TECHNICAL SPECIFICATION

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Guidance on design, selection and installation of vents to safeguard the structural integrity of enclosures protected by gaseous fire-extinguishing systems

Lignes directrices pour la conception, la sélection et l'installation d'évents pour préserver l'intégrité structurelle des enceintes protégées par des systèmes fixes de lutte contre l'incendie à gaz

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 21, *Equipment for fire protection and fire fighting*, Subcommittee SC 8, *Gaseous media and firefighting systems using gas*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The guidance presented here is based on the results of a joint research program conducted in 2006 and 2007 by several fire protection system manufacturers and interested parties. The program of work consisted of several series of tests to evaluate the peak pressure response and pressure-relief vent area effects for each agent addressed in this document. The key data used in the development of this document were the values of peak enclosure pressure response (PMAX) at each value of the volume-normalized pressure-relief vent area of the test enclosure, hereinafter referred to as the “leakage-to-volume ratio” or LVR. Other test parameters (enclosure temperature, agent quantity, discharge time, and humidity) were held constant or varied in a specified manner. For each test series employing a single agent, the several pairs of LVR and resultant PMAX values were graphically analysed and a best-fit correlation curve was determined.

The LVR vs. PMAX correlation curve for each agent or system forms the basis of the associated equations in cases where discharge of the agent results in cooling the air temperature below its dew point. (See Humidity effects and humidity correction factor below.) In most cases, only halocarbon agents cause sufficient cooling to cause humidity related effects on the peak enclosure pressure. Thus, a correction for humidity effects is included in the equations for estimating vent area and maximum pressure on the discharge of the following agents:

— FK-5-1-12

— HFC-23

— HFC-125

— HFC-227ea

The humidity corrections used in this document are based on the results of tests conducted with HFC-227ea at different conditions of humidity.

The resulting values for humidity correction will be assumed to be equally applicable to the agents FK-5-1-12, HFC-125 and HFC-23 until further data or analysis indicates otherwise.

The correlations of LVR to maximum negative pressure and maximum positive pressure were based on test work performed in a test chamber at a relative humidity (RH) of approximately 38 %. If the RH in a protected enclosure differs from 38 % then a correction to the estimated maximum negative and positive pressures may be required. See 7.8 and 7.9 for further information on the effect of humidity. The temperature of the test enclosure was 21°C (nominal) for all tests that form the basis of the estimating methods given in this document.

In conducting the research program, described above, a large number of different venting arrangements were created in the test enclosure. The equivalent leakage area (ELA) for each test was determined by a “door fan test” and data analysis. The average enclosure pressure in effect during the many door fan tests varied from test to test. All values of ELA were normalized to an equivalent enclosure differential pressure of 125 Pa. The resulting enclosure correlations of peak pressure vs. LVR, and any resulting estimate of enclosure pressure-relief vent area, reflect a pressure-relief vent area calculated at an effective enclosure pressure of 125 Pa for a vent with discharge coefficient of 0,61.

The effectiveness of a gaseous total flooding firefighting system depends, in part, on retention of the air-extinguishant mixture within the protected volume for a period of time. Retention of the extinguishant-air mixture requires that gas exchange (“leakage”) between the enclosure and the ambient environment be restricted. In order to limit the rate of gas exchange the enclosure boundary should have a high degree of integrity. To put it another way, the sum total of the areas of the various penetrations in an enclosure’s bounding surfaces should be low, at least during the gas-retention period (hold time) after the end of extinguishant discharge.

Addition of a gaseous firefighting extinguishant to an enclosure having limited pressure-relief vent area will naturally result in a change of pressure therein. If the enclosure is sealed too tightly during the extinguishant discharge, i.e., too little pressure-relief vent area, the pressure change could exceed the structural strength of one or more of its bounding surfaces — windows, doors, walls, ceiling. Conversely, if the enclosure has too much pressure-relief vent area then gas exchange with the ambient atmosphere will occur rapidly, leading to short retention time of the extinguishant within the protected volume.

Thus, the use of gaseous firefighting systems should address two performance considerations:

a) Pressure management within the protected volume during the period of extinguishant discharge, and

b) Retention of the extinguishant-air mixture within the enclosure for a specified period of time after the completion of the discharge.

This document provides guidance for limiting pressure extremes in an enclosure during the discharge of a clean agent fire extinguishing system. This document does not provide the information necessary to determine all of the requirements related to the design, installation, service, maintenance, inspection, test, and/or requalification of fire suppression systems.

Some limitations and restrictions apply to the use of the equations contained in this document. Please refer to the text and notes that follow.

The information in this document does not supersede the manufacturer's guidance. The information contained in this document is presented as supplementary to the guidance provided by the respective system manufacturers. Guidance from the system manufacturer should always be followed and used for purposes of system design, installation, operation and maintenance.

It has been assumed in the preparation of this document that the execution of its provisions is entrusted to people appropriately qualified and experienced in the specification, design, installation, testing, approval, inspection, operation and maintenance of systems and equipment, for whose guidance it has been prepared, and who can be expected to exercise a duty of care to avoid unnecessary release of extinguishant.

Guidance on design, selection and installation of vents to safeguard the structural integrity of enclosures protected by gaseous fire-extinguishing systems

1 Scope

This document provides guidance on fulfilling the requirements contained in ISO 6183:2009, 6.4.1 and 7.4.1 and ISO 14520-1:2015, 5.2.1 h and 5.3 h, in respect to over and under pressurisation venting and post discharge extract.

It considers the design, selection and installation of vents to safeguard the structural integrity of enclosures protected by fixed gaseous extinguishing systems and the post discharge venting provisions where used.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

NOTE For the purposes of this document, the term "bar" signifies "gauge", unless otherwise indicated. Concentrations or quantities expressed in percentages (%) signify by volume, unless otherwise indicated.

3.1
back pressure
pressure downstream of a vent

3.2
fire damper
device designed to prevent the spread of fire

3.3
free pressure-relief vent area
sum of the free pressure-relief vent areas of the pressure-relief vents provided

Note 1 to entry: This is determined by the gross pressure-relief vent area x the vent efficiency.

3.4
gross pressure-relief vent area
total area of the pressure-relief vent

3.5
negative pressure
pressure in the protected room which is lower than the pressure immediately outside the enclosure boundary

3.6
peak pressure
The maximum pressure (positive and negative) generated within a an enclosure caused by the discharge of the gaseous agent

3.7
positive pressure
pressure in the protected room which is higher than the pressure immediately outside the enclosure boundary

3.8
enclosure strength
specified differential pressure limit for the protected enclosure

3.9
pressure-relief area
sum of the free pressure-relief vent area and the enclosure leakage area

3.10
pressure-relief vent
device that provides a flow path through an enclosure boundary to limit the pressure therein

4 Symbols and abbreviated terms

A_N	pressure-relief vent area to limit negative pressure to a specified P_N, cm^2 (in^2)
A_P	pressure-relief vent area to limit positive pressure to a specified P_P, cm^2 (in^2)
C	agent design concentration, in percent by volume
M_{AIR}	is the molecular weight of air = 0,029 (kg/mol)
M_{AGT}	molecular weight of the agent, (kg/mol)
Q	minimum design quantity of agent (kg)
P	pressure (Pa)
P_N	negative pressure, psf (Pa)
P_P	positive pressure, psf (Pa)
	P_N and P_P represent either
	— Design pressure limits for estimating A_N or A_P, or
	— Estimates of maximum values of P_N or P_P for given values of A_N or A_P
R	gas law constant, 8,314 (J/mol-K)
% RH	relative humidity in hazard space at 21 °C (70 °F), %
s	specific volume of the agent at the design temperature (m^3/kg)
s_H	specific volume of the homogenous agent-air mixture (m^3/kg), which is the inverse of the density

t agent discharge time, s

V volume of the protected space (m^3)

ρ_H agent-air mixture density at the specified temperature and pressure (kg/m^3)

5 Use and limitations

This document is for the use by those competent in the design, installation, servicing and maintenance of fixed gaseous firefighting systems. It also serves as guidance for those involved in the design, construction and operation of buildings in which such systems are installed.

