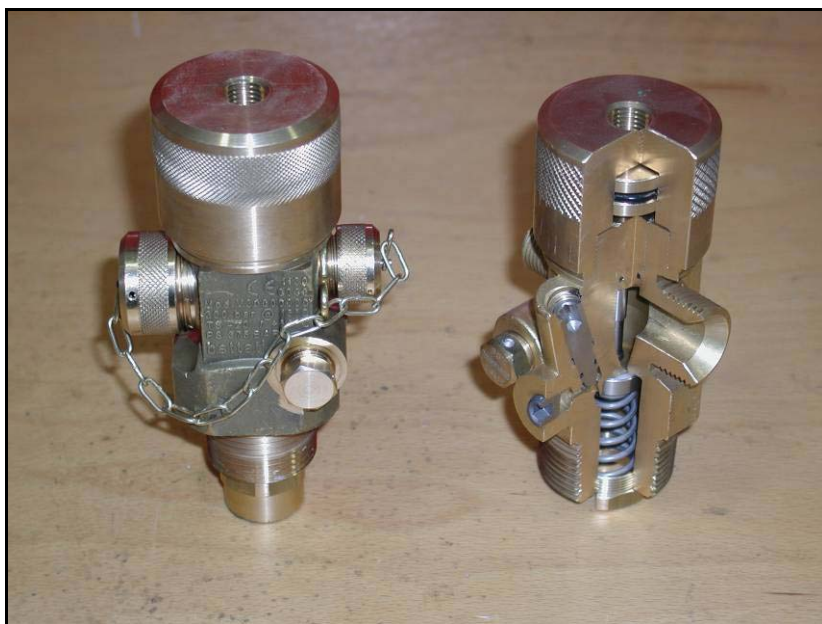


DESIGN MANUAL

FOR INERT GAS SYSTEM

IG 100 – IG 01 – IG 55 – IG 541



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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 “Argon IG01”, “Nitrogen IG100”, “Nitrogen+Argon IG55” e “Nitrogen+Argon+CO₂ IG541” 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 Nitrogen chemical and physical characteristics, and contains design technical specifications and safety requirements.

Working pressure of designed systems are 200 and 300 bar.

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 agent “Argon IG01”, “Nitrogen IG100”, “Nitrogen+Argon IG55” and “Nitrogen+Argon+CO₂ IG541” are designed according to these standards:

- ✚ EN 15004-1:2008 “Fixed firefighting systems. Gas extinguishing systems. Part 1: Design, installation and maintenance”.
- ✚ EN 15004-7:2008 “Fixed firefighting systems. Gas extinguishing systems. Part 7: Physical properties and system design of gas extinguishing systems for IG-01 extinguishant”.
- ✚ EN 15004-8:2008 “Fixed firefighting systems. Gas extinguishing systems. Part 8: Physical properties and system design of gas extinguishing systems for IG-100 extinguishant”.
- ✚ EN 15004-9:2008 “Fixed firefighting systems. Gas extinguishing systems. Physical properties and system design of gas extinguishing systems for IG-55 extinguishant”.
- ✚ EN 15004-10:2008 “Fixed firefighting systems. Gas extinguishing systems. Physical properties and system design of gas extinguishing systems for IG-541 extinguishant”

Components used in the system that use extinguishing agent “Argon IG01”, “Nitrogen IG100”, “Nitrogen+Argon IG55” and “Nitrogen+Argon+CO₂ IG541” are designed according to these 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 maintained according to these standards:

- ✚ EN 11280:2008 “Initial verification and maintenance of gaseous fire-extinguishing systems”

1.3 Approval / Certification of agent

“Argon IG01”, “Nitrogen IG100”, “Nitrogen+Argon IG55” e “Nitrogen+Argon+CO₂ IG541” wre approved as an extinguishing gas by:

- EPA (Environmental Protection Agency – USA)
- VDS “Verband der Schadenverhuetung” (Koeln Germania) – Fire extinguishing system
- LPCB (Loss Prevention Certification Board)
- Lloyds Register
- Bureau Veritas
- DNV (Det Norske Veritas)

- German Institute for Environmental Hygiene and Medicine (Approved)
- Danish Maritime Autorità

1.4 Terminology and Definitions

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

-Approved: 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 the 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.

-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 be 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 agent

2.1 Introduction

The design, installation, service and maintenance of gaseous fire-extinguishing systems “Argon IG01”, “Nitrogen IG100”, “Nitrogen+Argon IG55” and “Nitrogen+Argon+CO₂ IG541” 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 chemical and physical properties

Nitrogen and argon are clean, safe fire fighting agents for use in fire extinguishing systems.

Nitrogen is not a fire extinguishing agent in the strict sense, but works like carbon dioxide by displacing oxygen in the air.

The extinguishing mechanism is purely physical in nature, reducing the oxygen concentration to below the specific threshold level required by the combustible material.

Here is the table with “Argon IG01”, “Nitrogen IG100”, “Nitrogen+Argon IG55” and “Nitrogen+Argon+CO₂ IG541” physical properties as specified in EN 15004 part 13.

Nitrogen and argon provide excellent visibility during the agent discharging and do not produce thermo shock. From the point of view of their environmental impact these gases have no environmental impact (GWP = 0, Global Warming Potential) and not affect the ozone layer (ODP = 0, Ozone Depletion Potential)

Tabella 2 – Chemical and Physical properties

Property	Unit	Argon IG 01	Nitrogen IG 100	Argon+Nitrogen IG 55	Argon+Nitrogen+CO ₂ IG 541
Molecular mass	—	39,9	28,02	33,98	34,0
Boiling point at 1,013 bar (absolute)	°C	-185,9	-195,8	—	-196
Freezing point	°C	-189,4	-210,0	—	-78,5
Critical temperature	°C	-122,3	—	—	—
Critical pressure	bar abs	49,0	—	—	—
Critical volume	cm ³ /mol	—	—	—	—
Critical density	kg/m ³	536	—	—	—
Vapour pressure 20 °C	bar abs	—	—	—	152
Liquid density 20 °C	Kg/m ³	—	—	—	—
Saturated vapour density 20 °C	Kg/m ³	—	—	—	—
Specific volume of superheated vapour at 1,013 bar and 20 °C	m ³ /kg	0,602	0,858	0,708	0,697
Chemical formula		Ar	N ₂	50% Ar 50% N ₂	40% Ar 52% N ₂ 8% CO ₂
Chemical name		Argon	Nitrogen	Argon Nitrogen	Argon Nitrogen CO ₂

2.3 Extinguishing Agents applications

Nitrogen is a clean gaseous agent containing no particles or oily residues.

It is produced under ISO 9002 guidelines to strict manufacturing specifications ensuring product purity.

Nitrogen leaves no residue or oily deposits on delicate electronic equipment, and can be removed from the protected space by ventilation. It is present in the Earth's atmosphere at 79% by volume.

Nitrogen extinguishes a fire by reducing the concentration of oxygen in the hazard.

Nitrogen has the following advantages:

It can be used as a single gas. It does not need to be mixed with other gases so there is no possibility of getting the wrong mix in the cylinders when recharging. It has excellent mixing qualities when discharged and is very effective against fires at medium and high level. It is a genuine "clean agent" and does not add agent breakdown to the toxic or corrosive products of combustion from the fire. There are absolutely no environmental disadvantages, short or long term. Nitrogen is a genuine green alternative to other gases. No fogging of room atmosphere occurs on discharge.

Typical areas that can be protected by an Nitrogen 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 - Nitrogen 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 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 (Ref. EN 15004 Ed. 2008)

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 Inert Gas Agents

Table 2.2 provides information on physiological effects of inert gas agents covered by this standard. The health concern for inert gas clean agents is asphyxiation and hypoxic effects due to the lowered oxygen levels. With inert gas agents, an oxygen concentration of not less than 12 percent (sea level equivalent) is required for normally occupied areas. This corresponds to an agent concentration of not more than 43 percent.

Physiological Effects for Inert Gas Agents		
Agent	No Effect Level* (%)	Low Effect Level* (%)
IG-01	43	52
IG-100	43	52
IG-55	43	52
IG-541	43	52
*Based on physiological effects in humans in hypoxic atmospheres. These values are the functional equivalents of NOAEL and LOAEL values and correspond to 12 percent minimum oxygen for the No Effect Level and 10 percent minimum oxygen for the Low Effect Level.		

The IG-541 uses carbon dioxide to promote breathing features to keep life into an environment lacking oxygen for the protection of personnel. You should be careful not to design systems type for inert gas areas typically occupied by using concentrations higher than those specified in the project design manuals of the manufacturer of the system indicated for the dangers protected.

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

2.7 Safe Exposure Guidelines for Inert Gas Agents (Ref. annex G EN 15004-1 Ed. 2008)

Unnecessary exposure to inert gas agent systems resulting in low oxygen atmospheres 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:

Inert gas systems designed to concentrations below 43 percent (corresponding to an oxygen concentration of 12 percent, sea level equivalent of oxygen) shall be permitted, given the following:

- The space is normally occupied
- Means are provided to limit exposure to no longer than 5 minutes.

Inert gas systems designed to concentrations between 43 and 52 percent (corresponding to between 12 and 10 percent oxygen, sea level equivalent of oxygen) shall be permitted, given the following:

- The space is normally occupied.
- Means are provided to limit exposure to no longer than 3 minutes.

Inert gas systems designed to concentrations between 52 and 62 (corresponding to between 10 and 8 percent oxygen, sea level equivalent of oxygen) shall be permitted given the following:

- The space is normally unoccupied.
- Where personnel could possibly be exposed, means are provided to limit the exposure to less than 30 seconds.

Inert gas systems designed to concentrations above 62 percent (corresponding to 8 percent oxygen or below, sea level equivalent of oxygen), shall only be used in normally unoccupied areas where personnel are not exposed to such oxygen depletion.

