of such systems

1.2 Standards and Code of practice

Systems that use extinguishing Halocarbon HFC125, HFC227EA and HFC23 agents are designed according to these standards:

- EN 15004-1:2008 "Fixed firefighting systems. Gas extinguishing systems. Part 1: Design, installation and maintenance".
- EN 15004-4:2008 "Fixed firefighting systems. Gas extinguishing systems. Part 4: Physical Properties And System Design Of Gas Extinguishing Systems For Hfc 125 Extinguishant".
- EN 15004-5:2008 "Fixed firefighting systems. Gas extinguishing systems Part 5: Physical properties and system design of gas extinguishing systems for HFC 227ea extinguishant".
- EN 15004-6:2008 "Fixed firefighting systems. Gas extinguishing systems - Part 6: Physical properties and system design of gas extinguishing systems for HFC 23 extinguishant".

Components used in the system that use extinguishing Halocarbon HFC125, HFC227EA and HFC23 agents meet the requirements of the following standards:

- EN 12094-4:2004 "Fixed firefighting systems. Components for gas extinguishing systems. Requirements and test methods for container valve assemblies and their actuators".
- EN 12094-5:2004 "Fixed firefighting systems. Components for gas extinguishing systems. Requirements and test methods for high and low pressure selector valves and their actuators".
- EN 12094-6:2006 "Fixed firefighting systems. Components for gas extinguishing systems. Requirements and test methods for non-electrical disable devices".
- EN 12094-8:2006 "Fixed firefighting systems. Components for gas extinguishing systems. Requirements and test methods for flexible connectors".
- EN 12094-10:2004 "Fixed firefighting systems - Components for gas extinguishing systems . Requirements and test methods for pressure gauges and pressure switches"
- EN 12094-13:2002 "Fixed firefighting systems. Components for gas extinguishing systems. Requirements and test methods for check valves and non-return valves".

Systems that use extinguishing Halocarbon HFC125, HFC227EA and HFC23 agents must be maintened according to these standards:

- EN 15004-1:2008 "Fixed firefighting systems. Gas extinguishing systems. Part 1: Design, installation and maintenance". Chapter.9
- UNI 11280 (Italian standard) "preliminary inspection and maintenance of the gaseous fire–extinguishing system. *(this standard is more stringent compared to the EN 15004:2008-1 and ISO 14520:2006:1)*

1.3 Approval / Certification of agent

L'"HFC125", "HFC227ea" e "HFC23" were approved as an extinguishing gases by:

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

1.4 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 EN 15004.

-*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.

1.5 Unit of measurement system

The units of measurement are complying to the modern metric system known as International System of Unit (SI).Two units (litre and bar) are not included into SI but acknowledged by it and they are generally used in fire-fighting field as well

1.6 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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2 Use and Limitations of extinguishing agents

2.1 Introduction

The design, installation, service and maintenance of gaseous fire-extinguishing systems “HFC125”, “HFC227ea” and “HFC23” 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:

1. Electrical and electronic hazards;
2. Telecommunications facilities;
3. Flammable and combustible liquids and gases;
4. Other high-value assets.

2.2 Extinguishing agents and chemical and physical properties

“HFC125”, “HFC227ea” and “HFC23” are a safe, clean, and electrically nonconductive agents.
HFC227EA demonstrates the closest physical property match to Halon 1301 in terms of both flow characteristics and vapour pressure.

“HFC125”, “HFC227ea” and “HFC23” extinguishe 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.

The table below shows the chemical and physical properties of the “HFC125”, “HFC227ea” and “HFC23” extinguishing agents

Tab. – Chemical and Physical properties

Proprietà	Units	HFC125	HFC227ea	HFC23
Molecular mass	—	120,02	170	70
Boiling point at 1,013 bar (absolute)	°C	-48,09	-16,4	-82,0
Freezing point	°C	-101	-127	-155,2
Critical temperature	°C	66,02	101,7	25,9
Critical pressure	bar abs	36,18	29,26	48,36
Critical volume	cm^3/mol	210	274	133
Critical density	kg/m^3	573,6	573	525
Vapour pressure 20 °C	bar abs	12,05	3,9	41,8
Liquid density 20 °C	Kg/m^3	1.1218,0	1.410,0	806,6
Saturated vapour density 20 °C	Kg/m^3	77,97	31,035	263,0
Specific volume of superheated vapour at 1,013 bar and 20 °C	m^3/kg	0,1972	0,1374	0,3409
Chemical formula Chemical name		CF_3CHF_2	CF_3CHFCF_3	CHF_3
Critical temperature		Pentafluoroetano	Eptafluoropropano	Trifluorometano

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2.3 Applications

"HFC125", "HFC227ea" and "HFC23" are an ideal replacement for Halon 1301 for the total flooding of enclosures. They can be used in applications where people are normally present (normally occupied spaces) for Class-A fire assets.
"HFC125", "HFC227ea" and "HFC23" demonstrate the closest match to the flow characteristics of Halon 1301.
Typical areas that can be protected by an "HFC125", "HFC227ea" and "HFC23" systems 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 - HFC125, HFC227ea and HFC23 are not suitable for use with materials such as:

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

2.4 The extinguishing agent effects on personell (Ref. Annex G EN 15004 Ed. 2008)

The safety precautions required by this document is not toxicological or physiological effects associated with products of combustion caused by the fire. The maximum time exposure taken by the safety precautions in this paragraph is 5 min. Exposure times greater than 5 min may involve physiological or toxicological effects not covered here

2.5 Hazards to personnel (Reference:: EN-15004 ed 2008 ANNEX G)

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.

2.6 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.

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 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.

Tabella 2.2

Agent	LC_{50} o ALC (%)	NOAEL (%)	LOAEL (%)
HFC125	>70	7,5	10,0
HFC227ea	>80	9,0	10,5
HFC23	>65	50	>50

NOTE 1LC50 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

2.7 Safe Exposure Guidelines for Halocarbon Agents (Rif. Annex G EN 15004-1 Ed. 2008)

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 EN 15004 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.

Human exposure time for HFC-125 agent

HFC-125 Concentration % v/v	Human Exposure Time (minutes)
7,5	5,00
8,0	5,00
8,5	5,00

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9,0	5,00
9,5	5,00
10,0	5,00
10,5	5,00
11,0	5,00
11,5	5,00
12,0	1,67
12,5	0,59
13,0	0,54
13,5	0,49
NOTE 1 Data derived from the EPA-approved and peer-reviewed physiologically based pharmacokinetic (PBPK) model or its equivalent. NOTE 2 Based on LOAEL of 10.0 percent in dogs.	

Human exposure time for HFC227ea agent

HFC227ea Concentration % v/v	Human Exposure Time (minutes)
9,0	5,00
9,5	5,00
10,0	5,00
10,5	5,00
11,0	1,13
11,5	0,60
12,0	0,49
NOTE 1 Data derived from the EPA-approved and peer-reviewed physiologically based pharmacokinetic (PBPK) model or its equivalent. NOTE 2 Based on LOAEL of 10.0 percent in dogs.	

2.7.1 For spaces that are normally occupied

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

Table - (Ref. EN 15004- 1)

Maximum concentration	Pre-discharge alarm	Time delay device	Automatic/ manual switch	Lock-off device
Up to and including the NOAEL	Required	Required	Not required	Not required
Above the NOAEL and up to the LOAEL	Required	Required	Required	Not required
LOAEL and above	Required	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.

2.7.2 For spaces that are not normally occupied

The concentrations must be 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.

2.7.3 Spaces that CANNOT be occupied

The maximum concentration can exceeding the LOAEL for the extinguishing agent used, without having to install a device of exclusion

2.7.4 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.

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.

2.8 Hazard to environment

HFC125, HFC227ea and HFC23 is environmentally acceptable with an ODP=0 (Ozone Depletion Potential) as it is shown in Table 2.5

Tab. - Environmental impact

	A.L.T. (years) Atmospheric Life Time	G.W.P. Global Warming Potential	O.D.P. Ozone Depletion Potential
HFC-125	33	2800	0
HFC-227ea	37	2900	0

HFC-23	264	11700	0

2.9 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

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3 Basis of Halocarbon Systems Design

This section of the manual will detail the steps necessary to design an halocarbon gas extinguishing System .
The system designer must do a complete hazard analysis applying the guidelines from EN 15004 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:

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.

Class B: flammable liquids

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 EN-15004 :2008 standard – Annex C. These values have been multiplied by a Safety Factor (1,3 for EN-15004) as required by the applicable standard

Tab. 4 HFC227ea reference extinguishing and design concentrations EN-15004-5:2008

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	7,9
PP	6,1	
ABS	6,1	
Higher Hazard Class A	[a]	8,5

Tab. 4 HFC-125 reference extinguishing and design concentrations EN-15004-4:2008

Fuel	Extinguishment %	Minimum design %
Class B		
Heptane (cup burner)	9,3	12,1
Heptane (room test)	9,3	
Surface Class A		
Wood Crib	6,7	
PMMA	8,6	11,2
PP	8,6	
ABS	8,6	
Higher Hazard Class A	[a]	11,5

Tab. 4 HFC23 reference extinguishing and design concentrations EN-15004-6:2008

Fuel	Extinguishment %	Minimum design %
Class B		
Heptane (cup burner)	12,6	16,4
Heptane (room test)	12,3	
Surface Class A		
Wood Crib	10,5	
PMMA	12,5	16,3
PP	12,5	
ABS	12,4	
Higher Hazard Class A	[a]	16,3

3.3 Required Agent quantity

For this manual we will design an extinguishing HFC227ea system.
The first step in designing the HFC227EA 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 HFC227EA 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.)

HFC227EA quantity per cubic meter of the protected area determination is obtained by the table 3.3.

