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 15004-7:2008 “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 12094-10:2004 “Fixed firefighting systems - Components for gas extinguishing systems . Requirements and test methods for pressure gauges and pressure switches”


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” were 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)
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 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)

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Argon IG 01</th>
<th>Nitrogen IG 100</th>
<th>Argon+Nitrogen IG 55</th>
<th>Argon+Nitrogen+CO2 IG 541</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular mass</td>
<td>—</td>
<td>39,9</td>
<td>28,02</td>
<td>33,98</td>
<td>34,0</td>
</tr>
<tr>
<td>Boiling point at 1,013 bar (absolute)</td>
<td>°C</td>
<td>-185,9</td>
<td>-195,8</td>
<td>-196</td>
<td>-196</td>
</tr>
<tr>
<td>Freezing point</td>
<td>°C</td>
<td>-189,4</td>
<td>-210,0</td>
<td>—</td>
<td>-78,5</td>
</tr>
<tr>
<td>Critical temperature</td>
<td>°C</td>
<td>-122,3</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Critical pressure</td>
<td>bar abs</td>
<td>49,0</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Critical volume</td>
<td>cm³/mol</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Critical density</td>
<td>kg/m³</td>
<td>536</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Vapour pressure 20 °C</td>
<td>bar abs</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>152</td>
</tr>
<tr>
<td>Liquid density 20 °C</td>
<td>Kg/m³</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Saturated vapour density 20 °C</td>
<td>Kg/m³</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Specific volume of superheated vapour at 1,013 bar and 20 °C</td>
<td>m³/kg</td>
<td>0,602</td>
<td>0,858</td>
<td>0,708</td>
<td>0,697</td>
</tr>
<tr>
<td>Chemical formula</td>
<td></td>
<td>Ar</td>
<td>N₂</td>
<td>50% Ar</td>
<td>50% N₂</td>
</tr>
<tr>
<td>Chemical name</td>
<td></td>
<td>Argon</td>
<td>Nitrogen</td>
<td>Argon Nitrogen</td>
<td>Argon Nitrogen CO₂</td>
</tr>
</tbody>
</table>

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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 personnel (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 vaporizes rapidly when mixed with air and thus limits the hazard to the immediate vicinity of the discharge point. In humid atmospheres, minor reduction in visibility can occur for a brief period due to the condensation of water 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.

<table>
<thead>
<tr>
<th>Agent</th>
<th>No Effect Level* (%)</th>
<th>Low Effect Level* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IG-01</td>
<td>43</td>
<td>52</td>
</tr>
<tr>
<td>IG-100</td>
<td>43</td>
<td>52</td>
</tr>
<tr>
<td>IG-55</td>
<td>43</td>
<td>52</td>
</tr>
<tr>
<td>IG-541</td>
<td>43</td>
<td>52</td>
</tr>
</tbody>
</table>

*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:

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

**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 component 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>
<thead>
<tr>
<th>Fuel</th>
<th>Extinguishment</th>
<th>Minimum design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heptane (cup burner)</td>
<td>33,6</td>
<td>47,6</td>
</tr>
<tr>
<td>Heptane (room test)</td>
<td>36,6</td>
<td></td>
</tr>
<tr>
<td>Class A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood crib</td>
<td>30,0</td>
<td>40,3</td>
</tr>
<tr>
<td>PMMA</td>
<td>28,8</td>
<td></td>
</tr>
<tr>
<td>PP</td>
<td>30,0</td>
<td></td>
</tr>
<tr>
<td>ABS</td>
<td>31,0</td>
<td></td>
</tr>
<tr>
<td>Class A Higher hazard</td>
<td>a</td>
<td>45,2</td>
</tr>
</tbody>
</table>
### Table 4 - IG-01 reference extinguishing and design concentrations EN 15004-7