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

Prospetto 2 - (Ref. EN 15004- 1)

Maximum concentration	Pre-discharge alarm	Time delay device	Automatic/ manual switch	Lock-off device
Up to and including the NOAEL (up to 43%)	required	required	Not required	Not required
Above the NOAEL and up to the LOAEL (from 43% to 52%)	required	required	required	Not required
LOAEL and above (above 52%)	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

“Argon IG01”, “Nitrogen IG100”, “Nitrogen+Argon IG55” and “Nitrogen+Argon+CO₂ IG541” are an important components of our atmosphere; it doesn’t damage frail materials and doesn’t release residuals after discharge.

They have an ODP=0 (Ozone Depletion Potential) and a GWP=0 (Global Warming Potential), so they do not damage Ozone level and not augment greenhouse effect.

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.

3. Basis of Systems Design

This section of the manual will detail the steps necessary to design an Nitrogen IG-100 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, pressure relief venting, 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 standard – Annex C. These values have been multiplied by a Safety Factor (1,3 for EN-15004) as required by the applicable standard.

**Table 4 - IG-100 reference extinguishing
and design concentrations EN 15004-8**

Fuel	Extinguishment %	Minimum design %
Class B Heptane (cup burner) Heptane (room test)	33,6 36,6	47,6
Class A Wood crib PMMA PP ABS	30,0 28,8 30,0 31,0	40,3
Class A Higher hazard	a	45,2

**Table 4 - IG-01 reference extinguishing
and design concentrations EN 15004-7**

Fuel	Extinguishment %	Minimum design %
Class B Heptane (cup burner) Heptane (room test)	39,1 39,8	51,7
Class A Wood crib PMMA PP ABS	30,7 31,6 31,6 32,2	41,9
Class A Higher hazard	a	49,2

**Table 4 - IG-55 reference extinguishing
and design concentrations EN 15004-9**

Fuel	Extinguishment %	Minimum design %
Class B Heptane (cup burner) Heptane (room test)	36,5 36,6	47,6
Class A Wood crib PMMA PP ABS	28,7 30,7 29,3 31,0	40,3
Class A Higher hazard	a	45,2

**Table 4 - IG-541 reference extinguishing
and design concentrations EN 15004-10**

Fuel	Extinguishment %	Minimum design %
Class B Heptane (cup burner) Heptane (room test)	31,7 37,0	48,1
Class A Wood crib PMMA PP ABS	28,2 30,7 30,6 30,7	39,9
Class A Higher hazard	a	45,7

3.3 Required Agent quantity

For this manual is given an example with inert gas nitrogen IG100

The first step in designing the Nitrogen IG-100 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 Nitrogen IG-100 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.)

Nitrogen IG-100 quantity per cubic meter of the protected area determination is obtained by the table 3.3.

Table 3 –EN 15004:13 - 2008

Temperature <i>T</i> °C	Specific vapour volume <i>S</i> m ³ /kg	IG-100 volume requirements per unit volume of protected space, <i>TV</i> (m ³ /m ³) This information refers only to IG-100, and may not represent any other products containing nitrogen as a component.							
		Design concentration (by volume)							
		34 %	38 %	42 %	46 %	50 %	54 %	58 %	62 %
-40	0,6825	0,522	0,601	0,685	0,775	0,872	0,976	1,091	1,217
-35	0,6971	0,511	0,588	0,671	0,758	0,853	0,956	1,068	1,191
-30	0,7118	0,501	0,576	0,657	0,743	0,836	0,936	1,046	1,167
-25	0,7264	0,491	0,565	0,644	0,728	0,819	0,917	1,025	1,143
-20	0,7411	0,481	0,554	0,631	0,714	0,803	0,899	1,005	1,120
-15	0,7557	0,472	0,543	0,619	0,700	0,787	0,882	0,985	1,099
-10	0,7704	0,463	0,533	0,607	0,686	0,772	0,865	0,966	1,078
-5	0,7850	0,454	0,523	0,596	0,674	0,758	0,849	0,948	1,058
0	0,7997	0,446	0,513	0,585	0,661	0,744	0,833	0,931	1,038
5	0,8143	0,438	0,504	0,574	0,649	0,731	0,818	0,914	1,020
10	0,8290	0,430	0,495	0,564	0,638	0,718	0,804	0,898	1,002
15	0,8436	0,423	0,486	0,554	0,627	0,705	0,790	0,883	0,984
20	0,8583	0,416	0,478	0,545	0,616	0,693	0,777	0,868	0,968
25	0,8729	0,409	0,470	0,536	0,606	0,682	0,764	0,853	0,951
30	0,8876	0,402	0,462	0,527	0,596	0,670	0,751	0,839	0,936
35	0,9022	0,395	0,455	0,518	0,586	0,659	0,739	0,825	0,920
40	0,9169	0,389	0,448	0,510	0,577	0,649	0,727	0,812	0,906
45	0,9315	0,383	0,440	0,502	0,568	0,639	0,716	0,799	0,892
50	0,9462	0,377	0,434	0,494	0,559	0,629	0,704	0,787	0,878
55	0,9608	0,371	0,427	0,487	0,550	0,619	0,694	0,775	0,864
60	0,9755	0,366	0,421	0,479	0,542	0,610	0,683	0,763	0,851
65	0,9901	0,360	0,414	0,472	0,534	0,601	0,673	0,752	0,839
70	1,0048	0,355	0,408	0,465	0,526	0,592	0,663	0,741	0,827
75	1,0194	0,350	0,403	0,459	0,519	0,584	0,654	0,730	0,815
80	1,0341	0,345	0,397	0,452	0,511	0,575	0,645	0,720	0,803
85	1,0487	0,340	0,391	0,446	0,504	0,567	0,636	0,710	0,792
90	1,0634	0,335	0,386	0,440	0,497	0,560	0,627	0,700	0,781
95	1,0780	0,331	0,381	0,434	0,491	0,552	0,618	0,691	0,770
100	1,0927	0,326	0,376	0,428	0,484	0,545	0,610	0,682	0,760

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-125 vapour at a pressure of 1,013 bar may be approximated by the formula:

$$S = k_1 + k_2 T$$

where

$$k_1 = 0,79968$$

$$k_2 = 0,00293$$

c is the concentration (%); i.e. the volumetric concentration of IG100 in air at the temperature indicated, and a pressure of 1,013 bar absolute.

If concentration values wouldn't be in the table, IG100 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 $c = 40,3\%$.

$$S_R = k_1 + k_2 \cdot T = 0,799\,68 + 0,002\,93 \cdot 20 = 0,85828$$

$$S = k_1 + k_2 \cdot T = 0,799\,68 + 0,002\,93 \cdot 20 = 0,85828$$

$$m = \frac{V}{S} \cdot \ln\left(\frac{100}{100 - c}\right) = \frac{100}{0,85828} \cdot \ln\left(\frac{100}{100 - 40,3}\right) = 60,10138481$$

$$Q = m \cdot S_R = 60,10138481 \cdot 0,85828 = 51,58381656$$

$$x = \frac{Q}{V} = \frac{51,58381656}{100} = 0,5158381656$$

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

3.4 Additional Considerations

Additional quantities of Nitrogen IG-100 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 Nitrogen IG-100 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)

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

3.4.2 Oxygen Concentration after total discharge

It is important to determine the resulting Oxygen concentration in the protected hazard after the system has discharged. Exposure limit guidelines are discussed in Section 2 of this manual. The following table outlines the exposure limits based on the Oxygen concentrations within the hazard following agent discharge.

	Max Exposure time			
	Gas Concentration after total discharge			
	X < 43%	43% < X < 52%	52% < X < 62%	X > 62%
Oxygen Concentration	12%	12% - 10%	10% - 8%	< 8%
Area	Occupied	Occupied	Normally Unoccupied	Unoccupied
Max Exposure Time	5 min	3 min	30 sec	-

The first step in determining the resultant oxygen concentration in the hazard is to determine the concentration of Nitrogen IG-100 that is discharged into the hazard. The following equations allow us to determine the minimum oxygen concentration in the hazard.

$$R_{IG-01} = \left(e^{\left(\frac{(-1) \cdot M}{273 + C} \right)} - 1 \right) \cdot (-100)$$

Where

R_{IG-100} Is the resulting IG-100 concentration
 M Is the volume of IG-100 per volume of the room (V_{IG-100}/V_{ROOM})
 C Is the maximum temperature of the hazard in °C

Now to determine the oxygen concentration at the specified IG-100 concentration perform the following:

$$R_{OXYGEN} = \left(\frac{R_{IG-01}}{100} - 1 \right) \cdot 20,9 \cdot (-1)$$

NOTE This value can be automatically calculated by using the PreDimensioning.xls file, available from Bettati Antincendio.

3.5 Minimum Storage Quantity

In order to discharge the design quantity within 60 sec VdS software indicates a minimum gas storage quantity obtained multiplying by a supplementary factor.

The factor's values are between 1,1 and 1,2 depending on the pipeline's layout.

- Up to 19 cylinders there is a **10%** additional factor (Ref. CEA)

- Above 20 cylinders there is a 5% additional factor (Ref. CEA)

- The additional factor should in any way guarantee that 95% of the amount of gas is discharged into the space will be discharge in the design time (Ref. CEA)

The number of cylinders, at the end, is obtained dividing the minimum storage gas quantity and the cylinder capacity at a temperature of 15 °C, at a pressure of 300 bar with a gas volume of 0.8436 m³/kg and a gas density of 1.1854 kg/m³.

3.6 Discharge Time (rif. EN 15004-1:2008 chapter 7.9)

The discharge time required to achieve 95 % of the design concentration for Nitrogen IG-100 gas shall not exceed 60 s at 20 °C, or as otherwise required by the authority.

3.7 Duration of Protection (“Door Fan Test”) (rif. 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.*

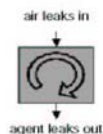
Annex E: “Door fan test for determining of minimum hold time”

Here there is an example of door fan integrity test performed.