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Table 3 — HFC 227ea total flooding quantity

Temperature *T*	Specific vapour volume *S*	HFC 227ea mass requirements per unit volume of protected space, *m/V* (kg/m³) This information refers only to the product HFC-227ea, and does not represent any other products containing 1,1,1,2,3,3,3-heptafluoropropane as a component.									
		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 HFC227EA 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 HFC227EA in air at the temperature indicated, and a pressure of 1,013 bar absolute.

If concentration values wouldn't be in the table, HFC227EA 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%.

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

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

$$x = \frac{m}{V} = \frac{62{,}5374235}{100} = 0{,}625374$$

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

3.4 Additional Considerations

Additional quantities of HFC227EA 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 HFC227EA 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: EN 15004)

Table 3.4

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 (ref. EN 15004-1:2008 chapter 7.9)

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. Hughes Associates hydraulic calculation software is used to demonstrate compliance with this clause.

3.6 Duration of Protection (“Door Fan Test”) (ref. EN 15004-1:2008 chapter 7.8)

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 EN 15004 annex E, or a full discharge test based on the following criteria:

a. *At the start of the hold time, the concentration throughout the enclosure shall be the design concentration.*
b. *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.*
c. *The hold time shall be not less than 10 min, unless otherwise specified by the authority.*

Annex E: “Door fan test for determination of minimum hold time”

Here below an example of door fan integrity test performed with **Retrotec Q5E Automated Blower Door**

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PASS/FAIL Enclosure Integrity Report

CleanAgent 2001 retention time prediction program revision 2.5.4. Complies with ISO draft standard 15420-1
By Retrotec, Inc, 2200 Queen Street, Bellingham, WA USA 98229 360-738-9835 www.retrotec.com
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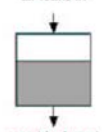


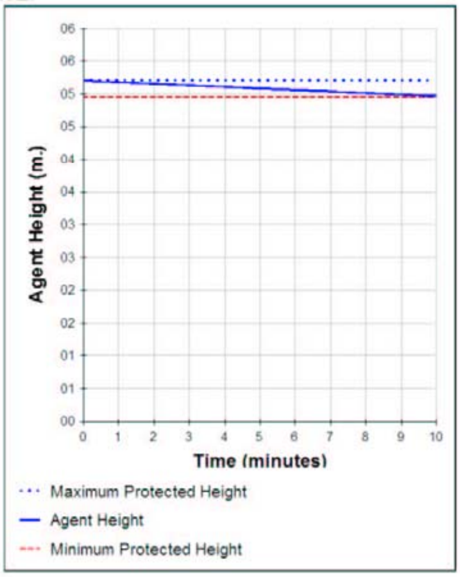
Building, Location ***XXXXX, Reggio Emilia, ITALIA***
Company, Contact ***XXXXX, SIG. XXXXX***
Room name ***ARCHIVIO*** Test number ***1***
Calibration Certificate # ***3794*** Certificate created **2009/01/05**

Test date/time	***2009/07/17 11.52***	Net protected volume, V_g	***1.213 m^3***
Tester	***Cecilia Bertolini***	Maximum Protected Height, H_o	***5,20 m.***
Certified to Level:	***No enclosure certification***	Minimum Protected Height, H	***4,95 m.***
Signature	....	Static during discharge, P_{SH}	***0,0 Pa***
Elevation above sea level	***0 m.***	Operating temperature	***20 C***
Correction method	***NFPA 2001 (2000) Formula A-3-5.3.3***	Initial concentration, C	***7,89%***
Correction factor	***1***	Mixing during retention	***No***
Agent	***FM200 (HFC227ea)***	Agent quantity	***759 kg.***
Actual total leakage, A_t	***0,0734 m^2***	Minimum concentration, C_{min}	***7,89%***
Actual lower leakage, A_l	***0,0367 m^2***	Minimum retention time	***10,0 minutes***

Below ceiling leakage defaulting to worst case -- 50% of total leakage.

This enclosure was tested in compliance with ISO 14520.1 Annex E.
Assuming no continual mixing during the retention period, enclosure leakage could allow sufficient agent to be lost to cause an air/agent interface to descend from a Maximum Protected Height of **5,20 m.** to the Minimum Protected Height specified of **4,95 m.**
The retention time would then be **10,7 minutes** which exceeds the minimum retention time of **10 minutes**. The enclosure therefore **passes** this acceptance procedure.

Notes



Witnesses

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DOOR FAN TEST – Total Room Leakage Data

CleanAgent 2001 retention time prediction program revision 2.5.4. Complies with ISO draft standard 15420-1
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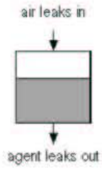

Building, Location ***INDUSTRIES S.P.A., TREBASELEGHE (PD), ITALIA***
Company, Contact ***SEI SICUREZZA, SIG. EDDO QUAGGIA***
Room name ***ARCHIVIO*** Test number ***1***
Calibration Certificate # ***3794*** Certificate created **2009/01/05**

Total Room Leakage

Operator Out of the room
Smoke doesn't move
Static pressure 0 Pa
Temperature during test (C) 20 inside 20 outside

Depressurization — Range for room pressures: -24,4 to -27,4

Blower range	Room pressure	-25,1
	Auto corrected RP	-25,1
Ring C8	Flow Pressure	89,7
	Auto corrected FP	89,7
	Corrected flow (m^3/sec.)	-0,3097

Pressurization — Range for room pressures: 24,4 to 27,4

Blower range	Room pressure	26,8
	Auto corrected RP	26,8
Ring C8	Flow Pressure	51,6
	Auto corrected FP	51,6
	Corrected flow (m^3/sec.)	0,2769

	ELA m^2	@Pa	F_A	Slope n	Intercept k_1	Correlation	Standard Error	ELA m^2		F
Pressurization	0,0786	25,1		0,5000	0,0618	NA	NA			
Depressurization	0,0680	26,8		0,5000	0,0535	NA	NA			
Average	0,0733	26,0	0,50	0,5000	0,0577			**0,0734**	10,0	0,50

Lower Leakage

Below ceiling leakage of 0,0367 m^2 @ 10,0 Pa is the worst case assumption of 50%

Technician: ***Cecilia Bertolini*** Certified to Level: ***No enclosure certification***

- ***No*** Level 1 - Fire enclosure design basics for improving agent retention and passive protection
- ***No*** Level 2 - adds single door fan operation and NFPA clean agent retention time calculations
- ***No*** Level 3 - adds double door fan operation for Lower Leak measurement
- ***No*** Level 4 - adds multi-point ISO door fan operation and discharge pressure relief vent

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DOOR FAN TEST -- Graph

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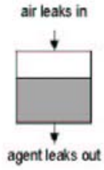
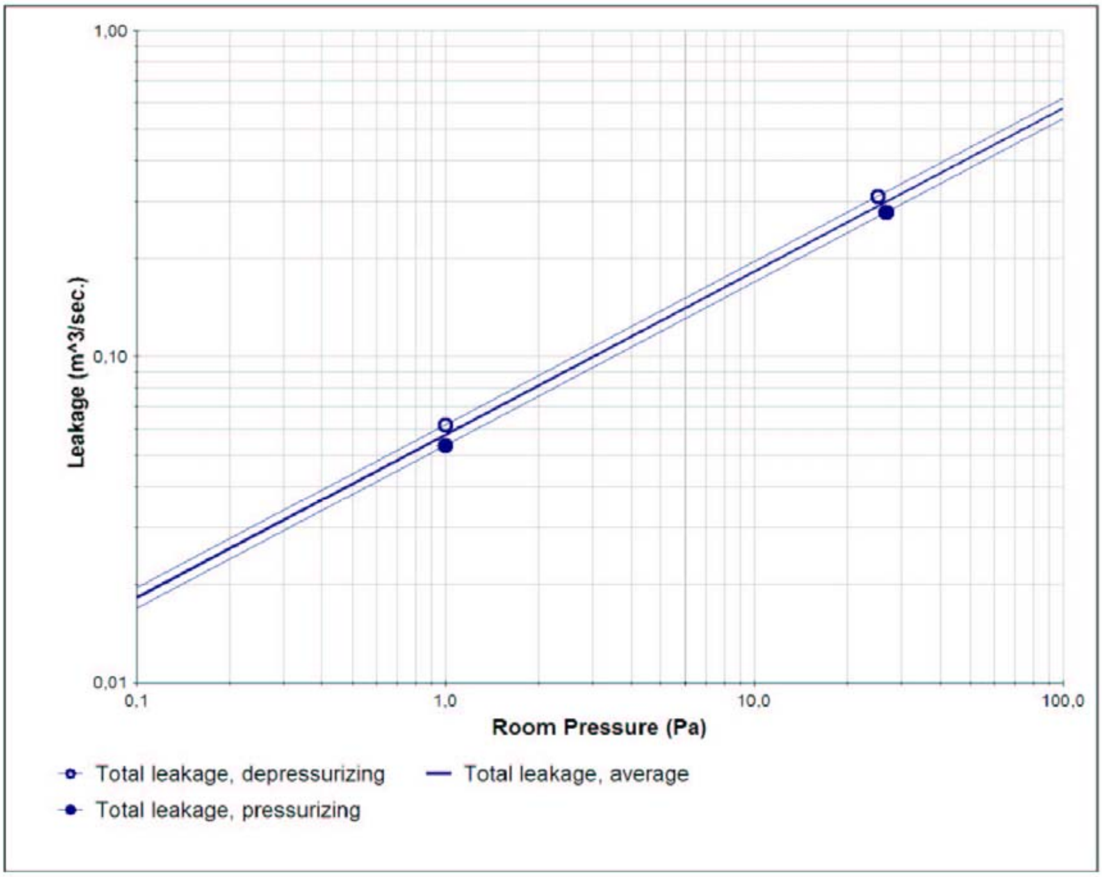


Building, Location ***INDUSTRIES S.P.A., TREBASELEGHE (PD), ITALIA***
Company, Contact ***SEI SICUREZZA, SIG. EDDO QUAGGIA***
Room name ***ARCHIVIO*** Test number ***1***
Calibration Certificate # ***3794*** Certificate created **2009/01/05**



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3.7 Overpressure in the enclosure volume

In halocarbon or inert gas fire fighting systems the overpressure inside the enclosure volume, after the gas discharge, depends on many factors related both the fire fighting system and the room.
In particular, pressurization depends on:

- total area of loss (openings and / or loss of volume);
- design gas concentration;
- Agent discharge speed (download time);
- Type of agent used

The type of the agent used characterizes directly the temporal evolution of the pressurization. The gas discharge generates a rapid increase in the pressure up to a maximum value followed by a relatively slow pressure reduction. The discharge of a Halocarbon instead generates an initial depressurization related to the cooling effects due to the changing phase (from liquid to vapour). Following an ambient pressurization caused by an heat transfer from the ambient to the cool air and the agent gas which is expanding .
Figure 1 and 2 show typical pressure trend for inert and halocarbon gas respectively and derive from a study conducted by Hughes Associates Inc. The enclosure pressure is expressed in *iwc* (inch of water column) a unit which is equal to 249.0889 Pa.