It does not replace the need for the person responsible for the design, construction and operation of the building to fulfil their obligations in respect to providing adequate structural provisions.

There may be other trades and services involved in the complete system and the document is limited to providing the guidance outlined in the document and does not purport to be expert in all areas.

After applying the enclosure peak pressure and pressure-relief vent area analysis of this document, the user may conclude that an enclosure may require additional pressure-relief vent area in order to avoid exceeding specified maximum pressure values upon discharge of a gaseous agent system. If that is the case, it is recommended that the user advise the supplier of a supplemental venting device that such device be specified and selected by use of this document.

The maximum pressure developed in an enclosure on discharge of a clean agent fire extinguishing system is affected by several characteristics of the system itself and the enclosure being protected. Of particular importance are the thermodynamic properties of the agent and the discharge characteristics of the hardware. Each of the following sections contains correlation equations that are specific to the agent type and manufacturer's hardware. The equations can be used to make estimates of the following:

a) enclosure pressure-relief vent area given a specified enclosure pressure limit;

b) maximum positive or negative pressure developed in an enclosure given a stated or calculated pressure-relief vent area.

NOTE The formulae in this document for halocarbon agents have a limited range of applicability based on the parametric limitations of the data from which they were derived. Table 1 indicates the applicable limits of design concentration, discharge time, and enclosure pressure response for the use of this document. The maximum peak pressure estimates (both positive and negative) based on data obtained for each agent are given in Table 1.

Caution — It is physically possible to develop pressures greater than those covered by this document during system discharges.

Table 1 — Summary of equation application limits

Agent	Minimum agent Conc % vol	Maximum agent Conc % vol	Minimum discharge time	Maximum discharge time	Maximum over-pressure pfs (Pa)	Maximum under pressure pfs (Pa)
FK-5-1-12	4,2	6	6	10	5 (239)	25 (1 197)
HFC-23	18	30	6	10	30 (1 437)	n/a
HFC-125	8	10,5	6	10	10 (479)	10 (479)
HFC-227ea	6,25	10,5	6	10	8 (383)	20 (958)

6 Safety

6.1 Structural safety

The provision of correctly designed and engineered pressure venting of enclosures protected by gaseous fire-extinguishing systems is essential in order to prevent the possibility of failure of structural integrity. This is essential to mitigate forces exerted by the changes in enclosure pressure when gaseous fighting media are discharged into an enclosure.

6.2 Personnel safety

The operation of pressure-relief vents or extract systems, requires the displacement of mixtures of air/gaseous media from a protected enclosure to atmosphere or another area not necessarily protected. The safety issue may arise due to exposures to the extinguishants themselves or products of combustion and/or extinguishant breakdown products. In addition, any hazards arising from the operation of the over/under pressurisation vents themselves should be considered.

7 System design — Pressure-relief venting

7.1 General

The basic design principle is to limit the pressure excursions imposed on the structure of the protected enclosure by the discharge of gaseous extinguishant to that within the limits the enclosure is able to withstand.

A room integrity test can be used to determine the equivalent leakage area, or simply” vent” area that exists at the time of evaluation. The methods of this document can use the known or estimated pressure-relief vent area to estimate the maximum pressure that will be developed on discharge of a clean agent system. In the event that the estimated maximum pressure exceeds a specified design threshold, the methods of this document may be used to estimate a pressure-relief vent area sufficient to limit development of pressure upon system discharge to an acceptable value.

7.2 Extinguishant characteristics

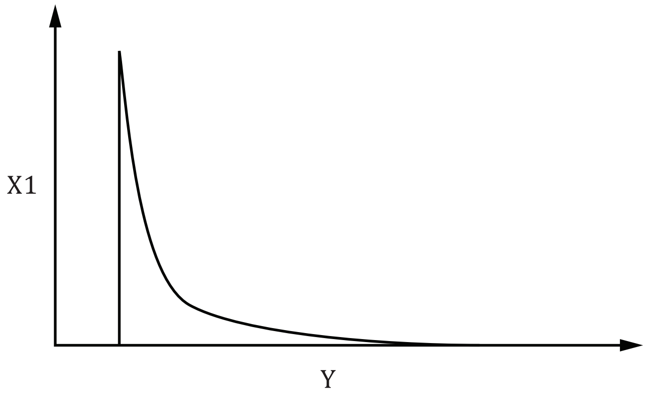
Consideration should be given to positive pressurisation created by all extinguishants and additionally to negative pressurisation created by some extinguishants as defined in Table 2.

Table 2 — Pressure effects of gaseous extinguishant

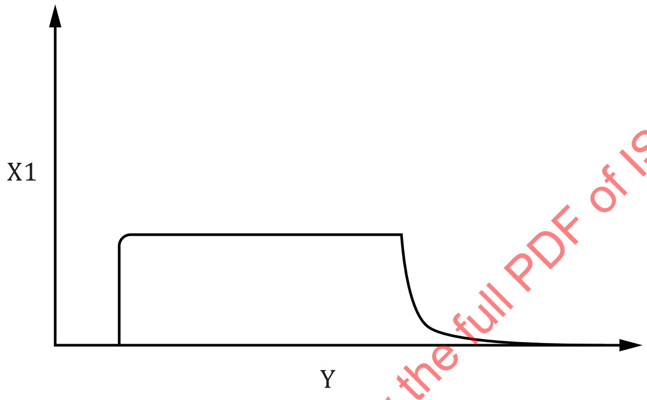
Extinguishant name	Positive pressure created	Negative pressure created
FK-5-1-12	Yes	Yes
HFC-125	Yes	Yes
HFC-227ea	Yes	Yes
HFC-23	Yes	No
IG 01	Yes	No
IG 100	Yes	No
IG 55	Yes	No
IG 541	Yes	No
CO_2	Yes	No[1]
NOTE Negative pressure has been observed, with adverse effects. It can occur in certain cases where large quantities of CO_2 are released into a space having low leakage to ambient.		

7.2.1 Pressure graphs

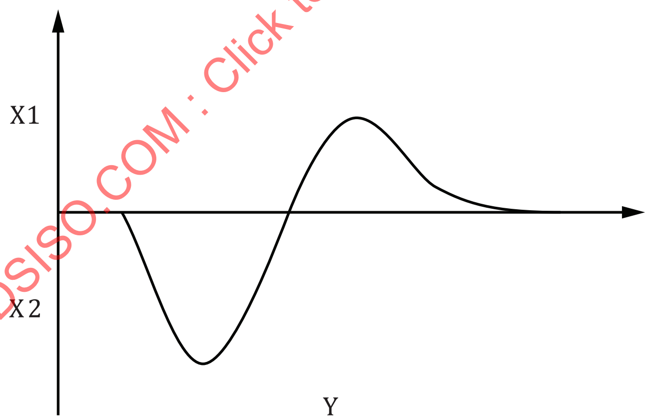
The graphs below illustrate the typical pressure excursions that would occur during discharge within the protected area.



a) Inert gas



b) Inert gas (constant flow)



c) Halocarbon gas

Key

X1 positive pressure

X2 negative pressure

Y time: (a): inert gas, (b): inert gas (constant flow), (c): halocarbon gas

Figure 1 — Typical pressure excursions

7.3 Enclosure characteristics

It is the client's responsibility and not the fire protection system supplier to determine the room strength. The client should advise the allowable pressure differential the protected enclosures can withstand without sustaining damage.