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Extinguishment</th>
<th>Minimum design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heptane (cup burner)</td>
<td>39,1</td>
<td>51,7</td>
</tr>
<tr>
<td>Heptane (room test)</td>
<td>39,8</td>
<td></td>
</tr>
<tr>
<td><strong>Class A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood crib</td>
<td>30,7</td>
<td></td>
</tr>
<tr>
<td>PMMA</td>
<td>31,6</td>
<td>41,9</td>
</tr>
<tr>
<td>PP</td>
<td>31,6</td>
<td></td>
</tr>
<tr>
<td>ABS</td>
<td>32,2</td>
<td></td>
</tr>
<tr>
<td><strong>Class A Higher hazard</strong></td>
<td>a</td>
<td>49,2</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Extinguishment</th>
<th>Minimum design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heptane (cup burner)</td>
<td>36,5</td>
<td>47,6</td>
</tr>
<tr>
<td>Heptane (room test)</td>
<td>36,6</td>
<td></td>
</tr>
<tr>
<td><strong>Class A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood crib</td>
<td>28,7</td>
<td></td>
</tr>
<tr>
<td>PMMA</td>
<td>30,7</td>
<td>40,3</td>
</tr>
<tr>
<td>PP</td>
<td>29,3</td>
<td></td>
</tr>
<tr>
<td>ABS</td>
<td>31,0</td>
<td></td>
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<tr>
<td><strong>Class A Higher hazard</strong></td>
<td>a</td>
<td>45,2</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Extinguishment</th>
<th>Minimum design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heptane (cup burner)</td>
<td>31,7</td>
<td>48,1</td>
</tr>
<tr>
<td>Heptane (room test)</td>
<td>37,0</td>
<td></td>
</tr>
<tr>
<td><strong>Class A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood crib</td>
<td>28,2</td>
<td></td>
</tr>
<tr>
<td>PMMA</td>
<td>30,7</td>
<td>39,9</td>
</tr>
<tr>
<td>PP</td>
<td>30,6</td>
<td></td>
</tr>
<tr>
<td>ABS</td>
<td>30,7</td>
<td></td>
</tr>
<tr>
<td><strong>Class A Higher hazard</strong></td>
<td>a</td>
<td>45,7</td>
</tr>
</tbody>
</table>

### 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

<table>
<thead>
<tr>
<th>Temperature</th>
<th>m/V (kg/m³)</th>
<th>V (m³/kg)</th>
<th>34 %</th>
<th>38 %</th>
<th>42 %</th>
<th>45 %</th>
<th>50 %</th>
<th>54 %</th>
<th>58 %</th>
<th>62 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>kg / m³</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>-40</td>
<td>0.8825</td>
<td>0.522</td>
<td>0.901</td>
<td>0.885</td>
<td>0.775</td>
<td>0.872</td>
<td>0.976</td>
<td>1.091</td>
<td>1.217</td>
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<td>0.9571</td>
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<td>0.588</td>
<td>0.671</td>
<td>0.758</td>
<td>0.833</td>
<td>0.956</td>
<td>1.068</td>
<td>1.191</td>
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<tr>
<td>-30</td>
<td>0.7118</td>
<td>0.501</td>
<td>0.576</td>
<td>0.657</td>
<td>0.743</td>
<td>0.836</td>
<td>0.936</td>
<td>1.046</td>
<td>1.167</td>
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</tr>
<tr>
<td>-25</td>
<td>0.7266</td>
<td>0.491</td>
<td>0.555</td>
<td>0.644</td>
<td>0.728</td>
<td>0.819</td>
<td>0.917</td>
<td>1.025</td>
<td>1.143</td>
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</tr>
<tr>
<td>-20</td>
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<td>0.554</td>
<td>0.631</td>
<td>0.714</td>
<td>0.803</td>
<td>0.899</td>
<td>1.005</td>
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<tr>
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<td>0.700</td>
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<td>0.882</td>
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<td>-10</td>
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<td>0.533</td>
<td>0.607</td>
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<td>0.875</td>
<td>0.978</td>
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<td>-5</td>
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<td>0.523</td>
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<td>0.948</td>
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<td>0.470</td>
<td>0.535</td>
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<td>0.853</td>
<td>0.951</td>
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<td>0.494</td>
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<td>0.479</td>
<td>0.542</td>
<td>0.610</td>
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<td>0.472</td>
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<td>0.730</td>
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<td>0.397</td>
<td>0.452</td>
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<td>0.575</td>
<td>0.645</td>
<td>0.720</td>
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<td>85</td>
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<td>0.391</td>
<td>0.445</td>
<td>0.504</td>
<td>0.567</td>
<td>0.603</td>
<td>0.710</td>
<td>0.792</td>
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</tr>
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<td>0.560</td>
<td>0.627</td>
<td>0.700</td>
<td>0.781</td>
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<td>0.491</td>
<td>0.552</td>
<td>0.618</td>
<td>0.691</td>
<td>0.770</td>
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<td>1.0927</td>
<td>0.326</td>
<td>0.376</td>
<td>0.423</td>
<td>0.484</td>
<td>0.545</td>
<td>0.610</td>
<td>0.682</td>
<td>0.760</td>
<td></td>
</tr>
</tbody>
</table>