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
 Software Licensed to: **Bettati Antincendio Srl**

Building, Location **EX PRETURA DI XXX, XXX, ITALIA**
 Company, Contact **EX PRETURA DI XXX, SIG. XXXX**
 Room name **ARCHIVIO 1** Test number **1**
 Calibration Certificate # **3794** Certificate created **2009/01/05**



Test date/time	2009/09/29 16.37	Net protected volume, V_p	256 m³
Tester	Paola Bertolini	Maximum Protected Height, H_o	3,11 m.
Certified to Level:	No enclosure certification	Minimum Protected Height, H	3,11 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	44,24%
Correction factor	1	Mixing during retention	Yes
Agent	IG-100	Agent quantity	174 kg.
Actual total leakage, A_t	0,0497 m²	Minimum concentration, C_{min}	36,60%
Actual lower leakage, A_l	0,0248 m²	Minimum retention time	10,0 minutes

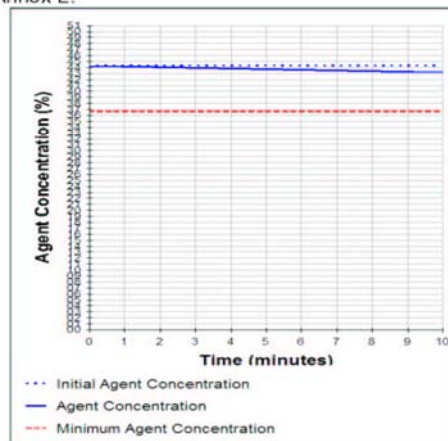
Below ceiling leakage defaulting to worst case -- 50% of total leakage.

This enclosure was tested in compliance with UNI EN 15004.1 Annex E.

Assuming continual mixing during the retention period, enclosure leakage could allow sufficient agent to be lost to cause the agent concentration to drop from the initial concentration of **44,24%** to the minimum specified concentration of **36,60%**.

The retention time would then be **82,7 minutes** which exceeds the minimum retention time of **10 minutes**. The enclosure therefore **passes** this acceptance procedure.

Notes

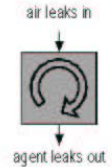


Witnesses

DOOR FAN TEST – Total Room Leakage Data

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
 Software Licensed to: **Bettati Antincendio Srl**

Building, Location **EX PRET EX PRETURA DI XXX, XXX, ITALIA**
 Company, Contact **ELGAL II EX PRETURA DI XXX, SIG. XXXX**
 Room name **ARCHIVIO 1** Test number **1**
 Calibration Certificate # **3794** Certificate created **2009/01/05**



Total Room Leakage

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

Depressurization		Range for room pressures: -10,0 to -13,0
Blower range	Room pressure	-11,7
	Auto corrected RP	-11,7
Ring C4	Flow Pressure	63,7
	Auto corrected FP	63,7
Corrected flow (m³/sec.):		-0,1398

Pressurization		Range for room pressures: 10,0 to 13,0
Blower range	Room pressure	13,2
	Auto corrected RP	13,2
Ring C4	Flow Pressure	48,8
	Auto corrected FP	48,8
Corrected flow (m³/sec.):		0,1352

	ELA m²	@Pa	F _A	Slope n	Intercept k ₁	Correlation	Standard Error	ELA m²		F
Pressurization	0,0520	11,7		0,5000	0,0409	NA	NA			
Depressurization	0,0473	13,2		0,5000	0,0372	NA	NA			
Average	0,0496	12,5	0,50	0,5000	0,0391			0,0497	10,0	0,50

Lower Leakage

Below ceiling leakage of 0,0248 m² @ 10,0 Pa is the worst case assumption of 50%

Technician: **Paola 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

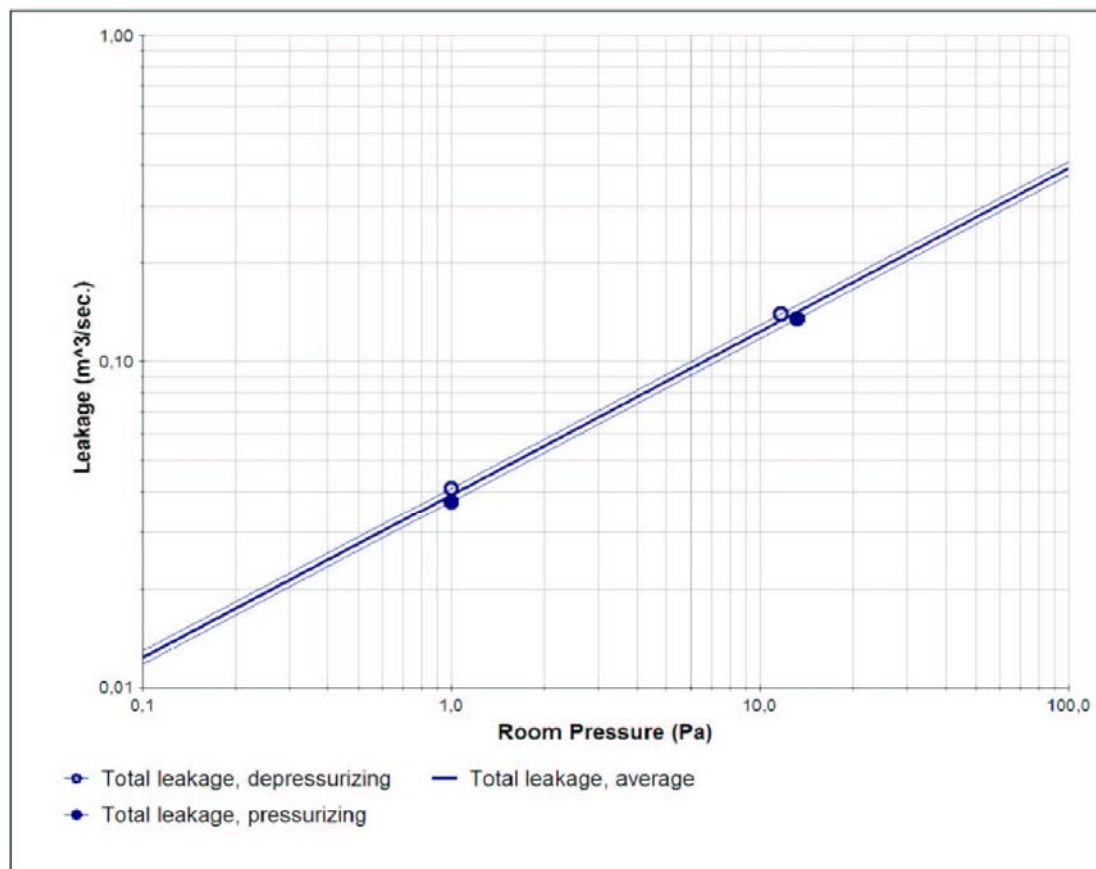
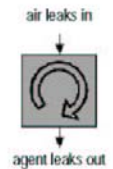
No Level 3 - adds double door fan operation for Lower Leak measurement

No Level 4 - adds multi-point ISO door fan operation and discharge pressure relief vent

DOOR FAN TEST -- Graph

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

Software Licensed to: **Bettati Antincendio Srl**Building, Location **EX PRETUI EX PRETURA DI XXX, XXX, ITALIA**Company, Contact **ELGAL IMF EX PRETURA DI XXX, SIG. XXXX**Room name **ARCHIVIO 1** Test number **1**Calibration Certificate # **3794** Certificate created **2009/01/05**

3.8 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.

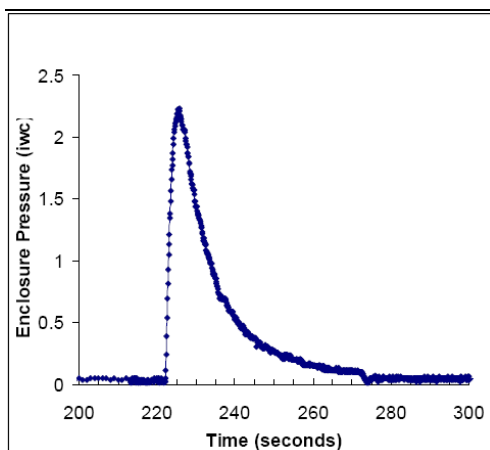


Fig. 1: Time evolution of the ambient pressure during the discharge of an inert gas.

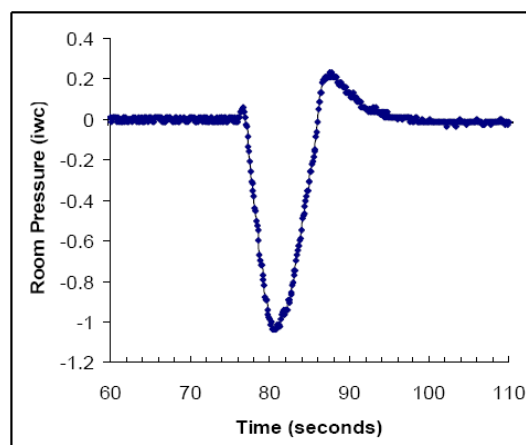


Fig. 2: Time evolution of the ambient pressure during the discharge of a halocarbon gas.

The pressurization of the enclosure volume must be carefully evaluated and, if necessary, must be provided appropriate relief surface

The strength of the protected 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. 5: An example of a high pressurization of the enclosure volume.



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

The calculation of the pressurization of the enclosure 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 research

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

$$A = \frac{M_p^* \cdot v_p}{\sqrt{\Delta p \cdot v_{HOM}}} C_2 \quad (1)$$

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

$$\varepsilon \text{} = \text{volume fraction} \leq 1$$

$$x \text{} = \text{mass fraction} \leq 1$$

$$\rho_p \text{} = \text{extinguishing gas density [kg/m}^3\text{]}$$

$$\rho_{HOM} = \text{..... mixture density [kg/m}^3\text{]}$$

The coefficient C_2 is set equal to:

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

Where coefficient C_1 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 $VVR=f(\Delta p)$ [4]. The experimental curves have been implemented in a spreadsheet, shown in Figure..

NFPA 2001 (2008 Edition) Designer Analysis									
Flooded Enclosure Volume	3116	meters ³ =	110119	feet ³					
"Specified Enclosure Pressure Limit"	1200	Pascals =	25,06	lb/ft ²					
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	cm ²

Fig. 6: Foglio di calcolo Retrotec Inc.