It is generally accepted that that normal masonry construction can withstand 500 Pa, whilst lightweight structures such as stud partitioning can withstand only 250 Pa. Both figures assume fixings at the top and bottom. Certain structure types may have even lower limits, particularly suspended ceilings. However, fire system engineers are not qualified to give guidance on room strengths, so it is up to the client to provide this information. In the event that the client does not make clear what the allowable pressure the enclosure will withstand, it is necessary to obtain his acceptance of the figures used.

In view of issues related to enclosures utilising suspended ceilings, it is recommended that protection is provided to volumes above and below the suspended ceiling where practical.

7.4 Pressure-relief vent paths

It is generally assumed that positive/negative pressure-relief vent paths will lead to/from atmosphere. Positive pressure-relief vent paths will assist in the safe transfer of the displaced air/extinguishant volume to atmosphere in the most efficient, uncomplicated manner as well as ensuring air/extinguishant contaminated with fire by-products also finds a safe route to outside air.

As positive pressure venting may involve the displacement of smoke the possible effect on fire detection systems along the vent path should be considered.

Under certain circumstances it may be necessary to consider the use of adjacent spaces as the means to dissipate the pressure condition, either directly as a function of the volume of that adjacent space or where the adjacent space acts as transit path to atmosphere. Under the circumstances described in the latter, special venting considerations may be required to ensure the pressure condition is not simply transferred to that adjacent space (see 7.9).

7.5 Types of pressure-relief vents

7.5.1 General

There are various types of pressure-relief vent, which are normally closed to preserve the integrity of the enclosure, which then open to relieve pressure impulse and close again. These pressure-relief vents may fall into the following categories:

7.5.2 Gravity vents

The blades for these vents are generally hinged on the top edge. They have no electric or pneumatic actuation but rely totally on the enclosure pressure change in order to move the vent blades.

This type of vent may provide a free pressure-relief vent area significantly less than the gross pressure-relief vent area. In addition, the vent design creates turbulent flow and therefore is likely to create higher pressure loss for any given flow. This additional pressure should be factored into the determination of the free pressure-relief vent area required.

Vents, if not fitted with an end stop, for example ‘cat flaps’, could relieve pressures in both directions, however, these are not recommended unless they are able to avoid compromising the enclosure fire rating.

Figure 2 — Gravity vent

7.5.3 Counter weighted flap vent

This type of vent is configured with the hinge located just off of the centre of gravity, so that when positive pressure is exerted on the upstream side of the vent it allows the vent blades to pivot to their fully open positions.

The vent can be designed such that there is a minimum operational release pressure, which will ensure that nuisance movement is avoided.

Typically, these vents are more efficient (i.e. larger discharge coefficient, lower opening pressure, lower intrinsic inertia) than gravity flap vents.

7.5.4 Electrically operated vents

This type of vent utilises blade(s) operated by an electric motor or an electromagnetic device.

This type of vent is reliant upon power at the time of the discharge, therefore if no other option is available there should be a protected power supply to the vent motor to ensure that failure of mains does not leave the vent in the closed position.

This type of vent generally opens more slowly than other types of vent and correct operation may be dependent on the sequence of activation and the time allowed for the vent to open fully.

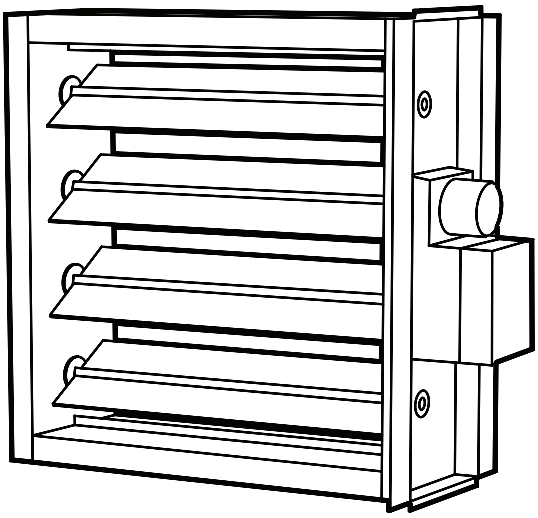


Figure 3 — Electrically operated vent

7.5.5 Pneumatically operated vent

Pneumatically operated vents are actuated by pressure, normally of gas flowing through the pipe work or alternatively by pilot containers or compressed air line.

7.5.6 Vent accessories

7.5.6.1 Security provisions

If the vent is located within an external wall at low level it is feasible that the client will have some concerns regarding forced entry, therefore it is likely that security bars could be fitted across the aperture in order to retain the building security.

7.5.6.2 Insect screen

If there is concern that insects could penetrate the building through the vent it may be necessary to specify insect screens, however, these are fine mesh and could have a significant impact on the free pressure-relief vent areas.

7.5.6.3 Weather louvres

When fitted on exposed, external faces of a building it is possible that rain may penetrate the opening even with the vent in the closed position. In this case a weather louvre could be fitted externally, however this could have a significant impact on the free pressure-relief vent areas.

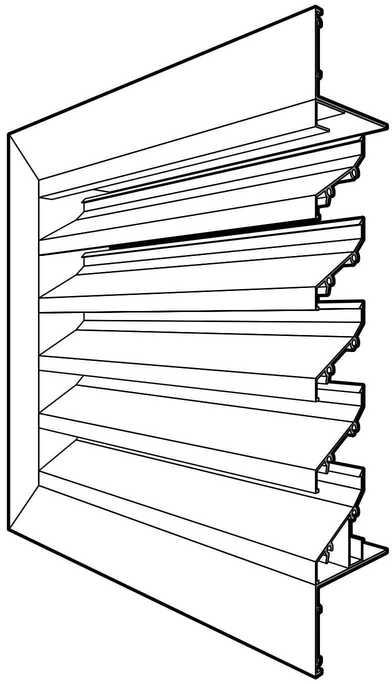


Figure 4 — Louvres

7.5.6.4 Decorative grilles

Where a decorative grille is used to cover the inner face of the vent assembly, however this could have an impact on the free pressure-relief vent areas.

7.5.6.5 Limit switches

Should electrically or pneumatically operated vents be inadvertently left in the open position they could become either a security risk or endanger the equipment within the space by the infiltration of pollution from external sources. In this case it may be desirable to fit limit switch(es) to monitor the position of the vent and create a warning signal, either locally, or through the building management system, or both.