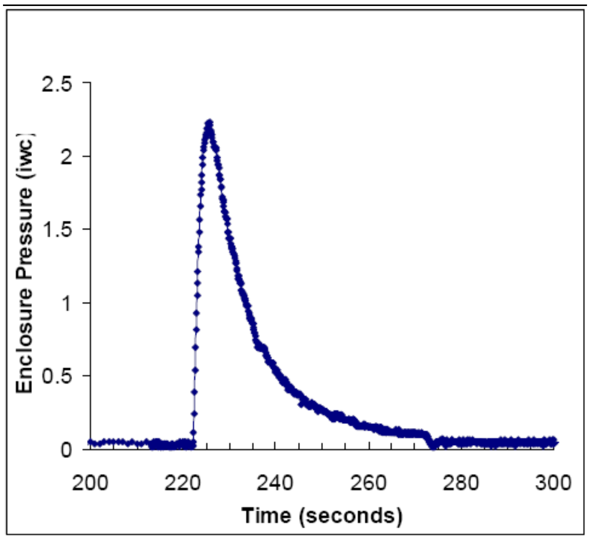

Fig. 1: Time evolution of the ambient pressure during the discharge of an inert gas.

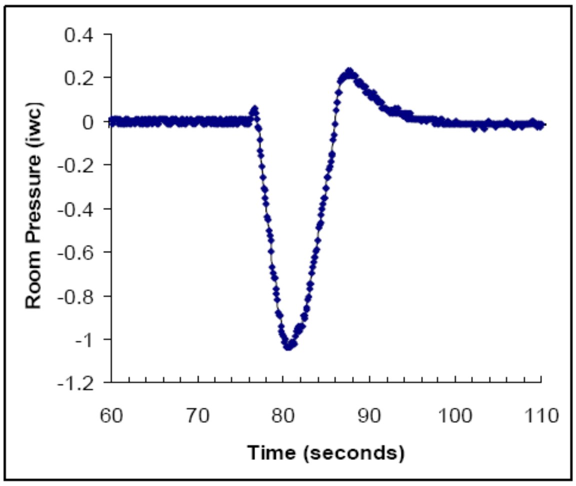

Fig. 2: Time evolution of the ambient pressure during the discharge of an halocarbon gas.

The pressurization of the enclosure volume must be carefully evaluated and, if necessary, must be provided appropriate relief surface
The strength of the enclosure volume can be determined using tables such as in tab. 1 that refers to the resistance values of typical building materials.
In practice, a resistance value of 500 Pa (50 mbar kgf/m2 or 5) is usually considered a conservative value.
The incorrect assessment of the pressurization of the enclosure volume could lead to destructive events such as those shown in Figures 3-5

Fig. 3: An example of a high pressurization of the enclosure volume (false ceiling)

Fig. 4: An example of a high pressurization of the enclosure volume.

Fig. 5: An example of a high pressurization of the enclosure volume.

The calculation of the pressurization of the enclosure room and, therefore, the evaluation of devices for pressure reduction is not currently regulated by a precise standards.
From a review of the literature, there are two methodologies that represent the state of the art:

1. CEA directive (Comité Européen des Assurances, (www.cea.eu) "Fire extinguishing systems using liquefied halocarbon gases: planning and installation" e "Fire extinguishing systems using non-liquefied inert gases: planning and installation";
2. Experimental data provided by Retrotec Inc. (www.retrotec.com), on years of experience and researce

CEA Directive

CEA directive "Fire extinguishing systems using liquified halocarbon gases: planning and installation" and "Fire extinguishing systems using non-liquefied inert gases: planning and installation" provides the following equation to calculate the area A [m2] pressure relief:

$$A = \frac{{M_P}^* \cdot v_P}{\sqrt{\Delta p \cdot v_{HOM}}} C_2 \qquad (1)$$

where

M_P^* ....= extinguishing gas flow [kg/s]

Δp ....= maximum allowable pressure of the structures of the protected volume ....[Pa]

v_p ....= extinguishing gas specific volume [m^3/kg]

v_{HOM}.............................= specific volume of the mixture [m^3/kg]

Specific volume v_{HOM} and density ρ_{HOM} of the mixture are given by:

$$v_{HOM} = x_{air} \cdot v_{air} + x_p \cdot v_p$$

$$\rho_{HOM} = \varepsilon_{air} \cdot \rho_{air} + \varepsilon_p \cdot \rho_p$$

where

ε ....= volume fraction ≤ 1

x ....= mass fraction ≤ 1

ρ_P ....= extinguishing gas density [kg/m^3]

ρ_{HOM}= .... mixture density .... [kg/m^3]

The coefficient C_2 is set equal to:

$$C_2 = \sqrt{\frac{C_1}{2}}$$

Where coefficient C1 is given by:

$$\Delta p = C_1 \frac{\rho_{HOM}}{2} w_{HOM}^2$$

where w_{HOM} [m/s] is the flow velocity.

The coefficient C_1 depends on the geometry of the opening and, in most cases, it is included in the following range: $0.5<C_1<2.5$. CEA directive suggests putting C_1 = 2 in the case of openings with a high resistance, this assumption simplifies the equation (1) because the coefficient C_2 is equal to 1

Experimental data Retrotec Inc.

Retrotec Inc., a company of reference for "Enclosure integrity tests" in accordance with EN 15004 (or NFPA 2001), has long been involved in a research project with the aim of assessing the pressurization of a room according to:

- Extinguishing gas discharged;
- VVR, venting to volume ratio, ie the ratio between the surface and the volume of openings in the same enclosure volume.

Experimentation allowed to collect a database of experimental data from which were determined for each gas extinguishing of the regression lines of the type *VVR=f(Δp)* [4]. The experimental curves have been implemented in a spreadsheet, shown in Figure.

NFPA 2001 (2008 Edition) Designer Analysis									
Flooded Enclosure Volume	3116	meters³ =	110119	feet³					
"**Specified** Enclosure Pressure **Limit**"	1200	Pascals =	25,06	lb/ft²					
Maximum Flooded height	2,5	meters =	8,2	feet					
Specified Retention Time	10	Minutes							
Lower Leak Fraction, F (0.15 to 0.55)	0,5	ratio of lower leaks to total leaks							
Leak Exponent, n (0.5 to 0.75)	0,500								
Allowable drop during **Specified Retention Time** is:	25%	in height or in concentration							
Agent >>>>>>>>	**IG-55**	**INERGEN**	**IG-55 Pro**	**IG-100**	**HFC-227ea**	**FK-5-1-12**	**HFC-125**	**HFC-23**	
Design concentration	42,3%	36,0%	40,0%	40,0%	7,0%	4,2%	7,0%	18,0%	%
Discharge time to 95% of design concentration is:	120	60	40	60	10	10	10	10	s
Required Area to keep Peak Pressure below **Specified Limit**	9269	15777	14338	17530	3327	4385	1524	12882	cm²

Fig. 6: Retrotec Inc. spreadsheet

Room characteristic

The archive reports in the example above door fan has a volume of 1213m^3.
In the room are present openings that have been quantified by the Door Fan Test Integry in an area of 0.0734 m^{2}as follows.
It is assumed that the facility type to withstand a pressure of 500 Pa (equal to 5 mbar or 50 kgf/m2) may be a reasonable maximum permissible value during discharge of the extinguisher.

PASS/FAIL Enclosure Integrity Report

CleanAgent 2001 retention time prediction program revision 2.5.4. Complies with ISO draft standard 15420-1
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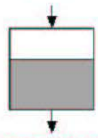
Building, Location ***XXXXX, Reggio Emilia, ITALIA***
Company, Contact ***XXXXX, SIG. XXXXX***
Room name ***ARCHIVIO*** Test number ***1***
Calibration Certificate # ***3794*** Certificate created **2009/01/05**



Test date/time	***2009/07/17 11.52***	Net protected volume, V_g	***1.213 m^3***
Tester	***Cecilia Bertolini***	Maximum Protected Height, H_o	***5,20 m.***
Certified to Level:	***No enclosure certification***	Minimum Protected Height, H	***4,95 m.***
Signature	....	Static during discharge, P_{SH}	***0,0 Pa***
Elevation above sea level	***0 m.***	Operating temperature	***20 C***
Correction method	***NFPA 2001 (2000) Formula A-3-5.3.3***	Initial concentration, C	***7,89%***
Correction factor	***1***	Mixing during retention	***No***
Agent	***FM200 (HFC227ea)***	Agent quantity	***759 kg.***
Actual total leakage, A_t	***0,0734 m^2***	Minimum concentration, C_{min}	***7,89%***
Actual lower leakage, A_l	***0,0367 m^2***	Minimum retention time	***10,0 minutes***

Extinguishing system

The room is protected with a fire extinguishing system fire extinguishing Halocarbon HFC227ea. In particular, the quantity needed to extinguish the fire, determined in accordance with the Italian standard EN 15004:2008, corresponds to a final volume of 7,9 %. the fire extinguishing system has been sized to discharge the gas in 10 s.