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
- \( S \) 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
  \[
  k_1 = 0.79968, \quad k_2 = 0.00293
  \]
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 \( c = 40,3\% \).

\[ S_k = k_1 + k_2 \cdot T = 0,799 \, 68 + 0,002 \, 93 \cdot 20 = 0,85828 \]
\[ S = k_1 + k_2 \cdot T = 0,799 \, 68 + 0,002 \, 93 \cdot 20 = 0,85828 \]
\[ m = \frac{V}{S} \cdot \ln \left( \frac{100}{100 - c} \right) = \frac{100}{0,85828} \cdot \ln \left( \frac{100}{100 - 40,3} \right) = 60,10138481 \]
\[ Q = m \cdot S_k = 60,10138481 \cdot 0,85828 = 51,58381656 \]
\[ x = \frac{Q}{V} = \frac{51,58381656}{100} = 0,5158381656 \]

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)

<table>
<thead>
<tr>
<th>Equivalent altitude m</th>
<th>Correction factor (for ideal gases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1000</td>
<td>1,130</td>
</tr>
<tr>
<td>0</td>
<td>1,000</td>
</tr>
<tr>
<td>1000</td>
<td>0,885</td>
</tr>
<tr>
<td>1500</td>
<td>0,830</td>
</tr>
<tr>
<td>2000</td>
<td>0,785</td>
</tr>
<tr>
<td>2500</td>
<td>0,735</td>
</tr>
</tbody>
</table>

Revised 05/2010
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.

<table>
<thead>
<tr>
<th>Max Exposure time</th>
<th>Gas Concentration after total discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>Oxygen Concentration</td>
</tr>
<tr>
<td>Max Exposure Time</td>
<td>X &lt; 43%</td>
</tr>
<tr>
<td></td>
<td>43% &lt; X &lt; 52%</td>
</tr>
<tr>
<td></td>
<td>52% &lt; X &lt; 62%</td>
</tr>
<tr>
<td></td>
<td>X &gt; 62%</td>
</tr>
<tr>
<td>Occupied</td>
<td>12%</td>
</tr>
<tr>
<td>Normally Unoccupied</td>
<td>12% -10%</td>
</tr>
<tr>
<td>Unoccupied</td>
<td>10% - 8%</td>
</tr>
<tr>
<td></td>
<td>&lt; 8%</td>
</tr>
</tbody>
</table>

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.

\[
R_{IG-101} = \left( \frac{(-1)M}{283} \right) e^{\left( \frac{293}{283+C} \right)} - 1 \cdot (-100)
\]

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:

\[
R_{OXYGEN} = \left( \frac{R_{IG-101}}{100} - 1 \right) \cdot 20,9 \cdot (-1)
\]

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. Compiles with ISO draft standard 15420.1

By Retrotec, Inc. 2200 Cleason 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: ARCHIVO 1  Test number: 1
Calibration Certificate: 4 3794  Certificate created 2009/01/05

Test date/time: 2009/09/29 16.37  Testa: Paola Bertolini
Certified to Level: No enclosure certification
Signature: -------------------------------
Elevation above sea level: 8 m
Correction factor: 1  NFPA 2001 (2000) Formula A-3.5.3.3
Agent: IG-100
Actual total leakage: A: 0.0497 m^2
Actual lesser leakage: A: 0.0248 m^2

Net protected volume: V_n 256 m^3
Maximum Protected Height, H_{max} 3.11 m
Minimum Protected Height, H 3.11 m
Static pressure discharge, P_{sw} 0.0 Pa
Operating temperature 20 C
Initial concentration, C 44.24%
Mixing during retention Yes
Agent quantity 174 kg
Minimum concentration, C_{min} 36.60%
Minimum retention time 10.8 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

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Printed on: 2009/10/05 08:36  Page 2
**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.reتروtec.com