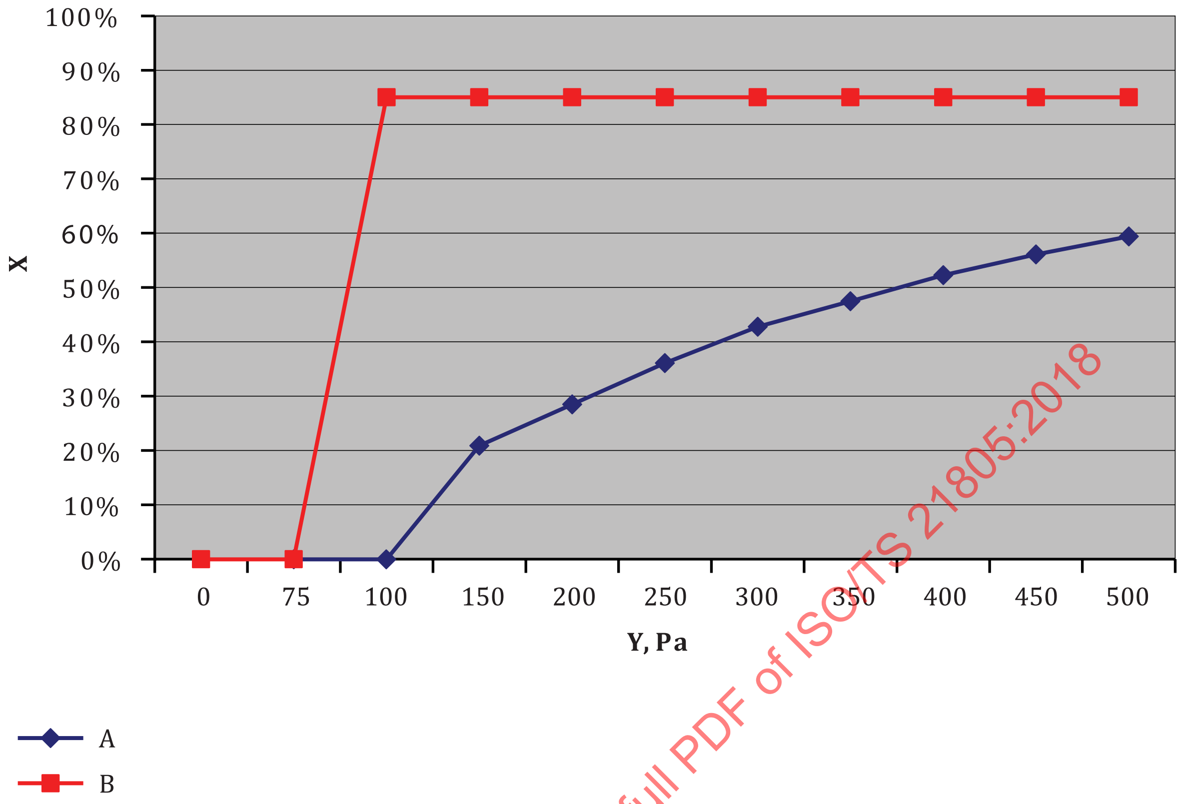
7.6 Pressure-relief vent characteristics

7.6.1 Vent efficiency

Pressure-relief vents, of whatever type (see 7.5), control the flow of air by the movement of air control elements (blades). The design of the blades and the extent to which they open at any given pressure determines the free pressure-relief vent area of the vent at that pressure. For example, if a vent has a nominal area of 1,0 m^2 and an efficiency of 50 % at 100 Pa it will provide a free pressure-relief vent area of 0,5 m^2 at 100 Pa. The blades of the same vent may open more at higher pressures, perhaps having an efficiency of 80 % at 250 Pa and thus provide a free pressure-relief vent area of 0,8 m^2 at 250 Pa. Examples of vent efficiencies for gravity and weighted vents are shown in Figure 5. It is therefore recommended that free pressure-relief vent areas are specified at no less than 3 pressures, for example 100 Pa, 250 Pa and 500 Pa.

Vent efficiency will be reduced by the addition of other accessories in the vent path, e.g. weather louvres, grilles etc. Vent manufacturers should provide a safe assessment of the potential effect based on the free pressure-relief vent area of the accessory proposed.

NOTE Vent efficiencies are provided by vent manufacturers.



Key

X efficiency (%)

Y pressure (Pa)

A gravity

B counter-weighted

Figure 5 — Efficiency of pressure-relief vents

7.6.2 Minimum opening pressure

The vent should be designed to have a minimum opening pressure to avoid nuisance opening. This should be at least 50 Pa.

7.6.3 Minimum closing pressure

The vent should be designed to have a minimum closing pressure to ensure closure at the end of the discharge. This should be at least 30 Pa.

7.6.4 Fire rating

Where vents are included in an enclosure they should not reduce the fire rating of the structure and therefore be of equivalent fire rating.

7.7 Vent location and mounting

7.7.1 Vent location

The most favourable location for the vent is on an exterior wall of the building.

The vent should be located taking due account of the discharge nozzles and any objects both inside and outside the enclosure in the vicinity of the vent.

The vent should be located on an area of wall within the enclosure which is devoid of all services or other fixtures or fittings that could impede the flow path. Where available free wall space is limited, consideration may have to be given to having a bespoke vent manufactured which will fit the available space constraints.

The most significant hazard which arises from obstructions placed on either side of the vent are those which are of a non-fixed or temporary arrangement, which may impede flow or prevent the vent from functioning correctly. Such items may not be present at the time at which the gaseous firefighting system is designed and ultimately handed over. Examples may include skips, packing boxes, filing cabinets, etc.

Where obstruction of either side of the vent is possible, suitable warning notices or physical barriers should be provided.

The discharge of a gaseous firefighting system causes concentrated streams of extinguishant from the discharge nozzles, which dissipate the further the flow gets from the nozzle. It follows therefore that placing a vent in close proximity to nozzles and directly in the path of discharge, may cause a disproportionate quantity of extinguishant to be vented during the discharge.

Vents should be positioned taking into account the above points and any location in the enclosure boundary may be suitable.

7.7.2 Vent mounting

The following are provided as general information which may vary between suppliers.

Vents may feature a mounting flange which is fixed to the surface to which the vent is to be mounted, using suitable screws. The surface to which the vent is to be fitted needs to be flat and where the surface is stepped or uneven, additional mounting frames may be required. Additional mounting frames may also need to be utilised where the vents are being fitted in very thin enclosure walls such as GRP cabins, or where existing window frames are used, or where the vents are to be mounted in a door.

Vents are generally fabricated from sheet steel and depending on the type of vent, will include items such as, weights on each vent blade, pneumatic actuators or electric motors. Consequently, the vents themselves will have a weight, which can be significant where either a number of small vents are located together in one area, or where a single large vent is used. The supplier should state the weight of the vent supplied and the building contractor make due allowance for this where it is necessary to build in additional structural members to support the weight.

The rigidity of the vent frame in which the blades are mounted varies between manufacturers. Furthermore, the larger the vent, the more prone to distortion the frames become. Where manufacturers fit cross braces to the vent to limit distortion, these shall not be removed until the vent is installed. Since the vent blades are invariably a close fit with the frame, any distortion of the frame can hamper the full and correct opening of the damper blades. It is therefore essential that the size of the hole physically made in the wall has a sufficient degree of slack around the vent frame to ensure that the frame does not become distorted by the wall. The building contractor should ensure that once the vent is fitted and the mounting screws fully tightened, that the vent is free of any distortion and all the blades are able to freely move such that they can fully open and will fully close under gravity (or normal power source) alone.

Some vents are supplied with a telescopic tube which lines the surface of the hole cut in the wall. The use of such telescopic tubes reduces the amount of builders work necessary in cleaning up the edges of the hole after it has been formed. All wall linings should retain the fire rating of the structure.

7.8 Pressure-relief vent area calculations

7.8.1 Use of agent-specific equations

In order to use the agent-specific equations the user needs to know the following:

a) Volume of the protected enclosure (ft^3 or m^3).

b) Agent type.

c) Agent design concentration based on an enclosure temperature of 70 °F (vol. %).

d) System discharge time in seconds, (s).

e) The mass of agent discharged, which may be different than the quantity stored.

f) Average relative humidity (% RH) in the protected enclosure; only required for FK-5-1-12, HFC-125, or HFC-227ea.

g) Equivalent leakage area of enclosure (in^2 or cm^2). Determined by a room-integrity (door-fan) test. See ISO 14520-1:2015 Annex E.

h) The specified maximum allowed enclosure pressure, the "pressure limit," (psf or Pa).