Calculation of the over pressure damper

The determination of the surface relief of pressure was determined with the relations of experimental Retrotec Inc., considered more reliable than the CEA report.
table 2 shows the characteristics of the environment to protect and plant shutdown required for determining the area of pressure relief.

Tab. 2: Caratteristiche dell'ambiente da proteggere ed dell'impianto di spegnimento.

Volume	1213 m^3
Maximum allowable pressure	500 Pa
Extinguishing gas concentration	7,9 %
Discharge time	10 s
"Natural" room opening	0,0734 m^2

The Retrotec Inc. spreadsheet, as shown in figure, indicates for the protected room a relief surface of 36 cm^2 (0.0366 m^2). Since the openings already present in the room is equal to 0.0496 m2 (quantified by Integrity Testing Door Fan), it is unnecessary to introduce any further area of pressure relief. Table 3 shows the results of calculating the pressure dampers.

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NFPA 2001 (2008 Edition)
Designer Analysis

Flooded Enclosure Volume	1213	meters^3 =	42867	feet^3
"**Specified** Enclosure Pressure **Limit**"	500	Pascals =	10,44	lb/ft^2
Maximum Flooded height	3	meters =	9,8	feet
Specified Retention Time	10	Minutes		
Lower Leak Fraction, F (0.15 to 0.55)	0,5	ratio of lower leaks to total leaks		
Leak Exponent, n (0.5 to 0.75)	0,500			
Allowable drop during **Specified Retention Time** is:	25%	in height or in concentration		

Agent >>>>>>>>	IG-55	INERGEN	IG-55 Pro	IG-100	HFC-227ea	FK-5-1-12	HFC-125	HFC-23	
Design concentration	40,3%	39,9%	40,3%	40,3%	7,9%	4,2%	7,0%	18,0%	%
Discharge time to 95% of design concentration is:	60	60	40	60	10	10	10	10	s
Required Area to keep Peak Pressure below **Specified Limit**	15572	15417	10939	15572	2630	3888	1291	10844	cm^2

Fig 8: Determining the area of pressure relief using spreadsheet Retrotec Inc

Tab. 3: Over pressure damper determination.

Area required for the vent overpressure	0,263 m2
No of overpressure damper	**1** **500x500**

Endnote

The analysis has dealt with the pressurization of the protected volume following the discharge of an extinguishing agent. In particular, it was done calculating the number of pressure reducing devices (overpressure dampers). The calculation was done based on experimental data collected by Retrotec Inc. and implemented in a spreadsheet. The Bettati overpressure damper requires no protective grill because, at rest, the damper is normally closed

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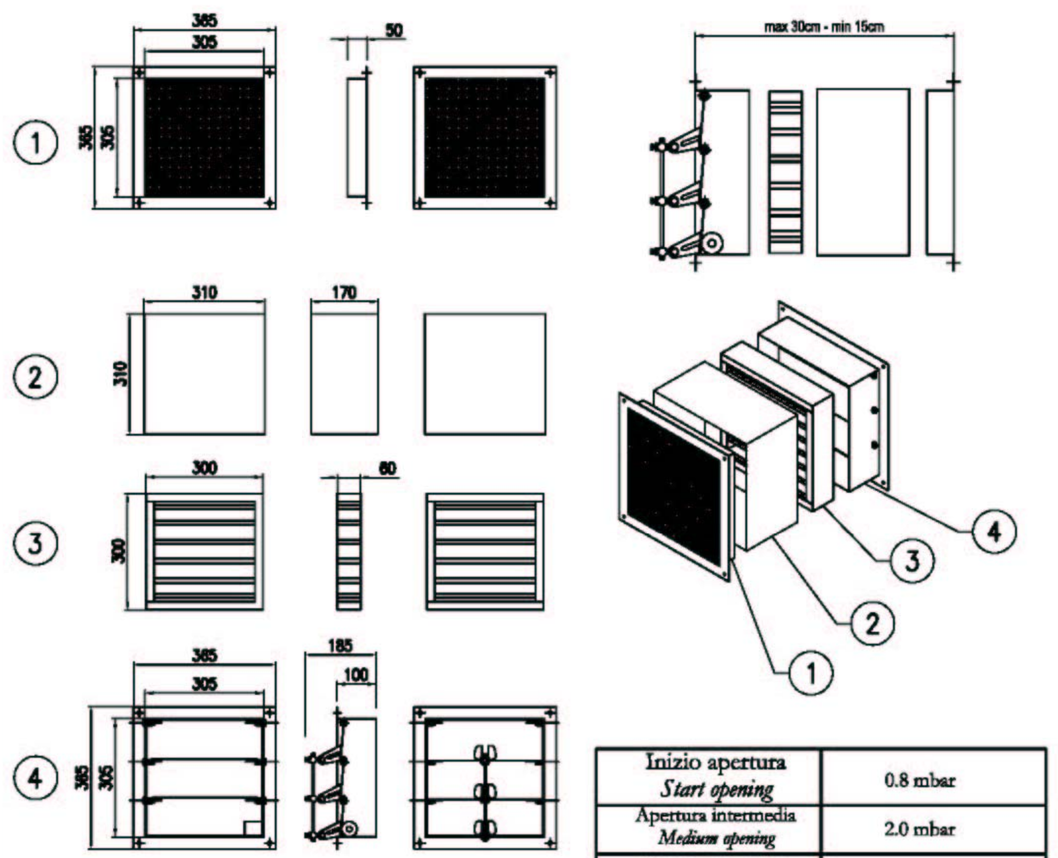
bettati ANTINCENDIO	Serranda di sovrappressione *Over pressure damper*	1022	
		Realizzato da: BERTOLINI	Approvato da: BETTATI

Serve a evitare una sovrappressione nel locale a seguito della scarica del gas inerte
It used to avoid a room overpressure for the discarge of the inert gases



Inizio apertura *Start opening*	0.8 mbar
Apertura intermedia *Medium opening*	2.0 mbar
Apertura completa *Complete opening*	3.5 mbar

4	Alette esterne con contrappesi / *External tongue with counter weight*	
3	Accessorio - serranda REI 120 / *Optional - dumper REI 120*	
2	Spessore / *Spacer*	
1	Griglia / *Wall secure damper*	
N°	DESCRIZIONE / *DESCRIPTION*	MATERIALE / *MATERIAL*

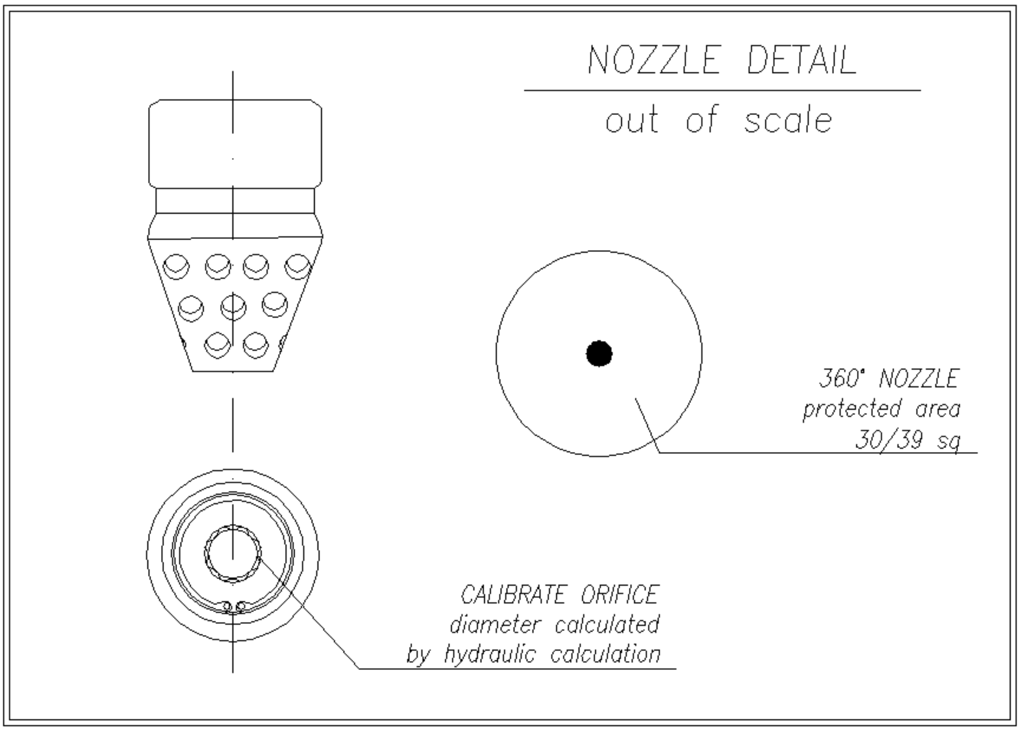
3.8 Nozzle selection and location (ref. EN 15004:1 chapter 6.3.6)

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 the Hughes Associates Inc. 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.
- m maximum protection height for single 360° and 180° nozzle



Bettati Antincendio srl has performed tests for verifying the characteristics of distribution of its nozzles at the Institute for Research and Testing, "M. Masini" the test was conducted according to the draft prEN 12094-7:2005, following the procedure described in section 5.4.3 of the standard.

The test room used had an area of 39.8 square meters and a volume of 139.4 m^3.

The results confirmed that all requirements are expressed by the standard in terms of distribution and concentration of oxygen delivered mass (flooding) declared by the manufacturer.

The value of oxygen after the download is included in the 13 ± difference measured by different sensors is equal to 0.4% less than 0.7% indicated by the standard measured within 60 seconds to download.

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M. MASINI S.r.l.