---

**Software Licensed to:** Bettati Antincendio Srl

**Building, Location:** EX PRET EX PRETURA DI XXX, XXX, ITALIA

**Company, Contact:** ELGAL I EX PRETURA DI XXX, SIG. XXXX

**Room name:** ARCHIVIO I  Test number 1

**Calibration Certificate:** # 3794  Certificate created 2009/10/05

---

### Total Room Leakage

<table>
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<th>Depressurization</th>
<th>Range for room pressures: -10.0 to -13.0</th>
</tr>
</thead>
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<td>Blower range</td>
<td>Room pressure -11.7</td>
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<tr>
<td></td>
<td>Auto corrected RF -11.7</td>
</tr>
<tr>
<td>Ring C4</td>
<td>Flow Pressure 63.7</td>
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<tr>
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<table>
<thead>
<tr>
<th>Pressurization</th>
<th>Range for room pressures: 10.0 to 13.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blower range</td>
<td>Room pressure 13.2</td>
</tr>
<tr>
<td></td>
<td>Auto corrected RF 13.2</td>
</tr>
<tr>
<td>Ring C4</td>
<td>Flow Pressure 48.8</td>
</tr>
<tr>
<td></td>
<td>Auto corrected FR 48.8</td>
</tr>
<tr>
<td>Corrected flow (m³/sec)</td>
<td>0.1353</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E.LA m²²</th>
<th>gPa</th>
<th>F</th>
<th>Slope m</th>
<th>Intercept k</th>
<th>Correlation</th>
<th>Standard Error</th>
<th>E.LA m²²</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0620</td>
<td>11.7</td>
<td></td>
<td>0.5000</td>
<td>0.0409</td>
<td>NA</td>
<td>NA</td>
<td>0.0497</td>
<td>10.0</td>
</tr>
<tr>
<td>0.0473</td>
<td>13.2</td>
<td></td>
<td>0.5000</td>
<td>0.0372</td>
<td>NA</td>
<td>NA</td>
<td>0.0497</td>
<td>10.0</td>
</tr>
</tbody>
</table>

**Lower Leakage**

**Below ceiling leakage of 0.0248 m²² @ 10.0 Pa is the worst case assumption of 50%**

---

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

**Level 1:** Fire enclosure design basics for improving agent retention and passive protection

**Level 2:** Adds single door fan operation and NFPA clean agent retention time calculations

**Level 3:** Adds double door fan operation for Lower Leak measurement

**Level 4:** Adds multi-point ISO door fan operation and discharge pressure relief vent

---

*Printed on: 2009/10/05 08:36*  
*Page 2*
DOOR FAN TEST – Graph

CleanAgent 2007 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: ELGAL IMI EX PRETURA DI XXX, SIG: XXXX
Room name: ARCHIVO 1 Test number 1
Calibration Certificate # 3794 Certificate created 2009/01/05

Leakage (m³/sec.)

Room Pressure (Pa)

- Total leakage, depressurizing
- Total leakage, pressurizing

Printed on: 2009/10/05 08:36
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.](image)

![Fig. 2: Time evolution of the ambient pressure during the discharge of an halocarbon gas.](image)

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.
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](http://www.cea.eu)) “Fire extinguishing systems using liquefied halocarbon gases: planning and installation” and “Fire extinguishing systems using non-liquefied inert gases: planning and installation”;

2. Experimental data provided by Retrotec Inc. ([www.retrotec.com](http://www.retrotec.com)), on years of experience and research.

**CEA Directive**

CEA directive “Fire extinguishing systems using liquefied 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

$$A = \frac{M_P \cdot v_P}{\sqrt{\Delta p \cdot \gamma_{HOM}}} C_2$$

(1)

where
Specific volume $v_{HOM}$ and density $\rho_{HOM}$ 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

$\varepsilon$ ...................... = volume fraction $\leq 1$

$x$ ...................... = mass fraction $\leq 1$

$\rho_p$ ...................... = extinguishing gas density $[kg/m^3]$

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

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..
**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.

**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.

**Tab. 2: Features of protected room and extinguishing system**

<table>
<thead>
<tr>
<th>Volume</th>
<th>256 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum allowable pressure</td>
<td>500 Pa</td>
</tr>
<tr>
<td>Extinguishing gas concentration</td>
<td>44.24 %</td>
</tr>
<tr>
<td>Discharge time</td>
<td>60 s</td>
</tr>
<tr>
<td>“Natural” room opening</td>
<td>0.05 m²</td>
</tr>
</tbody>
</table>
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 m\(^2\) (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.