Enclosure characteristic

The archive reports in the example above door fan has a volume of 185 m³.

In the room are present openings that have been quantified by the Door Fan Test Integrity in an area of 0.0575 m² 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.

Test date/time	2009/09/29 16.37	Net protected volume, V _g	256 m ³
Tester	Paola Bertolini	Maximum Protected Height, H _o	3,11 m.
Certified to Level:	No enclosure certification	Minimum Protected Height, H	3,11 m.
Signature	Static during discharge, P _{sh}	0,0 Pa
Elevation above sea level	0 m.	Operating temperature	20 C
Correction	NFPA 2001 (2000) Formula A-3-5.3.3	Initial concentration, C	44,24%
Correction factor	1	Mixing during retention	Yes
Agent	IG-100	Agent quantity	174 kg.
Actual total leakage, A _t	0,0497 m ²	Minimum concentration, C _{min}	36,60%
Actual lower leakage, A _l	0,0248 m ²	Minimum retention time	10,0 minutes

Fig. 7: Esito prova Door Fan IntegrityTest.

Extinguishing system

The enclosure is protected with a fire extinguishing system fire extinguishing inert gas IG100. 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 36.60%. 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: Features of protected room and extinguishing system

Volume	256 m ³
Maximum allowable pressure	500 Pa
Extinguishing gas concentration	44.24 %
Discharge time	60 s
"Natural" room opening	0.05 m ²

The Retrotec Inc. spreadsheet, as shown in figure, indicates for the protected room a relief surface of 36 cm² (0.0366 m²). 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.

NFPA 2001 (2008 Edition) Designer Analysis									
Flooded Enclosure Volume	256	meters³ =	914	feet³					
"Specified Enclosure Pressure Limit"	500	Pascals =	10.44	lb/ft²					
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	36.0%	36.0%	40.0%	40.0%	7.0%	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	2936	2936	2292	3262	555	820	272	2289	cm²

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

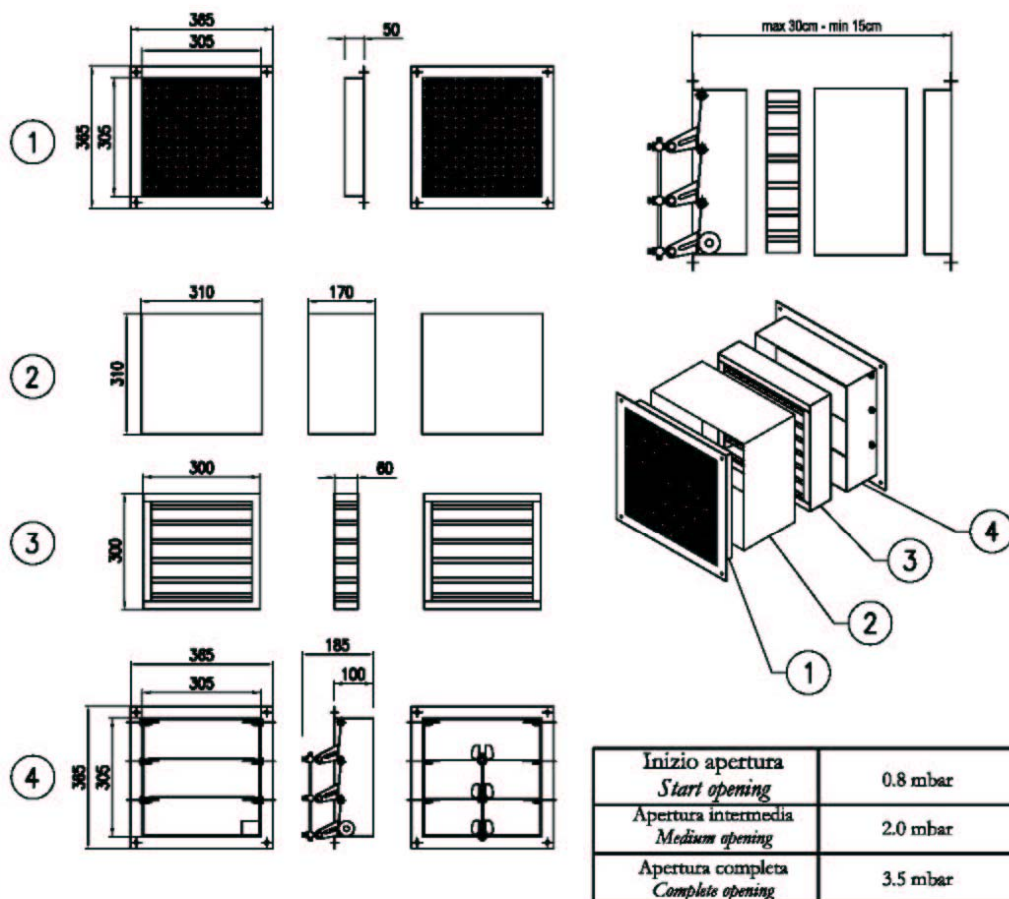
Tab. 3: Overpressure damper determination.

Area required for the vent overpressure	0.32 m2
No of overpressure damper	1

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

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



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

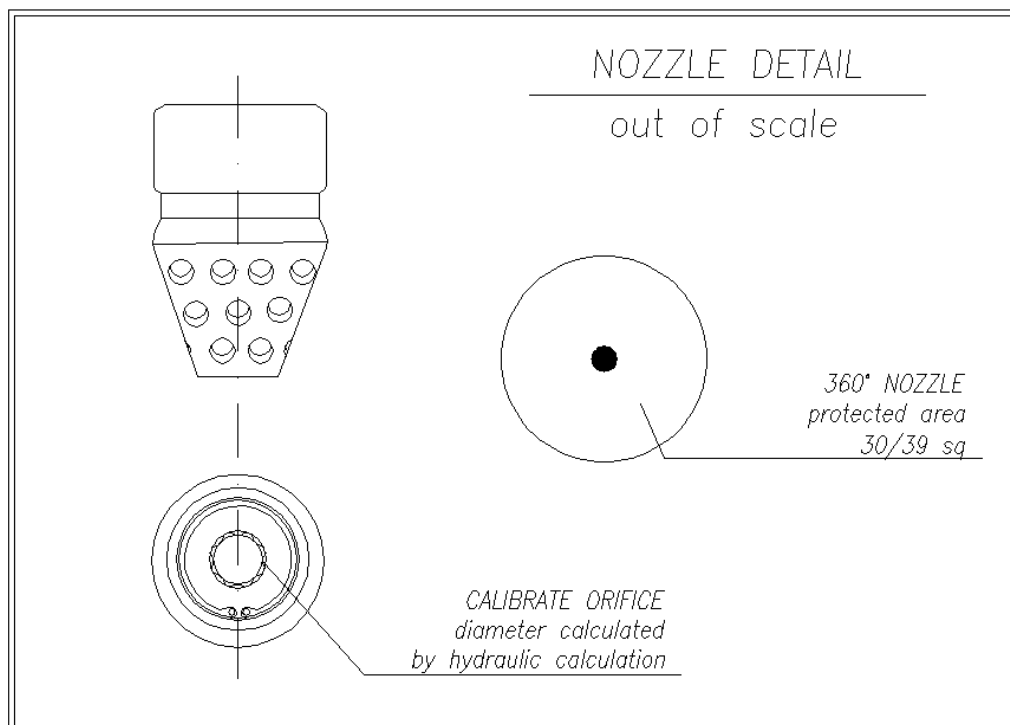
3.9 Nozzle selection and location (rif. EN 15004:1 cap. 6.3.6)

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 m³

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 $13 \pm$ difference measured by different sensors is equal to 0.4% less than 0.7% indicated by the standard measured within 60 seconds to download.

**ISTITUTO DI RICERCHE E COLLAUDI****M. MASINI S.r.l.**

Sede amministrativa e laboratori: Via Moscova, 11 - 20017 RHO (MI)

Tel. 02/930.15.17 r.a. - Fax 02/930.81.76 - Internet: www.istitutomasini.it - E-mail istitutomasini@istitutomasini.it

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

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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.

3.10 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.

Tubazione	Pipe	Schedule	Diameter (inches)	Material	Thread	Pipe
Manifold	API 5LX	XXS	2"	11.07		NPT
Placed after the orifice plate with directional valves	API 5LGRB	160	2"	8.74	ASTM A-106 Galvanized seamless	NPT
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

Fittings	Type	Material	Screw thread
Placed after the orifice plate with directional valves	ASA 6000	ASTM A-105 galvanized	NPT
Placed after the orifice plate without directional valves	ASA 3000	ASTM A-105 galvanized	NPT

3.11 Estimating Pipe Sizes

The following are approximate flow rate for estimating pipe sizes

Nitrogen IG100	
inch	Kg/sec x 60sec
1/2"	0-26
3/4"	26-45
1"	46-92
1"1/4	93-138
1"1/2	139-220
2"	221-565
2"1/2	566-940
3"	941-1254
4"	1255-2245

Argon+Nitrogen IG55	
inch	Kg/sec x 60sec
1/2"	0-33
3/4"	34-57
1"	58-117
1"1/4	118-176
1"1/2	177-280
2"	281-719
2"1/2	720-1196
3"	1197-1596
4"	1597-2857

Argon 01 Sch40	
inch	Kg/sec x 60sec
1/2"	0-41
3/4"	60-71
1"	72-145
1"1/4	146-217
1"1/2	218-346
2"	347-889
2"1/2	890-1479
3"	1480-1973
4"	1974-3533

Argon+Nitrogen+CO ₂ IG55	
inch	Kg/sec x 60sec
1/2"	0-26
3/4"	26-45
1"	46-92
1"1/4	93-138
1"1/2	139-220
2"	221-565
2"1/2	566-940
3"	941-1254
4"	1255-2245

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

3.12 Pipes Hangers and Support (EN 15004-1)

All support and parts thereof shall conform to the requirements for EN-15004-1

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

3.13 Hydraulic calculation software

All systems using inert gases IG100 Nitrogen, Argon IG01, Argon + Nitrogen IG55 and Argon + Nitrogen + CO2 IG541 are based on the hydraulic calculation software developed by VdS

The software uses the values of equivalent length of the components of production Bettati Fire, derived from VdS laboratories (see test report nr. CHL00049)

Since the application software hydraulic calculation appears to be a delicate change the outcome of the design, only trained staff of Bettati Fire Ltd is authorized to perform the calculation for systems IG100 Nitrogen, Argon IG01, Argon + IG55 Nitrogen and Argon + Nitrogen + CO2 IG541.