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Notificato CE 0068 – Accreditato SINCERT 047A – Accreditato SINAL 0019 -- Competent Body: EMC CE 2004/108 e BT CE 2006/95

Autorizzazioni:
Ministero delle Infrastrutture e dei Trasporti per legge 1086 – Ministero dell'Università e della Ricerca Scientifica e Tecnologica per Legge 46/82 - Ministero delle Attività Produttive – Ministero dell'Interno per prove reazione al fuoco, estintori portatili e carrellati, evacuatori di fumo e calore - Ministero della Salute per analisi in BPL e prove I.S.P.E.S.L. – Regione Lombardia per analisi acque potabili e non - Ministère de l'Industrie, de la Poste et des Télécommunications per pentole a pressione e verifiche di sorveglianza alla produzione

Certificazione di prodotto – Controlli non distruttivi – Prove tecnologiche – Termografia – Prove termotecniche – Rilievi estensimetrici – Prove calcestruzzi – Geotecnica Analisi chimica – Agroalimentare – Cosmesi – Metallografia – Microscopia elettronica – Sicurezza – Ecologia – Controllo qualità – Ricerche – Consulenze

Rho, 29 Settembre 2006

Spett. le
BETTATI ANTINCENDIO S.r.l.
Via Disraeli, 8
42100 REGGIO EMILIA

RAPPORTO DI PROVA N. 3537-2006
foglio 1 di 4

OGGETTO: VERIFICA DELLE CARATTERISTICHE DI DISTRIBUZIONE DI UGELLI PER IMPIANTI DI GAS INERTE.

In data 28 settembre sono state effettuate verifiche su ugelli per impianti fissi di estinzione di incendi al fine di verificare le caratteristiche di distribuzione durante la scarica di estinguenti costituiti da gas inerti.
La verifica è stata effettuata in accordo al progetto di norma prEN 12094-7:2005, seguendo la procedura descritta al punto 5.4.3 della norma.

Gli ugelli provati sono stati così identificati:
- ugello in alluminio da 1"
- ugello di alluminio da 1,5 "

Le prove sono state effettuate in camera di prova utilizzando azoto con gas inerte e monitorando la concentrazione di ossigeno nelle sei zone previste dalla norma verificando il rispetto di quanto indicato in essa al termine dell'erogazione della quantità dichiarata dal costruttore di gas estinguente.

Le condizioni di prove ed i risultati delle stesse sono riportate nelle pagine seguenti.

L'esito del presente rapporto di prova, riproducibile solo nella sua stesura integrale, si riferisce ai soli campioni esaminati.

Il Tecnico di laboratorio	Il Direttore

Camera di prova

Costruzione in cemento armato.

lunghezza (mm)	7920
larghezza (mm)	5030
Altezza (mm)	3500
Area (m^2)	**39.8**
Volume (m^3)	**139.4**

Impianto di distribuzione gas estinguente

La distribuzione del gas estinguente avviene attraverso bombole da 140 kg pressurizzate con ca 300 bar di azoto, distribuito attraverso una linea in acciaio all'ugello.

Strumentazione e Sistema di Acquisizione dati

I dati di prova rilevati in accordo alla norma comprendono la misura delle pressioni in tre posizioni:
a) linea gas estinguente all'uscita della bombola
b) linea gas estinguente dopo il restrictor (diametro 7 mm)
c) linea gas estinguente all'ingresso dell'ugello (con diaframma da 14 mm)
I segnali dal trasduttore di pressione sono acquisiti con cadenza di 5 scansioni al secondo mediante moduli multiplexer gestiti da software LbView e Max della stessa casa.
La misura dell'ossigeno è stata effettuata mediando i valori di ossigeno misurati nelle sei posizioni indicate dalla norma al punto 5.4 figura 1, utilizzando sensori di tipo elettrochimico con uscita seriale su PC e visualizzati e registrati con programma di tipo terminal. La cadenza di lettura era di ca 6 scansioni secondo con media su ogni secondo.
Per la misura del gas erogato le bombole sono state poste su bilancia digitale in grado di visualizzare il decimo di kg.

Dati dichiarati dal produttore

Flooding mass:
dichiarata dal produttore per una riduzione del livello di ossigeno al 13±1 % pari 72,5 kg per entrambi gli ugelli.

Risultati

La prova è stata condotta sui due diversi ugelli separatamente misurando i dati provenienti dai sensori di pressione, dai misuratori di concentrazione dell'ossigeno e dal sistema di pesatura delle bombole. Sono stati rilevati i dati prima della prova e durante la scarica.
La scarica è stata interrotta dopo l'erogazione della flooding mass dichiarata verificando il rispetto dei limiti di ossigeno indicati dalla norma e la permanenza in tali condizioni per ulteriori 60 secondi.
Nelle tabelle in allegati 1 e 2 e nei grafici da esse derivate e riportati a pag. 4, vengono riportati i dati di pressione in funzione al tempo di scarica rilevati durante la prova per ciascuno degli ugelli e i valori di ossigeno misurati nelle stesse condizioni.

Conclusioni

Per entrambi gli ugelli vengono rispettati i requisiti espressi dalla norma in termini di distribuzione e di concentrazione di ossigeno erogando la massa (flooding) dichiarata dal costruttore.
Il valore di ossigeno al termine della scarica è compreso nel 13±1 % e la differenza misurata dai diversi sensori è pari a 0,4 % inferiore allo 0,7 % indicato dalla norma misurato nei 60 secondi successivi alla scarica.

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3.9 Pipeline 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.

Table: Pipe type for extinguishing gas system HFC125 HFC227ea

	Pipe	Schedule	Diameter (inches)	Material	Thread	Pipe
Placed after the orifice plate without directional valves	API 5LGRB	40	½” ¾” 1” 1”1/4 1”1/2 2” 2”1/2 3”	2.77 2.87 3.38 3.56 3.68 3.91 5.16 5.49	ASTM A-106 Galvanized seamless	NPT

Table: Pipe type for extinguishing gas system HFC23

	Pipe	Schedule	Diameter (inches)	Material	Thread	Pipe
Placed after the orifice plate without directional valves	API 5LGRB	40	1” 1”1/4 1”1/2 2” 2”1/2 3”	3.38 3.56 3.68 3.91 5.16 5.49	ASTM A-106 Galvanized seamless	NPT

Fittings	Type	Material	Screw thread
Placed after the orifice plate without directional valves	ASA 3000	ASTM A-105 galvanized	NPT

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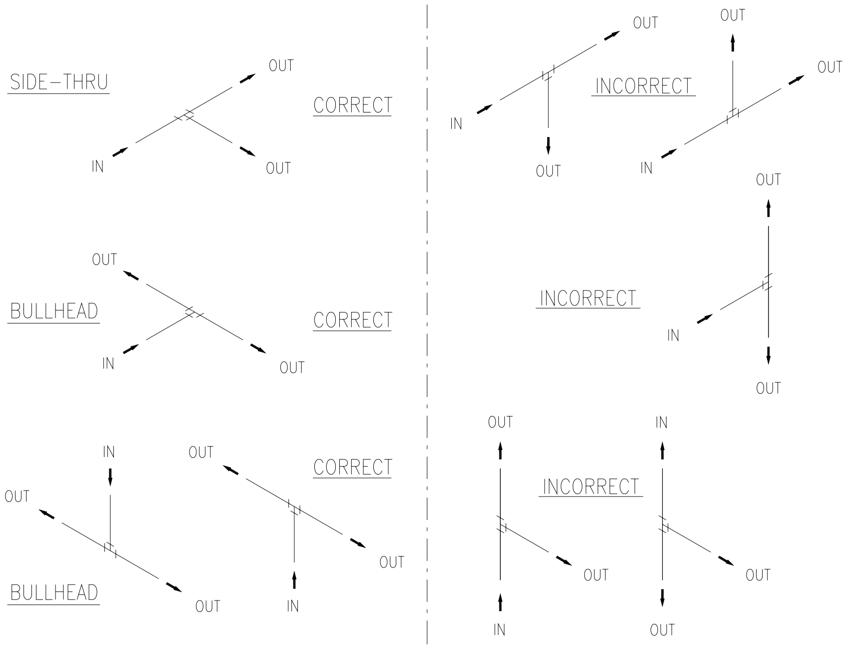
3.10 Tee Orientation

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 Estimating Pipe Sizes

The following are approximate flow rate for estimating pipe sizes:

HFC-125 Sch40	
Inches	**Kg/sec x 10sec**
1/2”	0-16
3/4“	17-27
1”	28-39
1”1/4	40-60
1”1/2	61-90
2”	91-160
2”1/2	161-270
3”	271-440
4”	441-600

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

HFC-23 Sch80	
Inches	**Kg/sec x 10sec**
1/2”	0-8
3/4“	9-15
1”	16-25
1”1/4	26-40
1”1/2	41-80
2”	81-140
2”1/2	141-190
3”	191-265
4”	266-380

NOTE – The Hughes Associates Inc. flow calculation programme must be used to verify exact pipe sizes, nozzles orifices for all systems designs and installations.

3.12 Pipes Hangers and Support (EN 15004-1 chapter. 6.3.4)

All support and parts thereof shall conform to the requirements for EN-15004.