The calculation of the required pressure-relief vent area and maximum pressure will usually consist of the following steps:

a) Determine the enclosure's positive pressure (P_P) and negative pressure (P_N) limits.

b) Determine the equivalent leakage area using the enclosure integrity test. See ISO 14520-1:2015, Annex E.

c) Use agent-specific equations and the measured equivalent leakage area, from (b), to estimate values of P_P and P_N.

d) If pressures P_P and P_N are less than or equal to the specified enclosure pressure limit then report P_P and P_N, and on the system plans if the measured equivalent leakage area results in pressure P_P and P_N that exceed the specified enclosure pressure limit:

    1) Use agent-specific equations and the specified enclosure pressure limits (for both positive and negative pressure) to calculate the required pressure-relief vent areas, A_P and A_N, then report P_P and P_N, and A_P and A_N on the system plans.

Figure 6 shows the sequence of steps to follow to develop the information required.

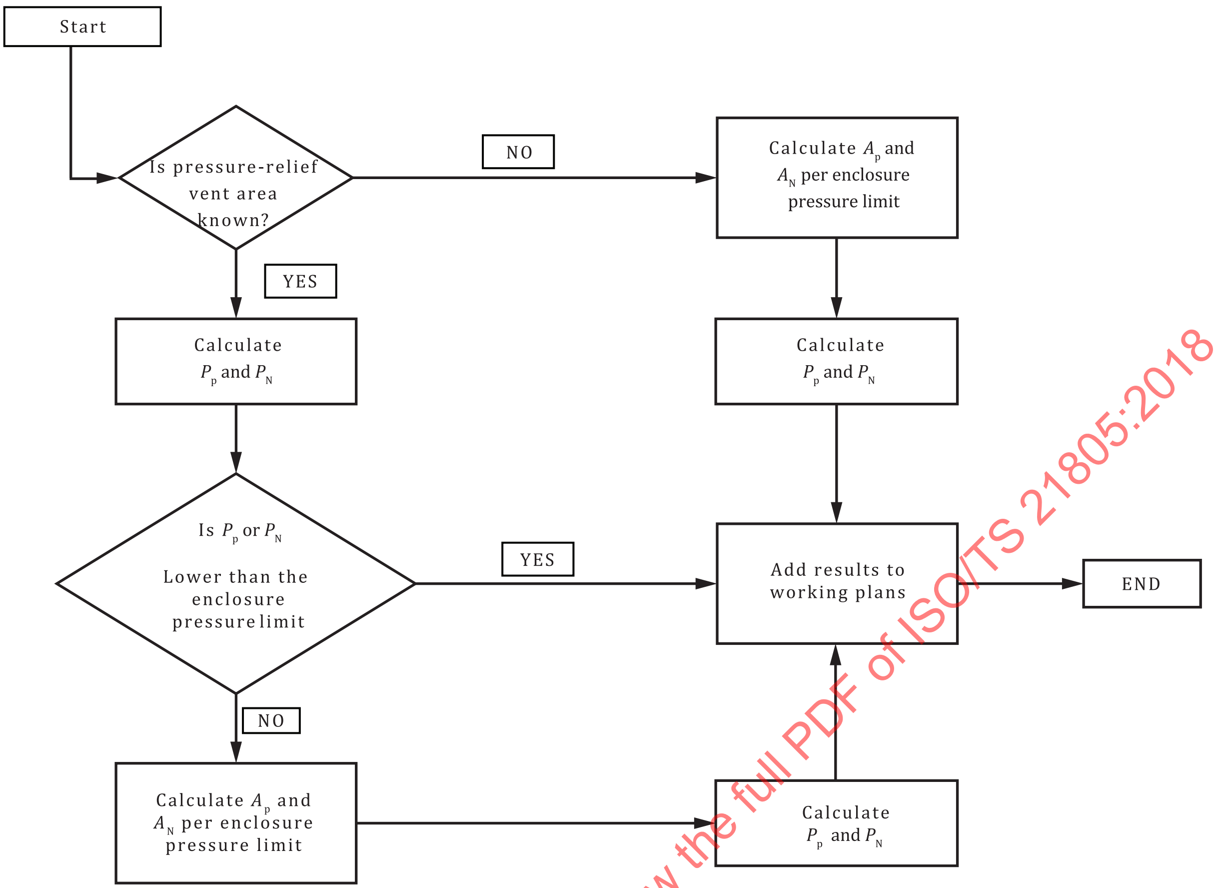


Figure 6 — Sequence of steps to follow to calculate P_P and P_N

7.8.2 Vent area requirement (non-liquefiable gases and CO_2)

The manufacturer's system flow calculations shall be used to determine the maximum agent flow rate. The required pressure-relief vent area depends on the maximum mass flow rate of agent, *w*. The maximum agent flow rate, *w*, depends on the discharge time, *t*, and the design of the discharge valve. The maximum flow rate may be approximated as follows:

a) Constant discharge rate: *w = m/t, kg/s*;

b) Initial discharge rate of x % per second: *w =(x/100) m, kg/s*, where *x* is determined by the system manufacturer.

m is determined as follows:

$$m = \frac{V}{s} Ln\left(\frac{100}{100 - C}\right) \quad (1)$$

where

m is the minimum design quantity of agent (kg);

C is the agent design concentration (vol. %);

s is the specific volume of the agent at the design temperature (m^3/kg);

V is the volume of the protected space (m^3).

Vent area

The pressure-relief vent area, A, is calculated using the formula below (where a value of 1,0 has been assumed for the co-efficient of resistance of the flow through an opening).

$$A = \frac{w \times s}{\sqrt{P \times s_H}} \tag{2}$$

where

A is the total pressure-relief vent area (m^2);

w is the mass flow of extinguishant (kg/s);

s is the specific vapour volume of extinguishant (m^3/kg);

P is the maximum room strength (Pa);

s_H is the specific volume of the homogenous agent-air mixture (m^3/kg), which is the inverse of the density.

The agent-air mixture density is calculated as follows:

$$\rho_H = \frac{P \times M_H}{R \times T} \tag{3}$$

where the mixture molecular weight is calculated as follows:

$$M_H = \frac{c \times M_{AGT} + (100 - c) \times M_{AIR}}{100} \tag{4}$$

and

$$s_H = {}^{1}\!/\!_{\rho_H} \tag{5}$$

where

ρ_H is the agent-air mixture density at the specified temperature and pressure (kg/m^3);

C is the agent design concentration (vol. %);

s = 0,029 (kg/mol);

M is the molecular weight of the agent, (kg/mol);

R is the gas law constant, 8,314 (J/mol-K);

P is the pressure (Pa);

T is the temperature (K).

7.8.2.1 Example calculations for inert gases (values taken from ISO 14520)

7.8.2.1.1 In these examples, the peak discharge rate relates to an assumed percentage of the stored quantity of gas per second. For actual calculations, the peak flow rate as determined by the hydraulic calculations for the system should be used:

7.8.2.1.2 IG-55 @20 °C 1,013 bar(a) (atmospheric pressure).

Temperature	20 °C
S (IG-55)	0,708 1 m^3/kg
S_{AIR}	0,830 5 m^3/kg
S_H	0,775 2 m^3/kg
P	500 Pa
Volume	260 m^3
Design concentration	45,2 %
Flooding factor	0,849 4 kg/m^3
Amount of gas required, calculated as follows {*m* = (530 / 0,814) × ln[100 / (100 − 40,3)]}	220,84 kg
Number of containers holding 32,09 kg (80 litre, 300 bar)	7
Actual gas flowing	224,63 kg

Pressure-relief vent area required assuming vent coefficient of 1 is:

1) 0,243 m^2 for 60 sec, discharge at a peak discharge rate of 6,74 kg/s, 0,122 m^2 for a 120 sec discharge at a peak discharge rate of 3,37 kg/s.