VdS software hydraulic calculation gives the following results:

- Calculate the quantity in kg of nitrogen IG100, IG01 Argon, Argon + Nitrogen IG55 Argon and Nitrogen + CO2 + IG541
- Calculation of the section of pipe, the nozzle orifice plate and pressure reducing device;
- Average pressure to the nozzles
- Discharge time calculation
- Calculation of opening request depending on the volume of overpressure.
- Calculation of the concentration of inert gas and oxygen remaining after the download.

Limitations of the software:

- 5 bar minimum nozzle pressure
- 30 bar maximum nozzle pressure
- 30/60 bar pressure after the calibrated orifice
- Max 21 zones
- Max 450 pipe sections
- Max 200 nozzles.

VdS SCHADENVERHÜTUNG



Laboratory for Fire Extinguishing Systems and
for Smoke and Heat Exhaust Ventilation Systems
Area CHL

Test report No. CHL 00049

on the determination of
the flow characteristic of
the Nitrogen nozzles (1/2"; 3/4"; 1" and 1.1/2")
and pressure reduction devices (1/2"; 3/4"; 1"; 1.1/2"; 2"; 3" and 4")

of the company
Bettati Antincendio, Italy

Tested by:

Head of the laboratory:

This report comprises 13 pages and 20 annexes. It may be reproduced in
unabridged and unmodified form only.

Cologne, 25.08.2000

3.14 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 protecte
2. Risk analysis
3. Gas extinguishing choosing
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)

3.14.1 Inspection

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

Data to be collected during the inspection			
Room Location			
Application			
System to be implemented			
Altitude a.s.l		Temperature °C	
Mechanical system surveys to be carried out and indicated in the plan	If not available dimension of the room		
	Type of masonry and / or celing		
	Cylinder displacement		
	Possible path distribution pipes and nozzles		
	Presence of primary air conditioning system		
	Any facilities that may affect the placement of cylinders, nozzles, tubes and accessories		
	Openings can not be eliminated		
	State of structures and supports		
	Any openings not confined to unprotected adjacent areas		
	Any existing installation: brand / model tanks - make / model valve - charge / gas extinguishing type - diameter / length of existing pipe		

3.14.2 Risk analysis

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

Tabella 4 - (Rif. EN 15004-8 Ed.2008)

Fuel	Extinguishing %	Minimum design %
Class B Heptane (cup burner) Heptane (room test)	33,6 36,6	47,6
Class A Wood crib PMMA PP ABS	30,0 28,8 30,0 31,0	40,3
Class A High Hazard	a	45,2

3.14.3 Gas extinguishing choosing

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

3.14.4 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

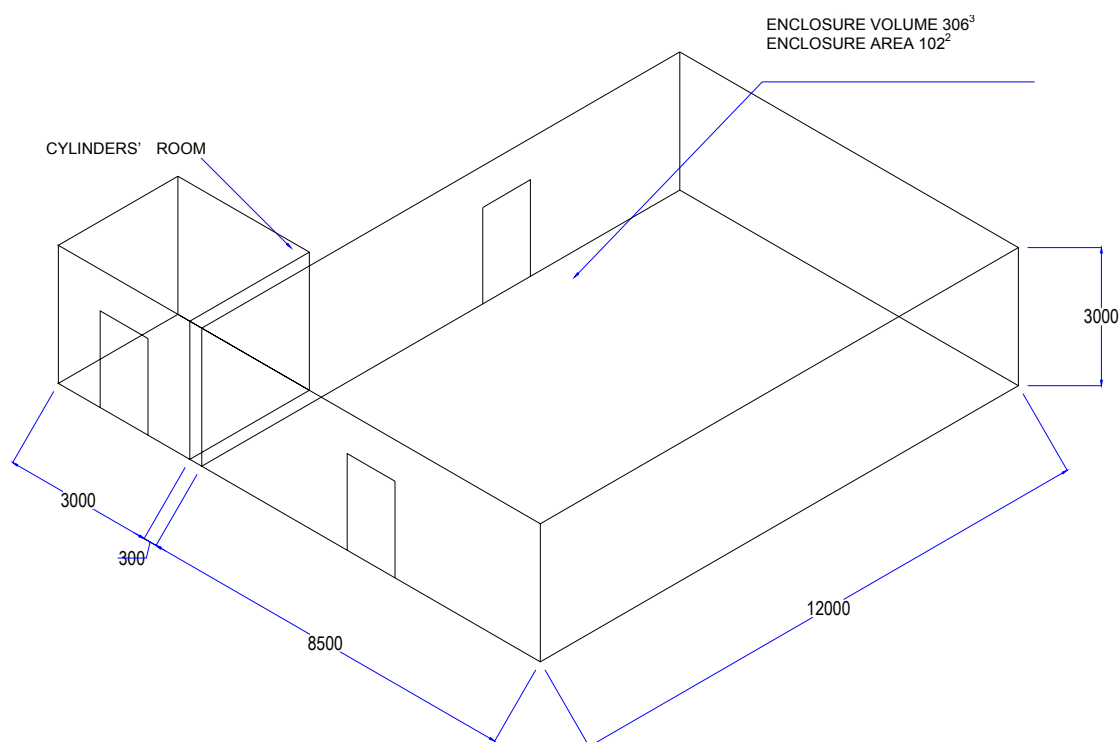
Bettati Antincendio srl has submitted its products to the assessment of notified bodies that have certified compliance with Directive 97/23/EC (PED) and verified compliance with the harmonized standards EN 12094 series of CPD.

Product	Notified body	Serial ID Notified body	Standard reference
Inert gas valve and actuator V300x	Consortium RINA-OMECO	0474	97/23/CE - PED
Inert gas valve and actuator V300x	Test and research institute "M. Masini"	068	EN 12094 Part 4:2004
Directional valve and actuator	Test and research institute "M. Masini"	068	EN12094 Part 5:2006
Nozzles	Test and research institute "M. Masini"	068	EN 12094 Part 7:2005

Check valve and non-return valve VNR300	Test and research istitute "M. Masini"	068	EN 12094 Part 13:2002
Flex hose	Test and research istitute "M. Masini"	068	EN 12094 part 8:2006

3.14.5 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 according to the EN 15004.4 Ed.2008

$c = 31.0\% + 30\% = 40.3\%$

Amount of nitrogen IG100 in cylinders of 140 l = 43.53

The specific volume of steam at 20 °C and $S = 0.8583 \text{ m}^3 / \text{kg}$

Therefore, in accordance with the following equation (found in the EN 15004 part 8):

$$S_R = k_1 + k_2 \cdot T = 0,799\,68 + 0,002\,93 \cdot 20 = 0,85828$$

$$S = k_1 + k_2 \cdot T = 0,799\,68 + 0,002\,93 \cdot 20 = 0,85828$$

$$m = \frac{V}{S} \cdot \ln\left(\frac{100}{100 - c}\right) = \frac{100}{0,85828} \cdot \ln\left(\frac{100}{100 - 40,3}\right) = 60,10138481$$

$$Q = m \cdot S_R = 60,10138481 \cdot 0,85828 = 51,58381656$$

$$x = \frac{Q}{V} = \frac{51,58381656}{100} = 0,5158381656$$

The value was derived from the formula as 40.3% did not appear in Table 3.2.

Quantity project in m³: $Q_{\text{design}} = V \cdot x = 306[\text{m}^3] \cdot 0,5158 = 157,8348 \text{ m}^3$

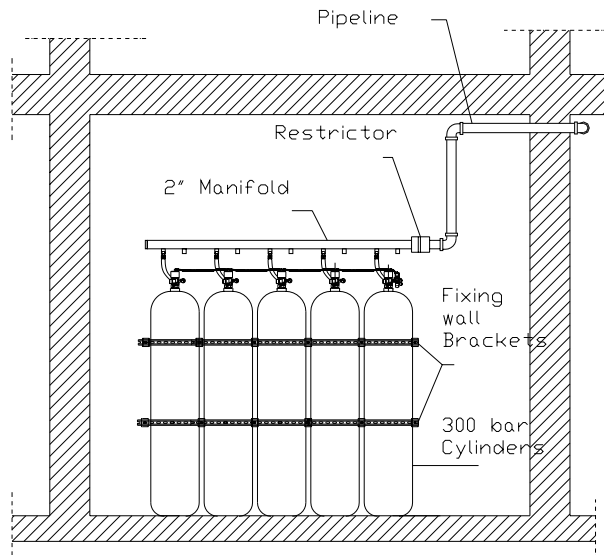
Quantity project in kg: $157,8348 \text{ [m}^3\text{]} / 0.8583 \text{ [kg/ m}^3\text{]} = 183,8923453 \text{ [kg]}$

Additional factor 1.15 (gas used as propellant to get the download in 60 seconds):

$$Q_{\text{real}} = Q_{\text{design}} + 15\% = 211,4761971 \text{ [kg]}$$

$$\text{Cylinders numbers : } N = \frac{Q_{\text{real}}}{43,53} = 4,858 \rightarrow 5 \text{ cylinder } 140 \text{ lt}$$

$$\text{Final amount of nitrogen : } Q_{\text{final}} = N (\rightarrow 5) \cdot 43,53 = 217,65 \text{ [kg]}$$