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

**Tab. 3: Overpressure damper determination.**

<table>
<thead>
<tr>
<th>Area required for the vent overpressure</th>
<th>0.32 m(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of overpressure damper</td>
<td>1</td>
</tr>
</tbody>
</table>

**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.
Serranda di sovrappressione
Over pressure damper

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

<table>
<thead>
<tr>
<th>N°</th>
<th>Descrizione / Description</th>
<th>Materiale / Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aloette esterne con contrappesi / External tongue with counter weight</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Accessori - serranda REI 120 / Optional - dumper REI 120</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Accessori / Spacer</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Griglia / Wall secure damper</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inizio apertura</th>
<th>0.8 mbar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apertura intermedia</td>
<td>2.0 mbar</td>
</tr>
<tr>
<td>Apertura completa</td>
<td>3.5 mbar</td>
</tr>
</tbody>
</table>
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.
- 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 ± 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 - 22017 RHO (MI)
Tel. 039/30.15.17 r.a. - Fax 039/30.31.76 - Internet: www.masmasini.it - E-mail masmasini@betatiantincendio.it


Autorizzazione:
Ministero delle Infrastrutture e dei Trasporti per legge 1086 - Ministero dell'Università e della Ricerca Scientifica e Tecnologica per Legge 40/2002 - Ministero dell'Interno per provvedimenti di piano, centri estesi per laboratori e servizi, esamini di fabbricazione e calibri - Ministero della Salute per analisi in EPL e prova I.S.P.E.S.L. – Regione Lombardia per analisi acute possibili e non – Ministero dell’Industria, de la Poste e dei Telecommunications per prove a pressione e verifiche di sorveglianza alla produzione


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 UGHELLI 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 inerenti.

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 inerente 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 stessa integrale, si riferisce ai soli campioni esaminati.
Camera di prova

Costruzione in cemento armato.

<table>
<thead>
<tr>
<th>Dimensione (mm)</th>
<th>7920</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunghezza</td>
<td>5030</td>
</tr>
<tr>
<td>Larghezza</td>
<td>3500</td>
</tr>
<tr>
<td>Altezza</td>
<td>39,8</td>
</tr>
<tr>
<td>Area (m²)</td>
<td>139,4</td>
</tr>
</tbody>
</table>

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 del trasduttore di pressione sono acquisiti con cadenza di 5 scansioni al secondo mediante moduli multiplexer gestiti da software LabView e Max della stessa casa.

La misura dell’ossigeno è stata effettuata mediante 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 del 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.

<table>
<thead>
<tr>
<th>Tubazione</th>
<th>Pipe</th>
<th>Schedule</th>
<th>Diameter (inches)</th>
<th>Material</th>
<th>Thread</th>
<th>Pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manifold</td>
<td>API 5LX</td>
<td>XXS</td>
<td>2”</td>
<td>11.07</td>
<td></td>
<td>NPT</td>
</tr>
<tr>
<td>Placed after the orifice plate with directional valves</td>
<td>API 5LGRB</td>
<td>160</td>
<td>2”</td>
<td>8.74</td>
<td>ASTM A-106 Galvanized seamless</td>
<td>NPT</td>
</tr>
<tr>
<td>Placed after the orifice plate without directional valves</td>
<td>API 5LGRB</td>
<td>40</td>
<td>½” 1” 1”1/4 1”1/2 2” 2”1/2 3”</td>
<td>2.77 2.87 3.38 3.56 3.68 3.91 5.16 5.49</td>
<td>ASTM A-106 Galvanized seamless</td>
<td>NPT</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fittings</th>
<th>Type</th>
<th>Material</th>
<th>Screw thread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placed after the orifice plate with directional valves</td>
<td>ASA 6000</td>
<td>ASTM A-105 galvanized</td>
<td>NPT</td>
</tr>
<tr>
<td>Placed after the orifice plate without directional valves</td>
<td>ASA 3000</td>
<td>ASTM A-105 galvanized</td>
<td>NPT</td>
</tr>
</tbody>
</table>
3.11 Estimating Pipe Sizes