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

3.13 Design example calculation according to EN 15004

The main step to follow when designing a extinguishing gas system are:

1. Inspection to verify the volumes to be protected
2. Risk analysis
3. Choosing gas extinguishing
4. Choice of system components EN12094 and CE marked PED \ TPED
5. Preliminary calculation of the quantity of gas extinguishing
6. Design of distribution network
7. Verification of the above by hydraulic calculation software
8. System Installation
9. System start-up
10. Carry out the door fan integrity test
11. Management (the ordinary and extraordinary maintenance)

3.13.1 Inspection

During the inspection is necessary to note the following information if not already in our possession

<table>
<tr><th colspan="4">Data to be collected during the inspection</th></tr>
<tr><td rowspan="2">Room Location</td><td colspan="3"></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Application</td><td colspan="3"></td></tr>
<tr><td rowspan="2">System to be implemented</td><td colspan="3"></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td>Altitude a.s.l</td><td></td><td>Temperature °C</td><td></td></tr>
<tr><td rowspan="6">Mechanical system surveys to be carried out and indicated in the plan</td><td colspan="2">If not available dimension of the room</td><td></td></tr>
<tr><td colspan="2">Type of masonry and / or celing</td><td></td></tr>
<tr><td colspan="2">Cylinder displacement</td><td></td></tr>
<tr><td colspan="2">Possible path distribution pipes and nozzles</td><td></td></tr>
<tr><td colspan="2">Presence of primary air conditioning system</td><td></td></tr>
<tr><td colspan="2">Any facilities that may affect the placement of cylinders, nozzles, tubes</td><td></td></tr>
</table>

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	and accessories	
	Presence openings can not be eliminated	
	State of the supports	
	Any openings not confined to unprotected adjacent areas	
	Any existing installation: brand / model tanks - brand / model valve - charge / gas extinguishing type - diameter / length of existing pipe	

3.13.2 Risk analisys

The risk for this example is a paper archive a risk class A

Table 4 - (Ref. EN 15004-4 Ed.2008)

Fuel	Exinguishing %	Minimum design %
Class B Heptane (cup burner) Heptane (room test)	6,7 6,7	9,0
Class A Wood crib PMMA PP ABS	4,9 6,1 6,1 6,1	7,9
Class A High Hazard	a	8,5

3.13.3 Gas extinguishing choosing

Depending on the requests received by the customer we have decided to install a fire extinguishing gas Halocarbon.

3.13.4 Choice of system components EN12094 and CE marked PED \ TPED

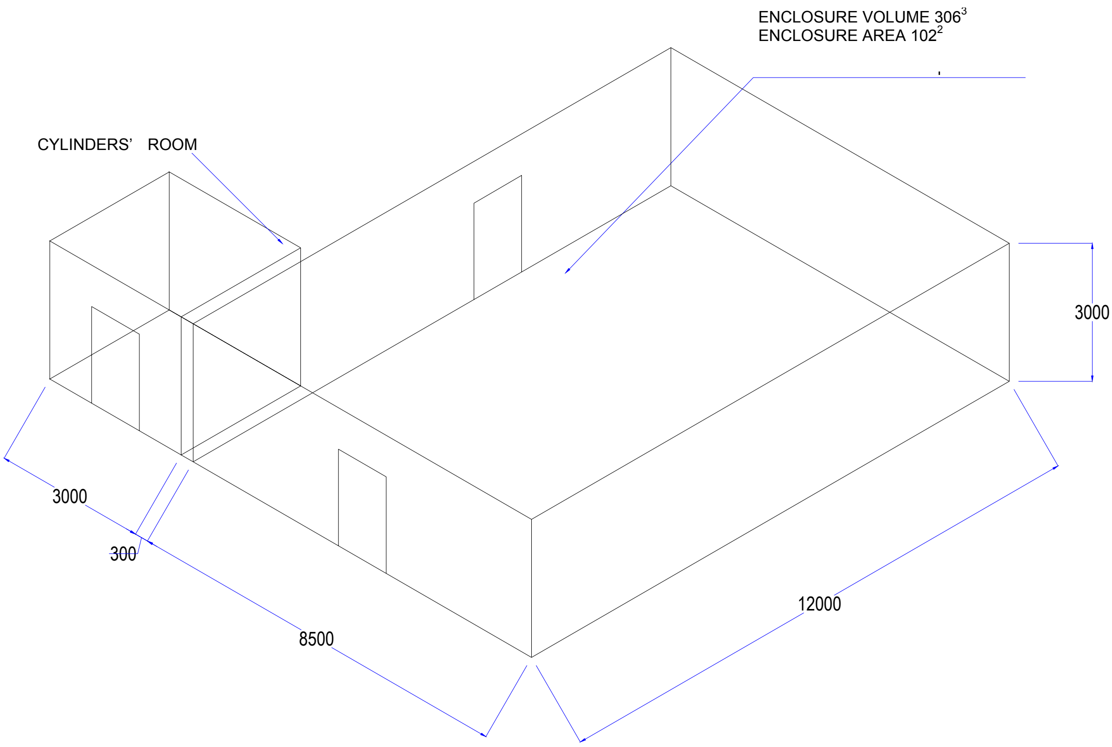
Marking according to European Directive PED 97/23/EC transposed in Italy by DL 93, 25/02/2000:
Applies to the design, manufacture and conformity assessment of pressure equipment (vessels, piping, safety accessories and pressure accessories) and assemblies with a maximum allowable pressure PS exceeding 0,5 bar.
Marking according to European Directive CE 89/106/EC transposed CPD DPR 246, 21/04/93:
This directive is born, as well as the PED and TPED, within the European Community Programme designed to remove technical barriers to trade and fall under the directives of such new approach to technical and regulatory.
The aim is to harmonize the national laws of individual member states for the design, construction, testing and conformity assessment of the components of firefighting equipment in order to introduce into the market products that respect because of harmonized technical standards, performance requirements and we common security and mutually accepted by member states
Bettati Antincendio srl has submitted its products to the assessment of notified bodies that have certified compliance with Directive 97/23/EC (PED) and verified compliance with the harmonized standards EN 12094 series of CPD.

Product	Notified body	Serial ID Notified body	Standard reference
Inert gas valve and	Consortium	**0474**	97/23/CE - PED

actuator VHFCx	RINA-OMECO		
Inert gas valve and actuator VHFCx	Testin and research istitute "M. Masini"	**068**	EN 12094 part 4:2004
Directional valve and actuator	Testin and research istitute "M. Masini"	**068**	EN12094 Part 5:2006
Check valve and non-returne valve VNRH	Testin and research istitute "M. Masini"	**068**	EN 12094 part 13:2002
Flex hose	Testin and research istitute "M. Masini"	**068**	EN 12094 part 8:2006

3.13.5 Preliminary calculation of the quantity of gas extinguishing

The risk is represented by a paper archive.



Volume = 306 m³
Local temperature = 20°C
Minimum project concentration of HFC227EA according to the EN 15004.4 Ed.2008
c = 6,1%+30% = 7,9%
Using the following equation (EN 15004 parte 4 Ed.2008):

$$S = k_1 + k_2 \cdot T = 0{,}1269 + 0{,}000513 \cdot 20 = 0{,}1375$$

$$m = \frac{V}{S} \cdot \left(\frac{c}{100 - c} \right) = \frac{306}{0{,}1375} \cdot \left(\frac{7{,}9}{100 - 7{,}9} \right) = 190{,}8913237$$

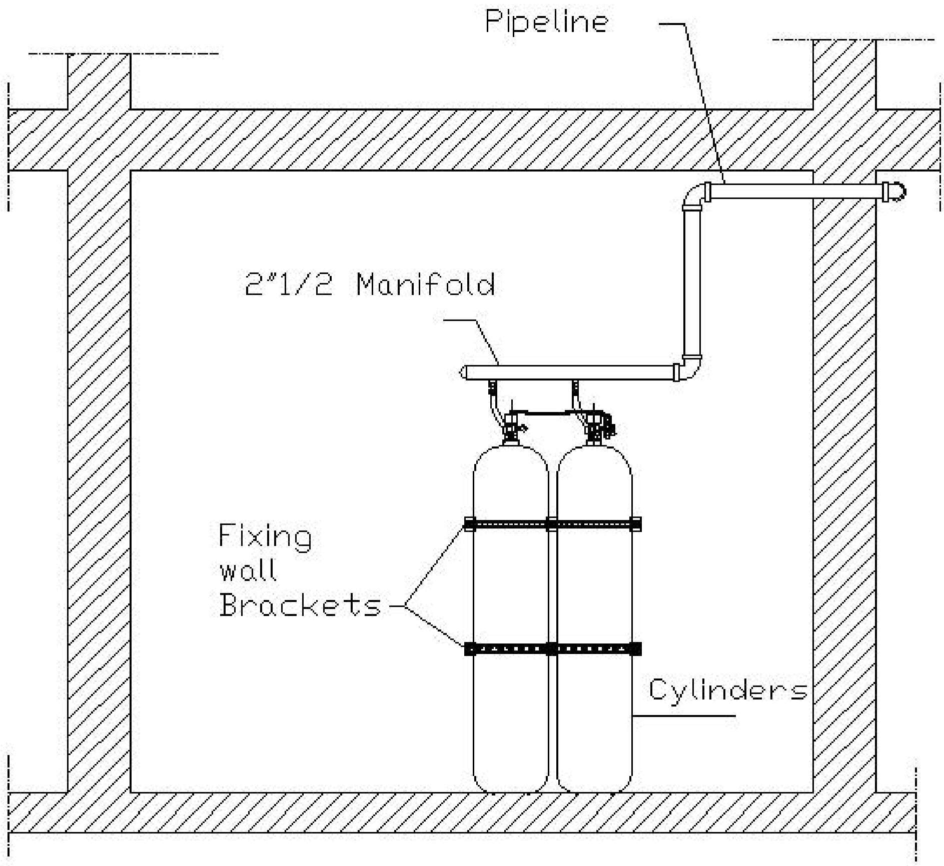
$$x = \frac{m}{V} = \frac{190{,}8913237}{306} = 0{,}6238$$

The value was obtained as 7,9% is not present in table 3.3.