CYLINDERS LAYOUT

Now you must test the concentration of oxygen within the room after the discharge:

$$O_{fin} = O_{in} - \left(\frac{O_{in} \cdot C_{fin}}{100} \right)$$

$$\text{The concentration is: } C_{fin} = 100 \cdot \frac{e^{x_f} - 1}{e^{x_f}} = 100 \cdot \frac{e^{0.6104} - 1}{e^{0.6104}} = 45,68\% \text{ per volume}$$

$$\text{with } x_f = Q_f \cdot \frac{v}{V} = 0.6104 \left[\frac{m_{\text{gas}}^3}{m_{\text{protectedspace}}^3} \right] \text{ (as you can see in the following spreadsheet)}$$

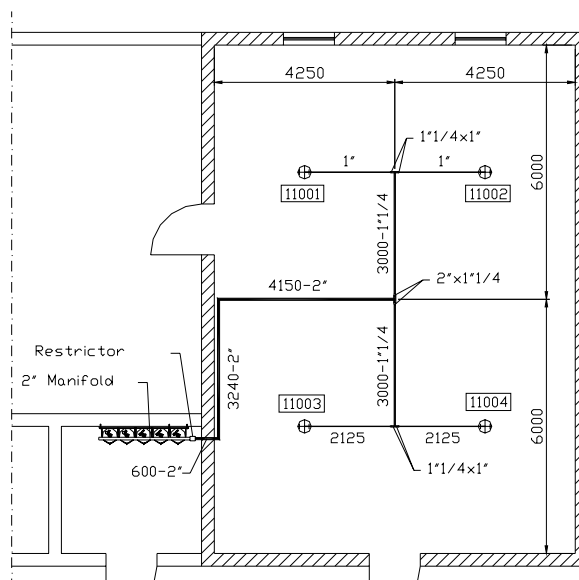
The oxygen in the room after the discharge appears to be:

$$O_{fin} = O_{in} - \left(\frac{O_{in} \cdot C_{fin}}{100} \right) = 20.9 - \left(\frac{20.9 \cdot 45,68}{100} \right) = 11,35\%$$

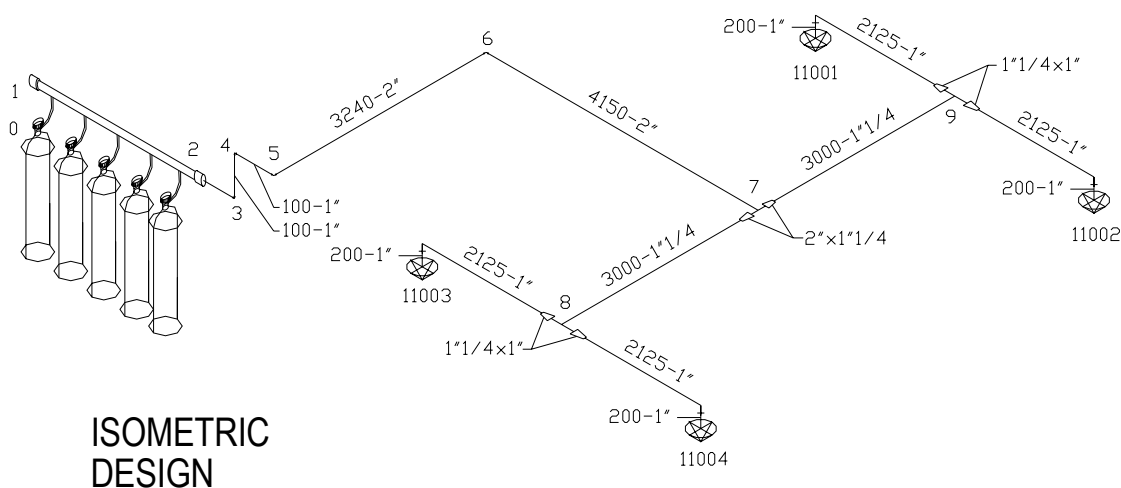
MINIMUM CONCENTRATION OF PROJECT CLASSE A	40,3
VOLUME [m^3]	306
TOTAL VOLUME [m^3]	306
TEMPERATURE [°C]	20

CONTENT CYLINDER AT 15 °C [KG]	43,53
SPECIFIC VOLUME AT 20°C [m³/KG]	0,8583
PERCENT OXYGEN IN THE DRY AIR	20,9
DISCHARGE TIME [s]	60
RESULTS	
VOLUME OF GAS ON UNIT OF ROOM VOLUME [m³/m³]	0,51840
NITROGEN ROOM PROJECT AMOUNT [m³]	158,6
TOTAL NITROGEN PROJECT AMOUNT [m³]	158,6
NITROGEN PROJECT AMOUNT [KG]	184,8179803
OXYGEN % AFTER 60 sec. DISCHARGE	12,477
ACTUAL AMOUNT OF NITROGEN IN kg (with 10% or 5% more)	203,300
CYLINDERS NUMBER	5
FINAL AMOUNT OF NITROGEN kg	217,65
FINAL VOLUME ON GAS UNIT 'VOLUME OF ROOM	0,6105
FINAL NITROGEN CONCENTRATION (with 10% or 5% more) VdS	45,691
OXYGEN % AFTER FINAL DISCHARGE (with 10% or 5% more)	11,350