The following are approximate flow rate for estimating pipe sizes

<table>
<thead>
<tr>
<th>Nitrogen IG100</th>
<th>Argon+Nitrogen IG55</th>
</tr>
</thead>
<tbody>
<tr>
<td>inch</td>
<td>Kg/sec x 60sec</td>
</tr>
<tr>
<td>1/2”</td>
<td>0-26</td>
</tr>
<tr>
<td>3/4”</td>
<td>26-45</td>
</tr>
<tr>
<td>1”</td>
<td>46-92</td>
</tr>
<tr>
<td>1”1/4</td>
<td>93-138</td>
</tr>
<tr>
<td>1”1/2</td>
<td>139-220</td>
</tr>
<tr>
<td>2”</td>
<td>221-565</td>
</tr>
<tr>
<td>2”1/2</td>
<td>566-940</td>
</tr>
<tr>
<td>3”</td>
<td>941-1254</td>
</tr>
<tr>
<td>4”</td>
<td>1255-2245</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Argon 01 Sch40</th>
<th>Argon+Nitrogen+CO₂ IG55</th>
</tr>
</thead>
<tbody>
<tr>
<td>inch</td>
<td>Kg/sec x 60sec</td>
</tr>
<tr>
<td>1/2”</td>
<td>0-41</td>
</tr>
<tr>
<td>3/4”</td>
<td>60-71</td>
</tr>
<tr>
<td>1”</td>
<td>72-145</td>
</tr>
<tr>
<td>1”1/4</td>
<td>146-217</td>
</tr>
<tr>
<td>1”1/2</td>
<td>218-346</td>
</tr>
<tr>
<td>2”</td>
<td>347-889</td>
</tr>
<tr>
<td>2”1/2</td>
<td>890-1479</td>
</tr>
<tr>
<td>3”</td>
<td>1480-1973</td>
</tr>
<tr>
<td>4”</td>
<td>1974-3533</td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>TABLE 3.8 - Maximum pipework spans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal diameter of pipe</td>
</tr>
<tr>
<td>DN</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Diameter (mm)</th>
<th>Discharge Rate (m³/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1.8</td>
</tr>
<tr>
<td>25</td>
<td>2.1</td>
</tr>
<tr>
<td>32</td>
<td>2.4</td>
</tr>
<tr>
<td>40</td>
<td>2.7</td>
</tr>
<tr>
<td>50</td>
<td>3.4</td>
</tr>
<tr>
<td>65</td>
<td>3.5</td>
</tr>
<tr>
<td>80</td>
<td>3.7</td>
</tr>
<tr>
<td>100</td>
<td>4.3</td>
</tr>
<tr>
<td>125</td>
<td>4.8</td>
</tr>
<tr>
<td>150</td>
<td>5.2</td>
</tr>
<tr>
<td>200</td>
<td>5.8</td>
</tr>
</tbody>
</table>
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:

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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 protected
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

<table>
<thead>
<tr>
<th>Room Location</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>System to be implemented</td>
<td></td>
</tr>
<tr>
<td>Altitude a.s.l</td>
<td>Temperature °C</td>
</tr>
<tr>
<td>Mechanical system surveys to be carried out and indicated in the plan</td>
<td></td>
</tr>
</tbody>
</table>

- If not available dimension of the room
- Type of masonry and / or ceiling
- 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

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Exinguishing</th>
<th>Minimum design</th>
</tr>
</thead>
</table>
| Class B
  Heptane (cup burner) | 33,6 % | 47,6 % |
  Heptane (room test) | 36,6 % | |
| Class A
  Wood crib | 30,0 | |
  PMMA | 28,8 | |
  PP | 30,0 | 40,3 |
  ABS | 31,0 | |
| Class A High Hazard | | 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.

<table>
<thead>
<tr>
<th>Product</th>
<th>Notified body</th>
<th>Serial ID Notified body</th>
<th>Standard reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inert gas valve and actuator V300x</td>
<td>Consortium RINA-OMECO</td>
<td>0474</td>
<td>97/23/CE - PED</td>
</tr>
<tr>
<td>Inert gas valve and actuator V300x</td>
<td>Test and research istitute “M. Masini”</td>
<td>068</td>
<td>EN 12094 Part 4:2004</td>
</tr>
<tr>
<td>Directional valve and actuator</td>
<td>Test and research istitute “M. Masini”</td>
<td>068</td>
<td>EN12094 Part 5:2006</td>
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<tr>
<td>Nozzles</td>
<td>Test and research istitute “M. Masini”</td>
<td>068</td>
<td>EN 12094 Part 7:2005</td>
</tr>
</tbody>
</table>
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):
\[
S = k_1 + k_2 \cdot T = 0.79968 + 0.00293 \cdot 20 = 0.85828
\]
\[
m = \frac{V}{S} \cdot \ln\left(\frac{100}{100 - c}\right) = \frac{100}{0.85828} \cdot \ln\left(\frac{100}{100 - 40.3}\right) = 60,10138481
\]
\[
Q = m \cdot S_k = 60,10138481 \cdot 0.85828 = 51,58381656
\]
\[
x = \frac{Q}{V} = \frac{51,58381656}{306} = 0.17\%
\]

The value was derived from the formula as 40.3% did not appear in Table 3.2.
Quantity project in m³:
\[
Q_{\text{design}} = V \cdot x = 306\text{[m}^3]\cdot 0.17\% = 51,58381656\text{ m}^3
\]
Quantity project in kg: 157,8348 [m³] / 0.8583 [kg/ m³] = 183,8923453 [kg]