The project quantity of HFC227EA in Kg is: $190{,}8913237$ [kg]

$Q_{real} = Q_{design} + 0{,}1086763 = 191$ [kg]

Number of cylinders: $N = \frac{Q_{real} / 1{,}12}{120} = 1{,}4211 \Rightarrow 2$ x 120lt Cylinders



CYLINDERS
LAYOUT

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Formulas taken from EN 15004 – 4 Ed. 2008

DATE

MINIMUM DESIGN CONCENTRATION	7,9
TEMPERATURE [°C]	20
ROOM VOLUME* [m^3]	306
SPECIFIC VOLUME AT 20°C [m^3/KG]	0,1373
MAXIMUM FILL DENSITY kg/l	1,12
MINIMUM FILL DENSITY kg/l	0,5
DISCHARGE TIME [s]	10

RESULTS

QUANTITY OF HFC227ea Kg	190,88

* For deductible part we mean volume impermeable to gas

CYLINDERS	lt	Kg min.	Kg max	n. cylinders
	14	7	15,68	13
	27	13,5	30,24	7
	50	25	56	4
	60	30	67,2	3
	75	37,5	84	3
	120	60	134,4	2
	150	75	168	2

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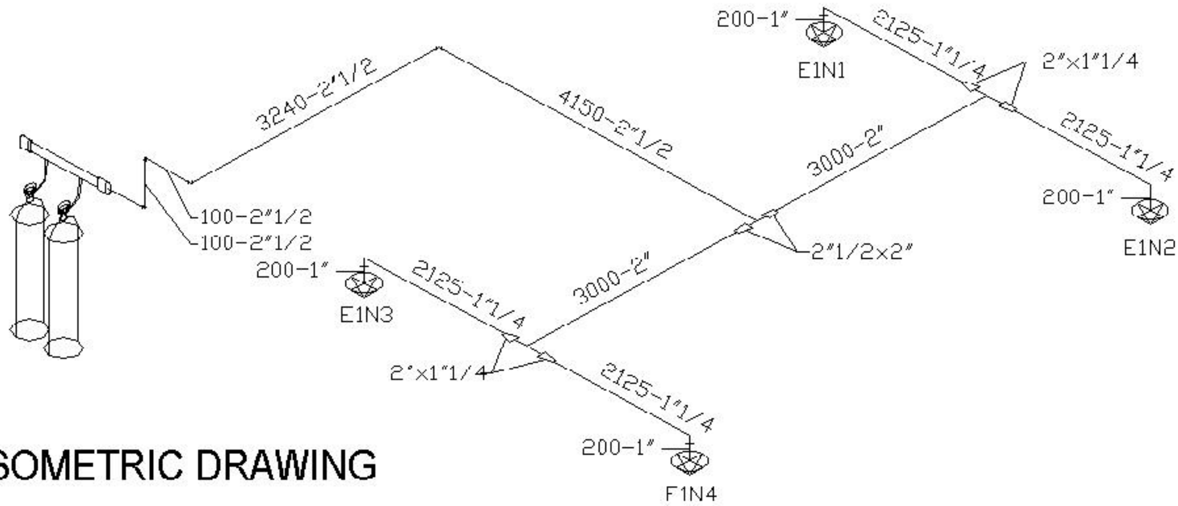
3.13.6 Design of distribution network

Depending on the room geometry has adopted this balanced distribution to H

Isometric view of the distribution of diameters and lengths between cylinders and nipples



ISOMETRIC DRAWING

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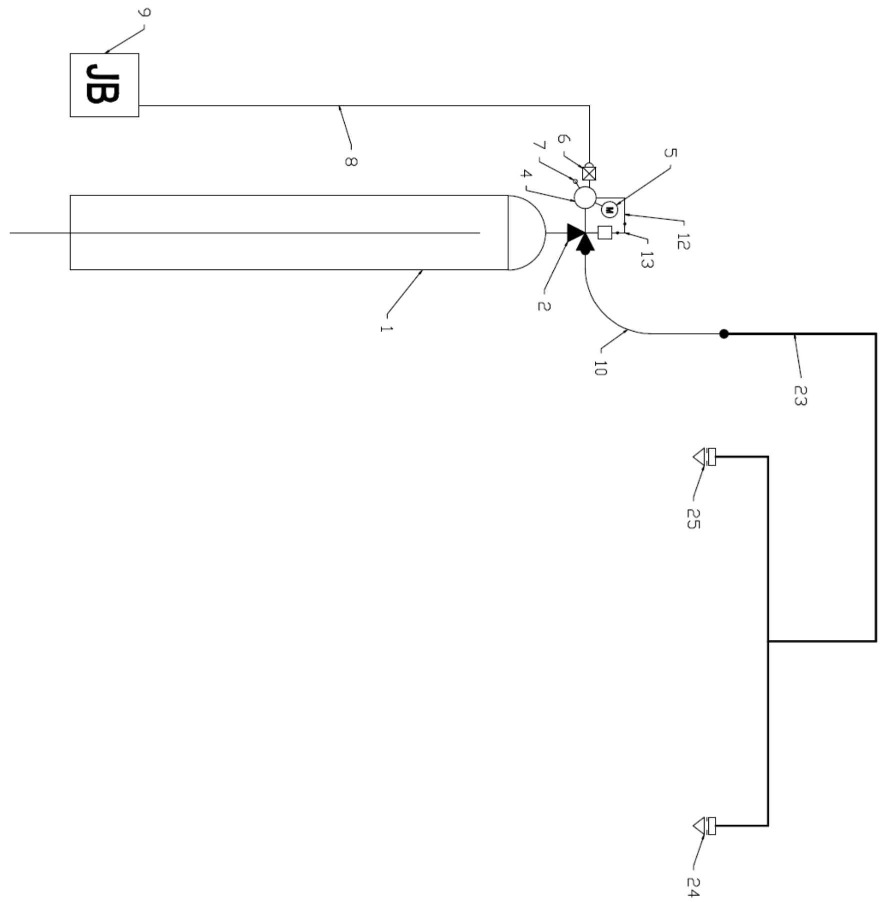
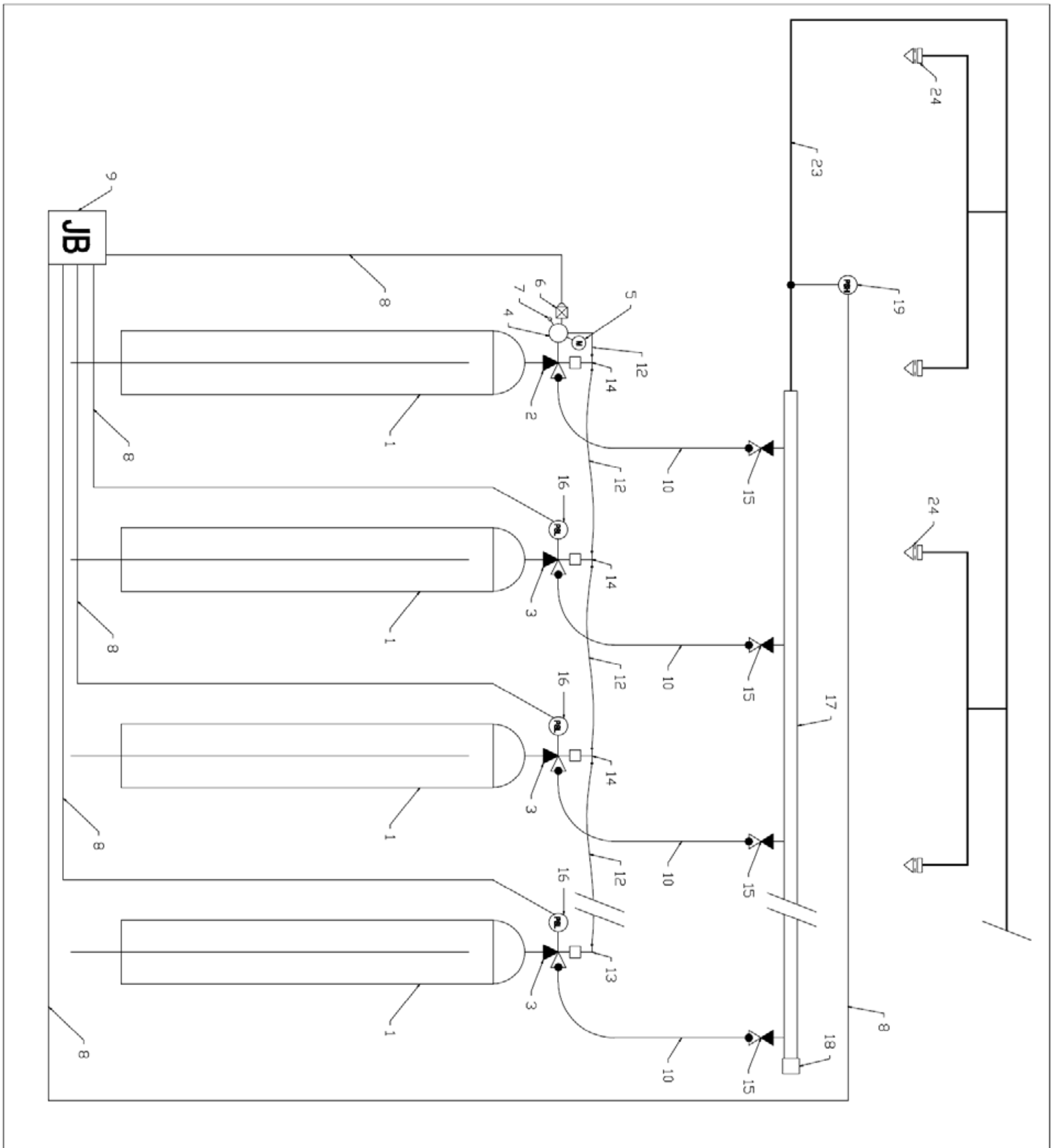
SINGLE CYLINDER