3.14.6 Design of distribution network

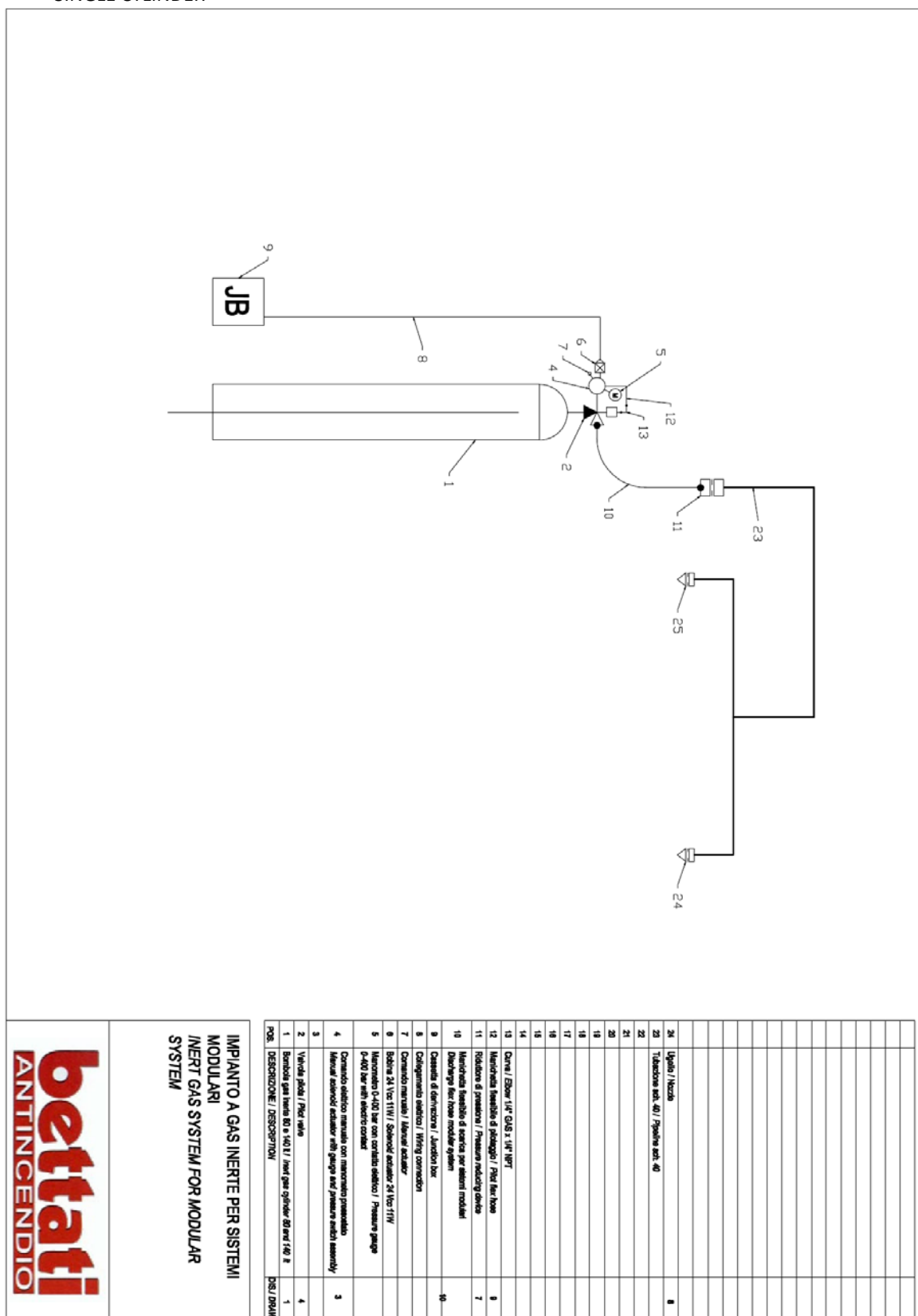


Depending on the room geometry has adopted this balanced distribution to H

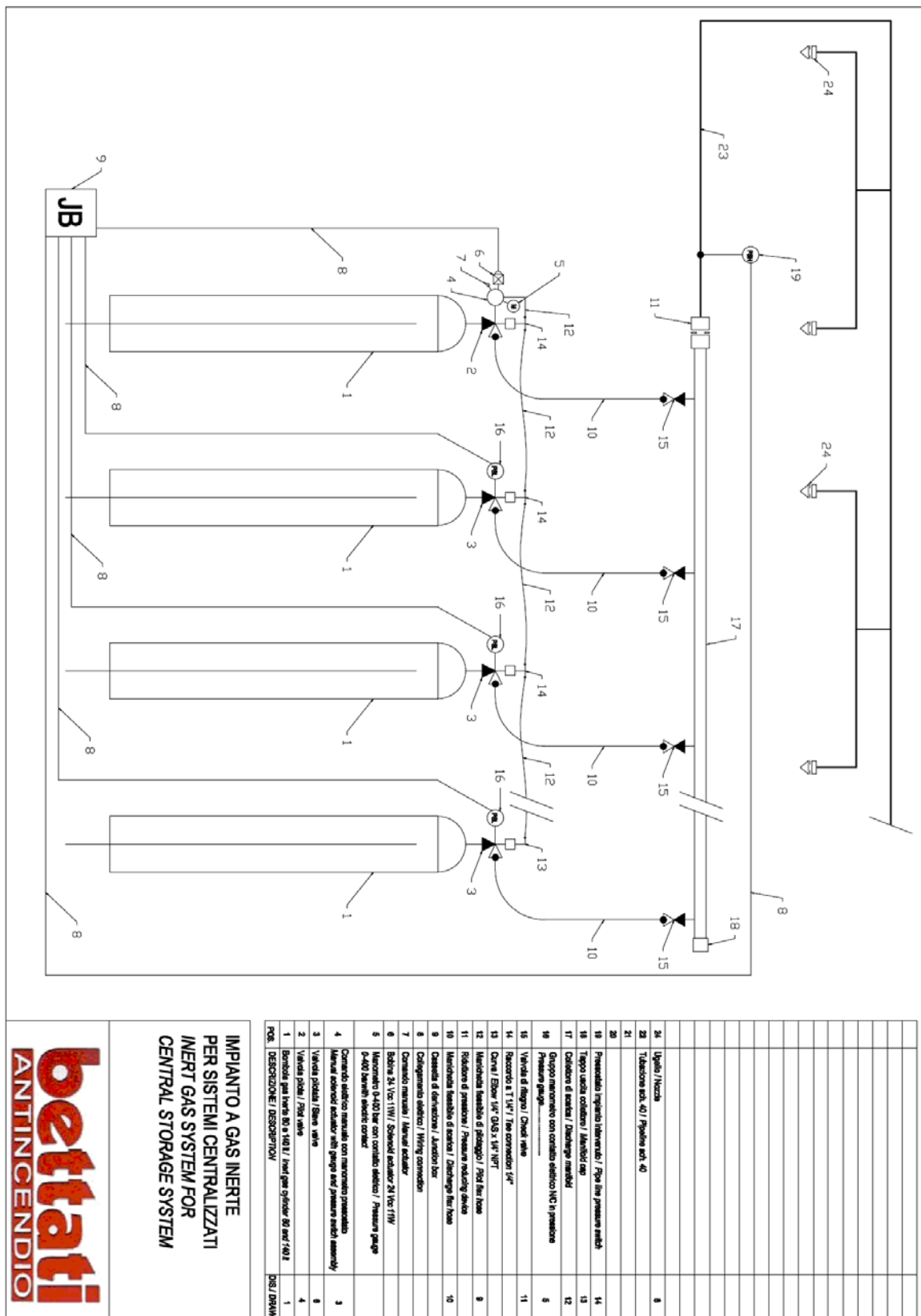


Isometric view of the distribution of diameters and lengths between cylinders and nipples

Wiring diagram:
SINGLE CYLINDER



MULTIPLR CYLINDER



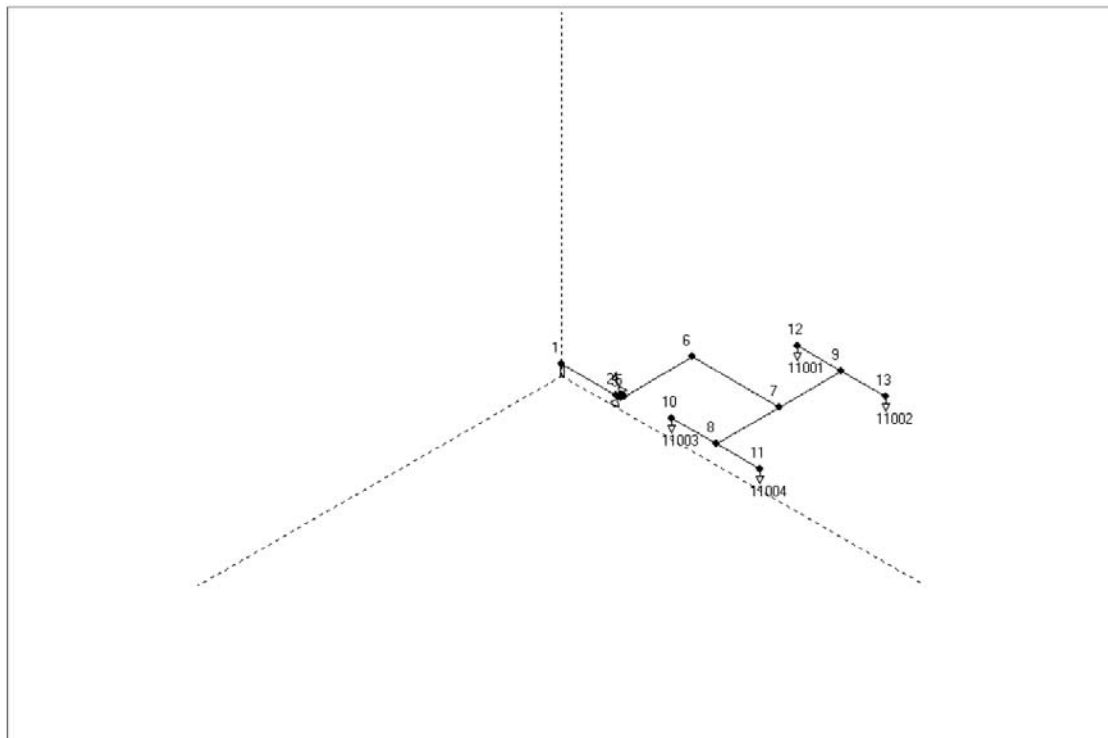
3.14.7 Verification of the above by hydraulic calculation software VDS



VdS SCHADENVERHÜTUNG Nitrogen-Calculationprogram Version 7.2
 Licenced to: Bettati Anticendio
 File: C:\Programmi\VdS\Nitrogen\Projects\Esempio Azoto.prj - Results

Page: 1
Serial no: N200306
06/03/2006

Project:	Esempio Azoto
Project-No:	Impianto di spegnimento ad Azoto B.IG-100
Building:	
Object:	
Contractor:	
Owner:	
Project engineer:	
Date:	06/03/2006
Altitude above sealevel:	0 m
Regulation rule for calculation of Nitrogen quantities:	
Pipe catalogue:	VdS.rkl
Component catalogue:	VdS.arm
Nozzle catalogue:	Bettati.noz





Pipesystem data:

Section- No:	Starting- node	Endnode Nozzle	Length [m]	Height [m]	Pipetype	Diameter [mm] **	Fitting *	Component code	coefficient	Nb of containers Nitrogen quantity
1	0	1	0,500	0,500	12	22,5		-	16,0000	0,0
2	1	2	2,600	0,000	21	54,0	E	-	-	0,0
3	2	3	0,150	0,000	21	54,0	R	-	-	0,0
4	3	4	0,100	0,100	11	54,0	E	-	-	0,0
5	4	5	0,100	0,000	11	54,0	E	-	-	0,0
6	5	6	3,240	0,000	11	54,0	E	-	-	0,0
7	6	7	4,150	0,000	11	54,0	E	-	-	0,0
8	7	8	3,000	0,000	11	36,5	T-90°	-	-	0,0
9	8	10	2,125	0,000	11	28,5	T-90°	-	-	0,0
10	10	11003	0,200	-0,200	11	28,5	E	-	-	0,0
11	8	11	2,125	0,000	11	28,5	T-90°	-	-	0,0
12	11	11004	0,200	-0,200	11	28,5	E	-	-	0,0
13	7	9	3,000	0,000	11	36,5	T-90°	-	-	0,0
14	9	12	2,125	0,000	11	28,5	T-90°	-	-	0,0
15	12	11001	0,200	-0,200	11	28,5	E	-	-	0,0
16	9	13	2,125	0,000	11	28,5	T-90°	-	-	0,0
17	13	11002	0,200	-0,200	11	28,5	E	-	-	0,0

* C=Component, B=Bend, T=T-Piece, E=Elbow, R=Restrictor

** If a pipe diameter is equal zero see the extra table of the calculated diameters

Legend of pipetypes

Type	Pipeclass	Pipe roughness
12	Pipeclass 1	hose
21	Pipeclass 2	galvanized
11	Pipeclass 1	galvanized

Nozzle data:

No.	Calculation zone	Diameter [mm]
11001	Locale	16,0
11002	Locale	16,0
11003	Locale	16,0
11004	Locale	16,0

Legend of nozzles and restrictor:

Type	Number of orifices	C1	C2	C3	C4	C5	C6
1 Nozzle Bettati	1	-0,147	0,006	0,001	0,000	0,000	0,000
Restrictor		-0,147	0,006	0,001	0,000	0,000	0,000

**Calculation zone data:****Calculation of design quantity:**

Zone	Total volume [m3]	Volume of building parts [m3]	Calculated volume [m3]	Total surface [m2]	Max. Over-pressure [mbar]	Design temp. [°C]	Extinguish-conc. [% Vol]	Design factor	Design conc. [% Vol]	Design quantity [kg]
1 Locale	306,0	0,0	306,0	0,0	1,000	20,0	31,0	1,30	40,3	183,89

Regulation rule for calculation of Nitrogen quantities:
Altitude above sealevel: 0,0 m

Nitrogen storage input data:

Container volume: 140,0 l
Container pressure: 300,0 bar abs
Storage temperature: 15,0 °C
Supplement factor: 1,15
Minimum storage quantity: 211,47 kg
Number of containers: 0

Discharge time (input value): 60,0 s
Pressure downstream restrictor: 60,0 bar

Further information:

Design with included gas discharge time
Design with predetermined orifice diameters
Design with predetermined restrictor diameter

**Calculation results:****Nitrogen design data:**

Design quantity:	183,89
Supplement factor:	1,15
Minimum storage quantity:	211,47
Container volume:	140,0 l
Container pressure:	300,0 bar abs
Nitrogen-mass in one container:	43,5 kg
Number of containers:	5
Actual storage quantity:	217,7 kg
Storage temperature:	15,0 °C
Starting container pressure:	300,0 bar abs