2) 0,135 m^2 for a 60 sec discharge at a constant discharge rate of 3,744 kg/s.

7.8.2.1.3 IG-100 @ 5 °C

Temperature	5 °C
S (IG-100)	0,814 3 m^3/kg
Design concentration	40,3 %
S_{AIR}	0,788 0 m^3/kg
S_H	0,798 6 m^3/kg
P	250 Pa
Volume	530 m^3
Flooding factor	0,633 5 kg/m^3
Amount of gas required, calculated as follows {*m* = (250 / 0,814) × ln[100 / (100 − 40,3)]}	335,73 kg
Number of containers holding 24,88 kg (80 litre, 300 bar)	14
Actual gas flowing	348,32 kg

Pressure-relief vent area required is:

1) 0,803 m^2 for a 60 sec discharge at a peak discharge rate of 13,93 kg/s;

2) 0,402 m^2 for a 120 sec discharge at a peak discharge rate of 6,97 kg/s, 0,334 m^2 60 sec discharge at a constant discharge rate of 5,80 kg/s.

7.8.2.1.4 IG-541 @ 35 °C

Temperature	35 °C
S (IG-541)	0,741 6 m^3/kg
Design concentration	39,9 %
S_{AIR}	0,820 6 m^3/kg
S_H	0,873 0 m^3/kg
P	350 Pa
Volume	435 m^3
Flooding factor	0,687 kg/m^3
Amount of gas required, calculated as follows {m = (435 / 0,741) × ln[100 / (100 – 39,9)]} 298,7	300,79 kg
Number of containers holding 57,39 kg (140 litre, 300 bar)	6
Actual gas flowing	344,34 kg

Vent area required is:

1) 0,376 m^2 for a 60 sec discharge at a peak discharge rate of 8,61 kg/s;

2) 0,188 m^2 for a 120 sec discharge at a peak discharge rate of 4,3 kg/s, 0,252 m^2 for a 60 sec discharge at a constant discharge rate of 5,74 kg/s.

7.8.2.2 Example calculations for carbon dioxide (based on ISO 6183)

7.8.2.2.1 In this example, the CO_2 quantity is based on hazard specifics, i.e. K_B factor for the hazard, overall volume and room surface area. The discharge time is assumed to be 1 min thereby the flow rate is the stored quantity according to ISO 6183/60s.

Temperature	0 °C
S (CO_2)	0,505 m^3/kg
S_H	0,682 4 m^3/kg
S_{AIR}	0,773 8 m^3/kg
P	100 Pa

Amount of gas required, calculated as follows: $m = K_B \times (0{,}2A + 0{,}7V)$, assuming a room 15,2 m long, 5,52 m wide, 3,65 high with no uncloseable openings with a K_B = 1,34:

A = (15,2 × 5,52 × 2) + (15,2 × 3,65 × 2) + (5,52 × 3,65 × 2) = 319,1 m^2

V = 15,2 × 5,52 × 3,65 = 306,3 m^3

Amount of gas required: 1,34 × (0,2 × 319,1) + (0,7 × 306,3) = 300 kgs

Number of containers holding 50 kg	6
Actual gas flowing	300 kg
Total pressure-relief vent area required:	
Based on 60 sec discharge (5 kg/s)	0,306 m^2

7.8.3 Vent area requirements (liquefiable gases)

The calculation methodology provides means to estimate the pressure excursion expected for a specified extinguishing agent and to estimate the required vent size in order to limit the maximum and minimum pressure within the enclosure.

The following input parameters are required to use the calculation methodology:

— Extinguishing agent;

— Protected enclosure volume;

— Extinguishing system discharge time;

— Extinguishing concentration;

— Relative humidity of enclosure.

If the enclosure strength is known it is possible to calculate the required total pressure-relief vent area.

If the total pressure-relief vent area is known then it is possible to calculate the expected pressure excursion following an extinguishing system discharge.

Parameter	Unit	Definition
+*ve*PE	Pa	Positive Pressure Excursion
−*ve*PE	Pa	Negative Pressure Excursion
A	m^2	Pressure-relief vent area
V	m^3	Protected enclosure volume
C	%	Agent design concentration used in the protected enclosure
t_d	s	Gaseous firefighting system discharge time
% RH	%	Relative humidity within the enclosure
+*ve*EPL	Pa	Enclosure positive pressure limit
−*ve*EPL	Pa	Enclosure negative pressure limit
+*ve*FVA	m^2	Positive free pressure-relief vent area required to ensure that the positive pressure excursion is below the enclosure positive pressure limit (+*ve*EPL)
−*ve*FVA	m^2	Negative free pressure-relief vent area required to ensure that the negative pressure excursion is below the enclosure negative pressure limit (−*ve*EPL)

CAUTION — The magnitude of both +*ve*EPL and −*ve*EPL for each extinguishant have limits of applicability. The calculation methodology is based on experimental data and therefore the prediction of the calculation tool should remain within the data envelope investigated. Calculations based on parameters outside the limits of applicability will not be accurate and it is strongly advised that such calculations are treated accordingly.

If the relative humidity level is not known, 50 % is the recommended value to use.

7.8.3.1 FK-5-1-12

7.8.3.1.1 FK-5-1-12: Limits of applicability

6 s ≤ t_d ≤ 10 s

4,2 % ≤ Conc ≤ 6,0 %

20 % ≤ RH % ≤ 80 %

+*ve*EPL ≤ 240 Pa

−*ve*EPL ≤ −1 200 Pa

7.8.3.1.2 Pressure excursion for FK-5-1-12

$$+ve\text{PE} = 0{,}042\ 649 \times \left(\frac{A}{V} \times \frac{t_\text{d}}{C}\right)^{-1{,}033\ 4} \times \left(0{,}81 + 0{,}51 \times \frac{\%\ \text{RH}}{100}\right) \quad (6)$$

$$-ve\text{PE} = 0{,}321\ 70 \times \left(\frac{A}{V} \times \frac{t_\text{d}}{C}\right)^{-1{,}031\ 8} \times \left(1{,}68 - 1{,}79 \times \frac{\%\ \text{RH}}{100}\right) \quad (7)$$

7.8.3.1.3 Total pressure-relief vent area for FK-5-1-12

$$\text{Positive Total Pressure-Relief Vent Area} = 0{,}046\ 78 \times \left(\frac{C}{t_\text{d}}\right) \times V \times \left(\frac{+ve\text{EPL}}{0{,}81 + 0{,}51 \times \frac{\%\ \text{RH}}{100}}\right)^{-0{,}967\ 7} \quad (8)$$

$$\text{Negative Total Pressure-Relief Vent Area} = 0{,}343\ 09 \times \left(\frac{C}{t_\text{d}}\right) \times V \times \left(\frac{-ve\text{EPL}}{1{,}68 - 1{,}79 \times \frac{\%\ \text{RH}}{100}}\right)^{-0{,}969\ 2} \quad (9)$$

7.8.3.2 HFC-227ea

7.8.3.2.1 HFC-227ea: Limits of applicability

6 s ≤ t_d ≤ 10 s

6,25 % ≤ Conc ≤ 10,5 %

20 % ≤ % RH ≤ 80 %

+*ve*EPL ≤ 380 Pa

−*ve*EPL ≤ −1 000 Pa

7.8.3.2.2 Pressure excursion for HFC-227ea

$$+ve\text{PE} = 48{,}359 \times \left[4{,}2 \times \ln\left(\frac{V \times C}{A \times t_\text{d}}\right) - 27{,}922\right] \times \left(0{,}81 + 0{,}51 \times \frac{\%\ \text{RH}}{100}\right) \quad (10)$$

$$-ve\text{PE} = 46{,}444 \times \left[9{,}41 \times \ln\left(\frac{V \times C}{A \times t_\text{d}}\right) - 62{,}76\right] \times \left(1{,}68 - 1{,}79 \times \frac{\%\ \text{RH}}{100}\right) \quad (11)$$