POS.	DESCRIZIONE / *DESCRIPTION*	DIS./ *DRAW.*
24	Ugello / *Nozzle*	8
22	Tubazione sch. 40 / *Pipeline sch. 40*	
21		
20		
19		
18		
17		
16		
15		
14		
13	Curva / *Elbow* 1/4" GAS x 1/4" NPT	
12	Manichetta flessibile di pilotaggio / *Pilot flex hose*	9
11		7
10	Manichetta flessibile di scarica per sistemi modulari *Discharge flex hose modular system*	10
9	Cassetta di derivazione / *Junction box*	
8	Collegamento elettrico / *Wiring connection*	
7	Comando manuale / *Manual actuator*	
6	Bobina 24 Vcc 11W / *Solenoid actuator 24 Vcc 11W*	
5	Manometro 0-400 bar con contatto elettrico / *Pressure gauge 0-400 bar with electric contact*	
4	Comando elettrico manuale con manometro pressostato *Manual solenoid actuator with gauge and pressure switch assembly*	3
3		
2	Valvola pilota / *Pilot valve*	4
1	Bombola halocarbon / Halocarbon *cylinder 14,27,50,75,120 lt*	1

IMPIANTO AD HALOCARBON PER SISTEMI MODULARI
HALOCARBON SYSTEM FOR MODULAR SYSTEM

MULTIPLE CYLINDERS



IMPIANTO AD HALOCARBON
PER SISTEMI CENTRALIZZATI
HALOCARBON SYSTEM FOR
CENTRAL STORAGE SYSTEM

POS.	DESCRIZIONE / DESCRIPTION	DIS./ DRAW.
1	Bombola halocarbon / Halocarbon cylinder 14,27,50,75,120 lt	1
2	Valvola pilota / Pilot valve	4
3	Valvola pilotata / Slave valve	8
4	Comando elettrico manuale con manometro pressostato / Manual solenoid actuator with gauge and pressure switch assembly	3
5	Manometro 0-400 bar con contatto elettrico / Pressure gauge 0-400 bar with electric contact	
6	Bobina 24 Vcc 11W / Solenoid actuator 24 Vcc 11W	
7	Comando manuale / Manual actuator	
8	Collegamento elettrico / Wiring connection	
9	Cassetta di derivazione / Junction box	10
10	Manichetta flessibile di scarica / Discharge flex hose	
12	Curva / Elbow 1/4" GAS x 1/4" NPT	
13	Raccordo a T 1/4" / Tee connection 1/4"	
14	Valvola di ritegno / Check valve	
15		11
16	Gruppo manometro pressostato / Pressure gauge and pressure switch assembly	5
17	Collettore di scarica / Discharge manifold	12
18	Tappo uscita collettore / Manifold cap	13
19	Pressostato impianto intervenuto / Pipe line pressure switch	14
20		
21		
22		
23	Tubazione sch. 40 / Pipeline sch. 40	
24	Ugello / Nozzle	8

3.13.7 Verification of the above by hydraulic calculation software

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Phone: +39 522 369711
AgentCalcs for HFC-227ea - 42 bar (600 psi)
File Name: C:\Programmi\Hughes Associates\AgentCalcs for HFC-227ea GEN310\Projects\manuale
Calculation Date/Time: martedì 18 maggio 2010, 15:46:25

Consolidated Report

Customer Information

Company Name:
Address:

Phone:
Contact:
Title:

Project Data

Project Name:
Designer: Bettati Antincendio srl
Number:
Account:
Location:
Description:

Page: 1 of 7

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Consolidated Report
Enclosure Information

Elevation:	0 m (relative to sea level)
Atmospheric Correction Factor:	1
Enclosure Number:	1
Name:	Ambiente
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
Adjusted Agent Required:	192,0 kg
Number of Nozzles:	4

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Consolidated Report
Agent Information

Agent:	HFC-227ea / Propellant N2
Adjusted Agent Required:	192,0 kg
Container Name:	120 L
Container Part Number:	
Number of Main Containers:	2
Number of Reserve Containers:	0
Manifold:	Baseline, Center, 2 Cyls, Up
Pipe Take Off Direction:	Up
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

Part 1 - Pipe

Description	Start	End	Type	Diameter	Pipe Length	Elevation
Main Cyl. X 2	0	1			1,00 m	1,00 m
Manifold X 2	1	2	40T	50 mm	0,50 m	0,31 m
Manifold X 2	2	3	40T	65 mm	0,46 m	0,00 m
Pipe	3	4	US40GTS	65 mm	0,10 m	0,10 m
Pipe	4	5	US40GTS	65 mm	0,10 m	0,00 m
Pipe	5	6	US40GTS	65 mm	3,24 m	0,00 m
Pipe	6	7	US40GTS	65 mm	4,15 m	0,00 m
Pipe	7	8	US40GTS	50 mm	3,00 m	0,00 m
Pipe	8	9	US40GTS	32 mm	2,12 m	0,00 m
Pipe/E1-N1	9	10	US40GTS	25 mm	0,20 m	-0,20 m

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Consolidated Report

Part 1 - Pipe

Description	Start	End	Type	Diameter	Pipe Length	Elevation
Pipe	8	11	US40GTS	32 mm	2,12 m	0,00 m
Pipe/E1-N2	11	12	US40GTS	25 mm	0,20 m	-0,20 m
Pipe	7	13	US40GTS	50 mm	3,00 m	0,00 m
Pipe	13	14	US40GTS	32 mm	2,12 m	0,00 m
Pipe/E1-N4	14	15	US40GTS	25 mm	0,20 m	-0,20 m
Pipe	13	16	US40GTS	32 mm	2,12 m	0,00 m
Pipe/E1-N3	16	17	US40GTS	25 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	4,60 m
1	2	0	0	0	0	0		3,00 m	3,47 m
2	3	1	0	0	1	0		0,00 m	6,55 m
3	4	0	0	0	0	0		0,00 m	0,09 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	1,07 m
8	11	0	0	0	1	0		0,00 m	4,42 m
11	12	1	0	0	0	0		0,00 m	1,07 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	1,07 m
13	16	0	0	0	1	0		0,00 m	4,42 m
16	17	1	0	0	0	0		0,00 m	1,07 m

Part 3 - Nozzles

Start	End	Flow	Name	Size	Type	Nozzle Area
0	1	96,0 kg				
1	2	96,0 kg				
2	3	96,0 kg				

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Part 3 - Nozzles

Start	End	Flow	Name	Size	Type	Nozzle Area
3	4	192,0 kg				
4	5	192,0 kg				
5	6	192,0 kg				
6	7	192,0 kg				
7	8	96,2 kg				
8	9	48,1 kg				
9	10	48,1 kg	E1-N1	25 mm	Metric	334,52 square mm
8	11	48,1 kg				
11	12	48,1 kg	E1-N2	25 mm	Metric	334,52 square mm
7	13	95,8 kg				
13	14	47,9 kg				
14	15	47,9 kg	E1-N4	25 mm	Metric	334,52 square mm
13	16	47,9 kg				
16	17	47,9 kg	E1-N3	25 mm	Metric	334,52 square mm

Parts Information

Total Agent Required: 192,0 kg
Container Name: 120 L
Number Of Containers: 2
Manifold: Baseline, Center, 2 Cyls, Up

Nozzle	Type	Diameter	Nozzle Area	Part Number
E1-N1	Metric	25 mm	334,52 square mm	
E1-N2	Metric	25 mm	334,52 square mm	
E1-N3	Metric	25 mm	334,52 square mm	
E1-N4	Metric	25 mm	334,52 square mm	

Nozzle	Drill Diameter	Drill Size
E1-N1	20,6000 mm	13/16
E1-N2	20,6000 mm	13/16
E1-N3	20,6000 mm	13/16
E1-N4	20,6000 mm	13/16

Pipe:	Type	Diameter	Length
	US40GTS	25 mm	0,80 m

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Pipe:	Type	Diameter	Length
	US40GTS	32 mm	8,48 m
	US40GTS	50 mm	6,00 m
	US40GTS	65 mm	7,59 m
	40T	50 mm	1,00 m
	40T	65 mm	0,91 m

List of 90 degree elbows:
4 - 25 mm
5 - 65 mm

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

System Acceptance

System Discharge Time: 8,9 seconds
Percent Agent In Pipe: 38,6%
Percent Agent Before First Tee: 22,8%

Enclosure Number: 1
Enclosure Name: Ambiente

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	48,1 kg	48,0 kg	14,318 bar
E1-N2	48,0 kg	48,1 kg	48,0 kg	14,318 bar
E1-N3	47,9 kg	47,9 kg	48,0 kg	14,318 bar
E1-N4	47,9 kg	47,9 kg	48,0 kg	14,318 bar

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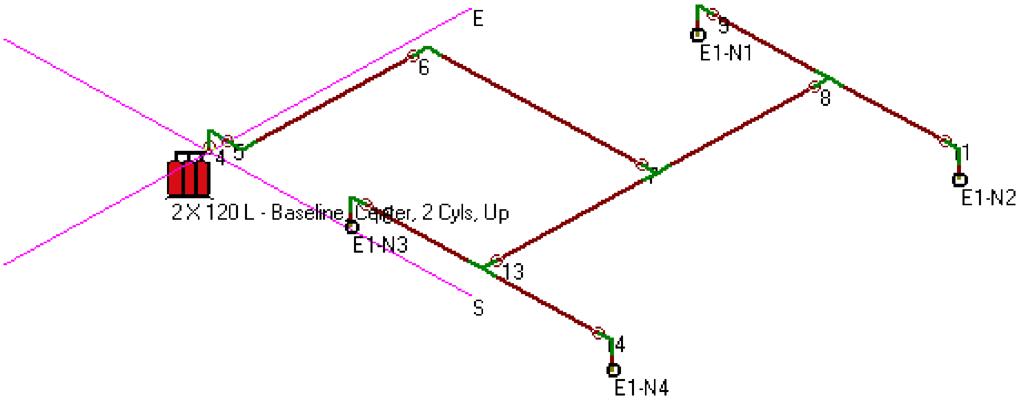
Standard Isometric View



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3.13.8 System installation
See: "Installation manual for halocarbon gas system"

3.13.9 System start-up
See: "Installation manual for halocarbon gas system"

3.13.10 Carry out the door fan integrity test
See: "Installation manual for halocarbon gas system"

3.13.11 Management (the ordinary and extraordinary maintenance)
See: "Maintenance manual"