Discharge time:

Total discharge time of air and Nitrogen:	52,6 s
---	--------

System information:

Restrictor diameter:	13,0 mm
Container working pressure:	208,1 bar abs
Total network volume:	34,6 l



Pipe system:

Section- No:	Starting- node	Endnode Nozzle	Pressure [bar abs]	Temperature [°C]	Flowrate [kg/s]	Pipedimension Di [mm]	DN
1	0	1	205,95	1,74	1,01	22,5	3/4
2	1	2	205,78	1,73	5,09	54,0	2
3	2	3	36,19	-25,43	5,09	54,0	2
4	3	4	35,70	-25,69	5,09	54,0	2
5	4	5	35,21	-25,95	5,09	54,0	2
6	5	6	34,33	-26,43	5,09	54,0	2
7	6	7	33,30	-27,01	5,09	54,0	2
8	7	8	31,69	-27,47	2,54	36,5	11/4
9	8	10	30,00	-27,73	1,27	28,5	1
10	10	11003	29,46	-28,08	1,27	28,5	1
11	8	11	30,00	-27,73	1,27	28,5	1
12	11	11004	29,46	-28,08	1,27	28,5	1
13	7	9	31,69	-27,47	2,54	36,5	11/4
14	9	12	30,00	-27,73	1,27	28,5	1
15	12	11001	29,46	-28,08	1,27	28,5	1
16	9	13	30,00	-27,73	1,27	28,5	1
17	13	11002	29,46	-28,08	1,27	28,5	1

**Nozzle data:**

Calculation- zone no:	Nozzle no.	Nozzle type	Number of orifices	Pipeconnection Di [mm]	DN	Orifice [mm]	Nitrogen out- put [kg]
1	11001	1	1	28,5	1	16,0	46,0
1	11002	1	1	28,5	1	16,0	46,0
1	11003	1	1	28,5	1	16,0	46,0
1	11004	1	1	28,5	1	16,0	46,0

MAX. TRANSPORT TIME DIFF. BETWEEN NOZZLES: 11004./ 11003. IS 0.00 S



Concentrations:

Calculation- zone no:	Gascomposition after the discharge of the design quantity [%]			
	O2	CO2	AR	N2
1	12,4	0,0	0,6	87,0

Total flooded design quantity within discharge time: 183,89 kg

Calculation- zone no:	Gascomposition after total discharge [%]			
	O2	CO2	AR	N2
1	11,3	0,0	0,5	88,2

Total flooded Nitrogen mass: 216.8 KG

Pressure relief opening:

Calculation- zone no:	Recommended area against overpressure		Max. flow [kg/s]
	Area [m²]	Overpressure [mbar]	
1	0,768	1,0	7,85



Component list:

Nozzle-type	Number	C1	C2	C3	C4	C5	C6
1	4	-0,147	0,006	0,001	0,000	0,000	0,000
Restrictor	1	-0,147	0,006	0,001	0,000	0,000	0,000

Pipe-type	Di [mm]	DN	Length [m]
12	22,50	3/4	0,500
21	54,00	2	2,800
11	54,00	2	7,600
11	36,50	1 1/4	6,000
11	28,50	1	9,200

Number of bends (+) and elbows (-)

Bend-type	Di [mm]	DN	Number
-90	54,00	2	1
-90	54,00	2	4
-90	28,50	1	4

Number of T-distributors (in- and outdiameter)

Number	Input	90-out	90-out	0-out
1	54,0	36,5	36,5	0,0
2	36,5	28,5	28,5	0,0

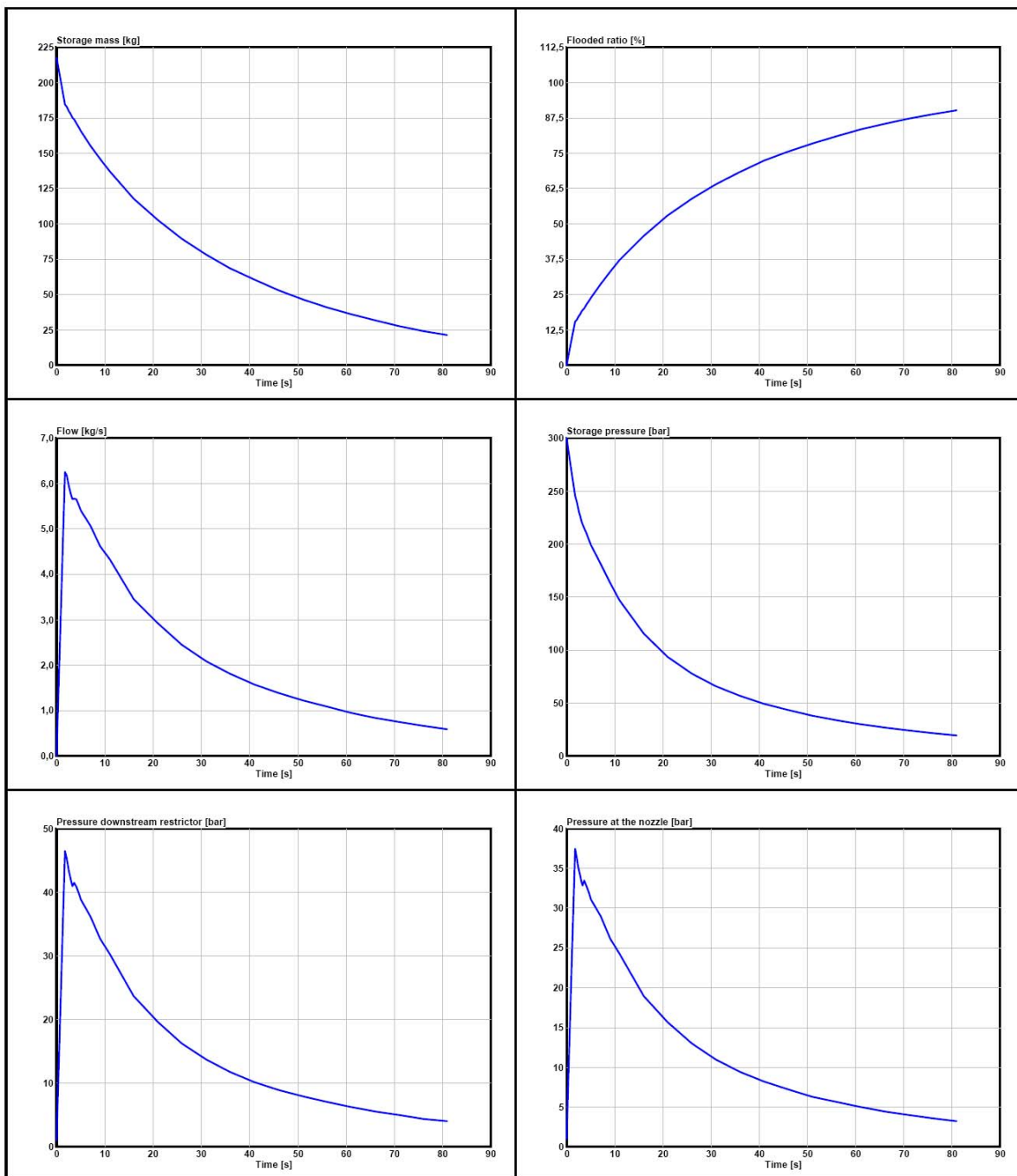


Dynamic flooding results

The calculation bases on a mean nozzle pressure!

Flooding time [s]	Storage mass [kg]	Flooded ratio [%]	Flow [kg/s]	Storage pressure [bar]	Pressure downstream restrictor [bar]	Pressure at nozzle [bar]
0,0	217,7	0,0	0,00	300,0	1,0	1,0
1,8	184,3	15,4	6,25	245,4	46,5	37,5
2,1	182,7	16,1	6,18	239,7	45,3	36,3
2,3	181,2	16,8	6,05	234,7	44,3	35,4
2,6	179,7	17,4	5,94	230,1	43,3	34,7
2,8	178,3	18,1	5,83	226,0	42,5	34,1
3,1	176,8	18,8	5,74	222,1	41,7	33,4
3,3	175,4	19,4	5,65	218,5	41,0	32,9
3,6	174,0	20,1	5,67	215,0	41,5	33,5
4,1	171,2	21,4	5,65	209,9	40,9	32,8
4,6	168,4	22,6	5,53	204,4	39,9	32,0
5,1	165,7	23,9	5,40	198,8	38,9	31,1
7,1	155,4	28,6	5,07	181,1	36,2	29,0
9,1	145,9	33,0	4,62	163,2	32,7	26,2
11,0	137,1	37,0	4,33	147,0	30,3	24,3
16,0	118,1	45,7	3,46	115,4	23,7	19,0
21,0	102,6	52,9	2,92	93,5	19,6	15,7
26,0	89,4	58,9	2,45	77,6	16,2	13,0
31,0	78,3	64,0	2,09	65,8	13,7	11,0
36,0	68,7	68,4	1,81	56,6	11,8	9,4
41,0	60,4	72,3	1,57	49,2	10,2	8,2
46,0	53,1	75,6	1,38	43,1	8,9	7,2
51,0	46,7	78,5	1,22	38,1	7,9	6,3
56,0	41,1	81,1	1,08	33,8	7,0	5,6
61,0	36,0	83,4	0,95	30,1	6,2	5,0
66,0	31,6	85,5	0,84	26,9	5,5	4,4
71,0	27,7	87,3	0,75	24,0	5,0	4,0
76,0	24,2	88,9	0,66	21,5	4,4	3,6
81,0	21,1	90,3	0,59	19,3	4,0	3,2

Discharge meantime at nozzle: 52,6 s



3.14.8 System installation

See: "Installation manual for inert gas system"

3.14.9 System start-up

See: "Installation manual for inert gas system"

3.14.10 Carry out the door fan integrity test

See: "Installation manual for inert gas system"

3.14.11 Management (the ordinary and extraordinary maintenance)

See: "Maintenance manual"

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