7.8.3.2.3 Total pressure-relief vent area for HFC-227ea

$$\text{Positive Total Pressure-Relief Vent Area} = 0{,}001\,30 \times \left(\frac{C}{t_\text{d}}\right) \times V \times \exp \times \left(\frac{-0{,}004\,97 \times +ve\text{EPL}}{0{,}81 + 0{,}51 \times \frac{\%\,\text{RH}}{100}}\right) \quad (12)$$

$$\text{Negative Total Pressure-Relief Vent Area} = 0{,}001\,27 \times \left(\frac{C}{t_\text{d}}\right) \times V \times \exp \times \left(\frac{-0{,}002\,22 \times -ve\text{EPL}}{1{,}68 - 1{,}79 \times \frac{\%\,\text{RH}}{100}}\right) \quad (13)$$

7.8.3.3 HFC-23

7.8.3.3.1 HFC-23: Limits of applicability

$6\ \text{s} \le t_\text{d} \le 10\ \text{s}$

18 % ≤ Conc ≤ 30 %

20 % ≤ RH % ≤ 80 %

+*ve*EPL ≤ 1 400 Pa

7.8.3.3.2 Pressure excursion for HFC-23

$$+ve\text{PE} = 0{,}088\,27 \times \left(\frac{A}{V} \times \frac{t_\text{d}}{C}\right)^{-1{,}165} \times \left(0{,}81 + 0{,}51 \times \frac{\%\,\text{RH}}{100}\right) \quad (14)$$

7.8.3.3.3 Total pressure-relief vent area for HFC-23

$$\text{Positive Total Pressure-Relief Vent Area} = 0{,}123\,84 \times \left(\frac{C}{t_\text{d}}\right) \times V \times \left(\frac{+ve\text{EPL}}{0{,}81 + 0{,}51 \times \frac{\%\,\text{RH}}{100}}\right)^{-0{,}858\,7} \quad (15)$$

7.8.3.4 HFC-125

7.8.3.4.1 HFC-125: Limits of applicability

$6\ \text{s} \le t_\text{d} \le 10\ \text{s}$

8,0 % ≤ Conc ≤ 10,5 %

20 % ≤ % RH ≤ 80 %

+*ve*EPL ≤ 480 Pa

−*ve*EPL ≤ 480 Pa

7.8.3.4.2 Pressure excursion for HFC-125

$$+ve\text{PE} = 0{,}045\,349 \times \left(\frac{A}{V} \times \frac{t_\text{d}}{C}\right)^{-1{,}037} \times \left(0{,}81 + 0{,}51 \times \frac{\%\,\text{RH}}{100}\right) \quad (16)$$

$$-ve\text{PE} = 0{,}039\,49 \times \left(\frac{A}{V} \times \frac{t_\text{d}}{C}\right)^{-1{,}039} \times \left(1{,}68 - 1{,}79 \times \frac{\%\,\text{RH}}{100}\right) \quad (17)$$

7.8.3.4.3 Total vent area for HFC-125

$$\text{Positive Total Pressure-Relief Vent Area} = 0{,}050 \times \left(\frac{C}{t_\text{d}}\right) \times V \times \left(\frac{+ve\text{EPL}}{0{,}81 + 0{,}51 \times \frac{\%\ \text{RH}}{100}}\right)^{-0{,}964} \quad (18)$$

$$\text{Negative Total Pressure-Relief Vent Area} = 0{,}045\ 89 \times \left(\frac{C}{t_\text{d}}\right) \times V \times \left(\frac{-ve\text{EPL}}{1{,}68 - 1{,}79 \times \frac{\%\ \text{RH}}{100}}\right)^{-0{,}962\ 2} \quad (19)$$

7.8.3.5 Example calculation 1: Determination of positive and negative pressure when the pressure-relief area is known

Protected enclosure	Volume = 125 m^3 Air conditioned – 50 % RH Room strength = 500 Pa Total pressure-relief vent area = 0,042 m^2
Extinguishing system	Agent = HFC-227ea Concentration = 8,5 vol. % System discharge time = 9,2 s

Calculate the expected pressure excursion following the discharge of the extinguishing system:

Select the HFC-227ea equation [Formula (10)] for positive pressure excursion (+*ve*PE).

$$+ve\text{PE} = 48{,}359 \times \left[4{,}2 \times \ln\left(\frac{V \times C}{A \times t_\text{d}}\right) - 27{,}922\right] \times \left(0{,}81 + 0{,}51 \times \frac{\%\ \text{RH}}{100}\right)$$

$$\begin{aligned} +ve\text{PE} &= 48{,}359 \times \left[4{,}2 \times \ln\left(\frac{125 \times 8{,}5}{0{,}042 \times 9{,}2}\right) - 27{,}922\right] \times \left(0{,}81 + 0{,}51 \times \frac{50}{100}\right) \\ &= 48{,}359 \times \left[4{,}2 \times \ln(2\ 750) - 27{,}922\right] \times (1{,}065) \\ &= 48{,}359 \times (5{,}339) \times (1{,}065) \\ &= +275\ \text{Pa} \end{aligned}$$

Select the HFC-227ea equation [Formula (11)] for negative pressure excursion (−*ve*PE).

$$-ve\text{PE} = 46{,}444 \times \left[9{,}41 \times \ln\left(\frac{V \times C}{A \times t_\text{d}}\right) - 62{,}76\right] \times \left(1{,}68 + 1{,}79 \times \frac{\%\ \text{RH}}{100}\right)$$

$$\begin{aligned} -ve\text{PE} &= 46{,}444 \times \left[9{,}41 \times \ln\left(\frac{125 \times 8{,}5}{0{,}042 \times 9{,}2}\right) - 62{,}76\right] \times \left(1{,}68 + 1{,}79 \times \frac{50}{100}\right) \\ &= 46{,}444 \times \left[9{,}41 \times \ln(2\ 750) - 62{,}76\right] \times (0{,}785) \\ &= 46{,}444 \times \left[9{,}41 \times (7{,}919) - 62{,}76\right] \times (0{,}785) \\ &= 46{,}444 \times (11{,}758) \times (0{,}785) \\ &= -429\ \text{Pa} \end{aligned}$$

7.8.3.6 Example calculation 2: Determination pressure-relief area required following discharge to limit the pressure excursion

Protected enclosure	Volume = 7 500 m^3 Air conditioned – 50 % RH Room strength = 500 Pa
Extinguishing system	Agent = HFC-227ea Concentration = 7,9 vol. % System discharge time = 9,6 s

Calculate the expected required free pressure-relief vent area following the discharge of the extinguishing system:

Select the HFC-227ea equation [Formula (12)] for positive total pressure-relief vent area such that the enclosure positive pressure limit is not exceeded. A key point here, is that the limit of applicability for the +*ve*EPL should be adhered; for HFC-227ea this limit is 380 Pa and so this is entered into the calculation even though the enclosure can withstand 500 Pa.

$$\text{Positive Total Pressure-Relief Vent Area} = 0{,}001\ 30 \times \left(\frac{C}{t_\text{d}}\right) \times V \times \exp \times \left(\frac{-0{,}004\ 97 \times +ve\text{EPL}}{0{,}81 + 0{,}51 \times \dfrac{\%\ \text{RH}}{100}}\right)$$

$$\begin{aligned}\text{Positive Total Pressure-Relief Vent Area} &= 0{,}001\ 30 \times \left(\frac{7{,}9}{9{,}6}\right) \times 7\ 500 \times \exp \times \left(\frac{-0{,}004\ 97 \times 380}{0{,}81 + 0{,}51 \times \dfrac{50}{100}}\right)\\ &= 0{,}001\ 30 \times (0{,}822\ 9) \times 7\ 500 \times \exp \times (-1{,}773)\\ &= 1{,}363\ \text{m}^2\end{aligned}$$