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

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

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

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

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

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

The concentration is: \( C_{\text{fin}} = 100 \cdot \frac{e^{x_f - 1}}{e^{x_f}} = 100 \cdot \frac{e^{0.6104}}{e^{0.6104}} = 45.68 \% \text{ per volume} \)

with \( x_f = Q_f \cdot \frac{V}{m^3} = 0.6104 \left(\frac{m^3_{\text{gas}}}{m^3_{\text{protected space}}}\right) \) (as you can see in the following spreadsheet)

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

\[
O_{\text{fin}} = O_{\text{in}} - \left(\frac{O_{\text{in}} \cdot C_{\text{fin}}}{100}\right) = 20.9 - \left(\frac{20.9 \cdot 45.68}{100}\right) = 11.35\%
\]

<p>| MINIMUM CONCENTRATION OF PROJECT CLASSE A | 40,3 |
| VOLUME [m³] | 306 |
| TOTAL VOLUME [m³] | 306 |
| TEMPERATURE [°C] | 20 |</p>
<table>
<thead>
<tr>
<th>CONTENT CYLINDER AT 15 °C [KG]</th>
<th>43,53</th>
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</thead>
<tbody>
<tr>
<td>SPECIFIC VOLUME AT 20°C [m^3/KG]</td>
<td>0,8583</td>
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<tr>
<td>PERCENT OXYGEN IN THE DRY AIR</td>
<td>20,9</td>
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<tr>
<td>DISCHARGE TIME [s]</td>
<td>60</td>
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</table>

### RESULTS

<table>
<thead>
<tr>
<th>VOLUME OF GAS ON UNIT OF ROOM VOLUME [m^3/m^3]</th>
<th>0,51840</th>
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</thead>
<tbody>
<tr>
<td>NITROGEN ROOM PROJECT AMOUNT [m^3]</td>
<td>158,6</td>
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<tr>
<td>TOTAL NITROGEN PROJECT AMOUNT [m^3]</td>
<td>158,6</td>
</tr>
<tr>
<td>NITROGEN PROJECT AMOUNT [KG]</td>
<td>184,8179803</td>
</tr>
<tr>
<td>OXYGEN % AFTER 60 sec. DISCHARGE</td>
<td>12,477</td>
</tr>
<tr>
<td>ACTUAL AMOUNT OF NITROGEN IN kg (with 10% or 5% more)</td>
<td>203,300</td>
</tr>
<tr>
<td>CYLINDERS NUMBER</td>
<td>5</td>
</tr>
<tr>
<td>FINAL AMOUNT OF NITROGEN kg</td>
<td>217,65</td>
</tr>
<tr>
<td>FINAL VOLUME ON GAS UNIT VOLUME OF ROOM</td>
<td>0,6105</td>
</tr>
<tr>
<td>FINAL NITROGEN CONCENTRATION (with 10% or 5% more) VdS</td>
<td>45,691</td>
</tr>
<tr>
<td>OXYGEN % AFTER FINAL DISCHARGE (with 10% or 5% more)</td>
<td>11,350</td>
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</table>
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

<table>
<thead>
<tr>
<th>Project:</th>
<th>Esempio Azoto</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project-No:</td>
<td>Impianto di spegnimento ad Azoto B.JG-100</td>
</tr>
<tr>
<td>Building:</td>
<td></td>
</tr>
<tr>
<td>Object:</td>
<td></td>
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<tr>
<td>Contractor:</td>
<td></td>
</tr>
<tr>
<td>Owner:</td>
<td></td>
</tr>
<tr>
<td>Project engineer:</td>
<td></td>
</tr>
<tr>
<td>Date:</td>
<td>08/03/2006</td>
</tr>
<tr>
<td>Altitude above sealevel:</td>
<td>0 m</td>
</tr>
<tr>
<td>Regulation rule for calculation of Nitrogen quantities:</td>
<td></td>
</tr>
<tr>
<td>Pipe catalogue:</td>
<td>VdS.rkl</td>
</tr>
<tr>
<td>Component catalogue:</td>
<td>VdS.arm</td>
</tr>
<tr>
<td>Nozzle catalogue:</td>
<td>Bettati.noz</td>
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</table>
### Pipesystem data:

<table>
<thead>
<tr>
<th>Section No.</th>
<th>Height [m]</th>
<th>Diameter [mm]</th>
<th>Fitting</th>
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<td>12</td>
<td>-</td>
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<tr>
<td>1</td>
<td>2</td>
<td>21</td>
<td>E</td>
</tr>
<tr>
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<td>3</td>
<td>21</td>
<td>E</td>
</tr>
<tr>
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<td>11</td>
<td>E</td>
</tr>
<tr>
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<td>11</td>
<td>E</td>
</tr>
<tr>
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<td>15</td>
<td>16</td>
<td>11</td>
<td>E</td>
</tr>
<tr>
<td>16</td>
<td>17</td>
<td>11</td>
<td>E</td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>Type</th>
<th>Pipeclass</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
</tr>
</tbody>
</table>

### Pipe roughness

<table>
<thead>
<tr>
<th>Pipeclass</th>
<th>Hose</th>
<th>Galvanized</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Nozzle data:

<table>
<thead>
<tr>
<th>No.</th>
<th>Calculation zone</th>
<th>Diameter [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>11001</td>
<td>Locale</td>
<td>16,0</td>
</tr>
<tr>
<td>11002</td>
<td>Locale</td>
<td>16,0</td>
</tr>
<tr>
<td>11003</td>
<td>Locale</td>
<td>16,0</td>
</tr>
<tr>
<td>11004</td>
<td>Locale</td>
<td>16,0</td>
</tr>
</tbody>
</table>

### Legend of nozzles and restrictor:

<table>
<thead>
<tr>
<th>Type</th>
<th>Number of orifices</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle Bettati</td>
<td>1</td>
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<td>0.006</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>Restrictor</td>
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<td>-0.147</td>
<td>0.006</td>
<td>0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Calculation zone data:

## Calculation of design quantity:

<table>
<thead>
<tr>
<th>Zone</th>
<th>Total volume (m³)</th>
<th>Volume of building parts (m³)</th>
<th>Calculated volume (m³)</th>
<th>Total surface (m²)</th>
<th>Max. Over-pressure (mm H2O)</th>
<th>Design temp. (°C)</th>
<th>Extinguishing conc. [%]</th>
<th>Design factor</th>
<th>Design conc. [%]</th>
<th>Design quantity (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Locale</td>
<td>306.0</td>
<td>0.0</td>
<td>306.0</td>
<td>0.0</td>
<td>1,000</td>
<td>20.0</td>
<td>31.0</td>
<td>1.30</td>
<td>40.3</td>
<td>183.89</td>
</tr>
</tbody>
</table>

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 predetermimated orifice diameters  
- Design with predetermimated 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
<table>
<thead>
<tr>
<th>Section- No:</th>
<th>Starting- node</th>
<th>Endnode Nozzle</th>
<th>Pressure [bar abs]</th>
<th>Temperature [°C]</th>
<th>Flowrate [kg/s]</th>
<th>Pipedimension DI [mm]</th>
<th>DN</th>
</tr>
</thead>
<tbody>
<tr>
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<td>28,5</td>
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<td>7</td>
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### Nozzle data:

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<tr>
<th>Calculation zone no.</th>
<th>Nozzle no.</th>
<th>Nozzle type</th>
<th>Number of orifices</th>
<th>Pipeconnection DI [mm]</th>
<th>DN</th>
<th>Orifice [mm]</th>
<th>Nitrogen output [kg]</th>
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<td>46.0</td>
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</tbody>
</table>

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

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<th>Calculation-zone no:</th>
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<th>CO2</th>
<th>AR</th>
<th>N2</th>
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Total flooded design quantity within discharge time: 183.89 kg

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<th>Calculation-zone no:</th>
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<th>CO2</th>
<th>AR</th>
<th>N2</th>
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</thead>
<tbody>
<tr>
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<td>88.2</td>
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Total flooded Nitrogen mass: 216.8 KG

### Pressure relief opening:

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<th>Calculation-zone no:</th>
<th>Recommended area against overpressure [m²]</th>
<th>Overpressure [mbar]</th>
<th>Max. flow [kg/s]</th>
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### Component list:

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<th>C2</th>
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<th>C4</th>
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<th>C6</th>
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</thead>
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<td>0.006</td>
<td>0.001</td>
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<td>0.000</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Pipe-type</th>
<th>DI [mm]</th>
<th>DN</th>
<th>Length [m]</th>
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<td>11</td>
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### Number of bends (+) and elbows (-)

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### Number of T-distributors (in- and outdiameter)

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<th>90-out</th>
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### Dynamic flooding results

The calculation bases on a mean nozzle pressure!

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</table>

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”
NOTE