Select the HFC-227ea equation [Formula (13)] for negative total vent area such that the enclosure negative pressure limit is not exceeded.

$$\text{Negative Total Pressure-Relief Vent Area} = 0{,}001\ 27 \times \left(\frac{C}{t_\text{d}}\right) \times V \times \exp \times \left(\frac{-0{,}002\ 22 \times -ve\text{EPL}}{1{,}68 - 1{,}79 \times \dfrac{\%\ \text{RH}}{100}}\right)$$

$$\begin{aligned}\text{Negative Total Pressure-Relief Vent Area} &= 0{,}001\ 27 \times \left(\frac{7{,}9}{9{,}6}\right) \times 7\ 500 \times \exp \times \left(\frac{-0{,}002\ 22 \times 500}{1{,}68 - 1{,}79 \times \dfrac{50}{100}}\right)\\ &= 0{,}001\ 27 \times (0{,}822\ 9) \times 7\ 500 \times \exp \times (-1{,}414)\\ &= 1{,}906\ \text{m}^2\end{aligned}$$

7.8.4 Leakage

When determining the overall pressure-relief vent area required, it has become practice in some countries to use enclosure leakage as a contribution to the total pressure-relief vent area. This enclosure leakage area is the equivalent leakage area (ELA) determined by the room integrity test carried out in accordance with ISO 14520-1. In some countries this is not common practice.

The use of enclosure leakage as a contribution to total pressure-relief vent area is a less conservative approach and should be used with caution and may not be acceptable to some authorities.

Integrity test are conducted with doors held open in adjacent rooms to the room under test, i.e. there could be less enclosure leakage available than may have been assumed from the ELA value.

If enclosure leakage is to be used for pressure relief, a repeat integrity test conducted with such doors closed should be conducted as in a fire condition or worst (venting) case scenario, and the ELA from this used in the calculations.

7.9 Cascade venting calculations

Where the over-pressure venting for a gaseous fire extinguishing system needs to transit through one or more adjacent enclosures in order to vent to atmosphere the vents in the enclosure boundaries should be determined as follows:

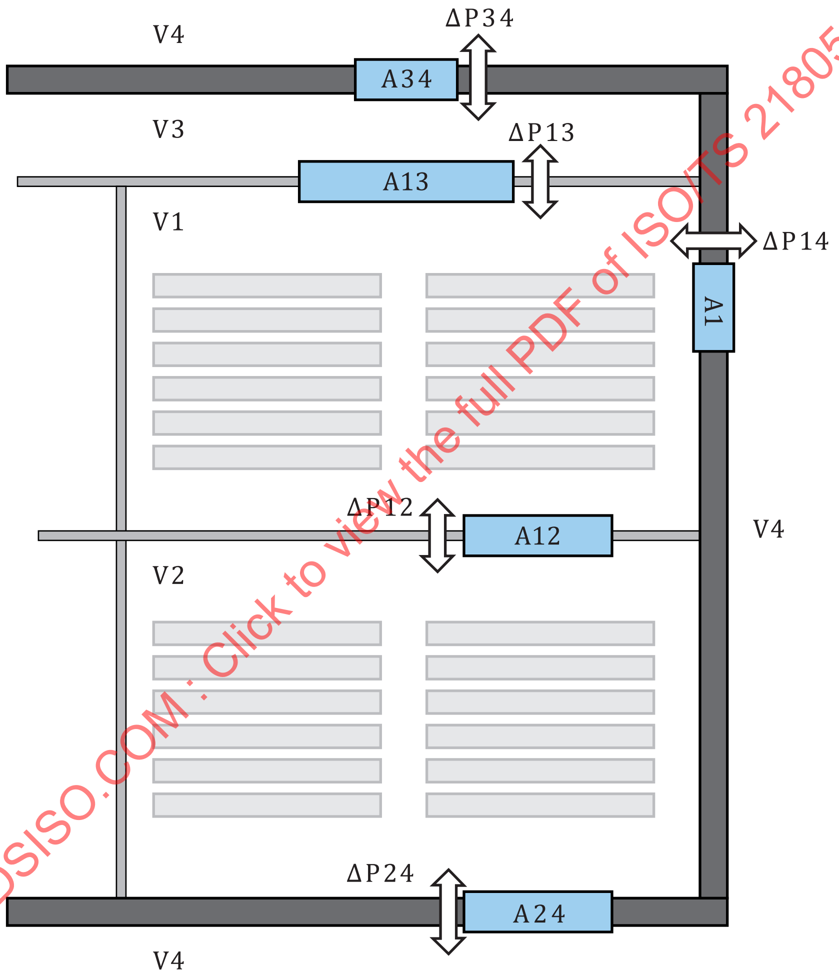


Figure 7 — Cascade venting

All volumes are in m^3, all free pressure-relief vent areas are in m^2, and all pressure differentials are in Pa. V1, V2, V3 and V4 are all discrete enclosures; for explanatory purposes V1 is an enclosure protected by gaseous extinguishing systems, V2 is an adjacent enclosure, V3 is a corridor and V4 is atmosphere.

A1: free pressure-relief vent area if the protected enclosure vented directly to atmosphere V4.

A12: free pressure-relief vent area from the protected enclosure V1 into the adjacent enclosure V2.

A24: free pressure-relief vent area from enclosure V2 to atmosphere V4.

A13: free pressure-relief vent area from the protected enclosure V1 into the adjacent enclosure V3.

A34: free pressure-relief vent area from the enclosure V3 to atmosphere V4.

ΔP14: pressure differential between V1 and V4. With V4 representing atmosphere, this will be equivalent to the maximum allowable pressure in V1.

ΔP12: pressure differential between V1 and V2.

ΔP14: pressure differential between V1 and V4.

ΔP13: pressure differential between V1 and V3.

ΔP24: pressure differential between V2 and V4.

ΔP34: pressure differential between V3 and V4.

When venting directly to the atmosphere from the protected space, the pressure loss (differential) through the free pressure-relief vent area A1 is ΔP14. When the vent flow has to pass through two vents then the optimum design occurs when the pressure differential is equal, i.e. ΔP12 = ΔP24. As a result A12 = A24 = √2 × A1. This is because, in order to achieve the same flow with only half the pressure differential, the area of each vent should be √2 × A1 when there are two vents in the flow path. Similarly the area of each vent should be √3 × A1, if there are three equally sized vents in the flow path, etc.

Of course any combination of pressure differentials can be used as long as the sum of differential pressures does not exceed the maximum enclosure strength.

For cascade venting, where more than one vent is employed, see 7.9.2.

7.9.1 Example calculation 3

Example — Cascade venting calculations for IG-541 (peak discharge)

Temperature	20 °C
S (IG-541)	0,70 m^3/kg
S_{air}	0,830 m^3/kg
Design concentration	40 %
S_H	0,781 m^3/kg
Enclosure 1	284 m^3
Flooding factor	51 %
IG-541 quantity	204 kg
Peak flow rate	2,5 %
ΔP14 — maximum allowable pressure	500 Pa

Venting directly to atmosphere:

$$A = \frac{M \times S}{\sqrt{P \times S_H}}$$ (see 7.8.2)

ΔP14 = 500Pa

$$\mathrm{A1} = \frac{0,0025 \times 204 \times 0,70}{\sqrt{(500 \times 0,781)}}$$