



Guidance on the pressure relief and post discharge venting of enclosures protected by gaseous fire fighting systems

FIA Guidance for the Fire Protection Industry

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Introduction

The effectiveness of a gaseous total flooding fire fighting 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 must 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 must be low, at least during the gas-retention period (hold time) after the end of extinguishant discharge.

Addition of a gaseous fire fighting extinguishant to an enclosure having limited 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 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 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 fire fighting systems must address two performance considerations:

- a. Pressure management within the protected volume during the period of extinguishant discharge
- b. Retention of the extinguishant-air mixture within the enclosure for a specified period of time after the completion of the discharge

1. Scope

This document provides guidance on fulfilling the requirements contained in BS EN15004-1 and BS 5306-4, in respect to over and under pressurisation venting - clauses 7.4.1 and 10.3.3. respectively and post discharge extract - clauses 5.3 h) and 15.9 respectively.

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

2. References

BS EN 15004-1 *Fixed Fire fighting systems – Gas Extinguishing Systems – Part 1 Design, installation and Maintenance*

BS 5306-4 - *Fire Extinguishing installations and equipment on premises — Part 4: Specification for carbon dioxide systems*

3. Definitions

3.1 back pressure

pressure downstream of a vent

3.2 fire damper

a device designed to prevent the spread of fire

3.3 free vent area

the effective area provided by the vent when subjected to the required pressure at the peak flow rate.

3.4 gross vent area

the overall area of the vent

3.5 negative pressure

a pressure in the protected room which is lower than ambient pressure

3.6 peak pressure

the maximum specified differential pressure in the enclosure used for design of the vent system. This must not exceed the room strength

3.7 positive pressure

a pressure in the protected room which is higher than ambient pressure

3.8 room strength

specified differential pressure limit for the protected enclosure

3.9 total vent area

sum of the free vent area and the natural leakage area

3.10 vent

a device or means to provide a flow path through an enclosure boundary to limit the pressure therein

4. Use and Limitations

This document is for the use by those competent in the design, installation, servicing and maintenance of fixed gaseous fire fighting 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.

5. Safety

5.1 Structural Safety

The provision of correctly designed and engineered pressure venting of enclosures protected by fixed gaseous fire fighting 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.

5.2 Personnel Safety

The operation of pressure vents or extract systems, requires the removal 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.

6. System Design – Pressure relief venting

6.1 General

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

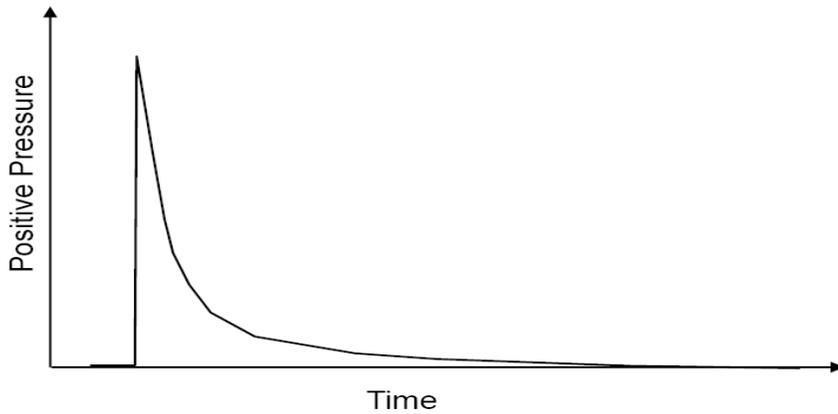
6.2 Extinguishant characteristics

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

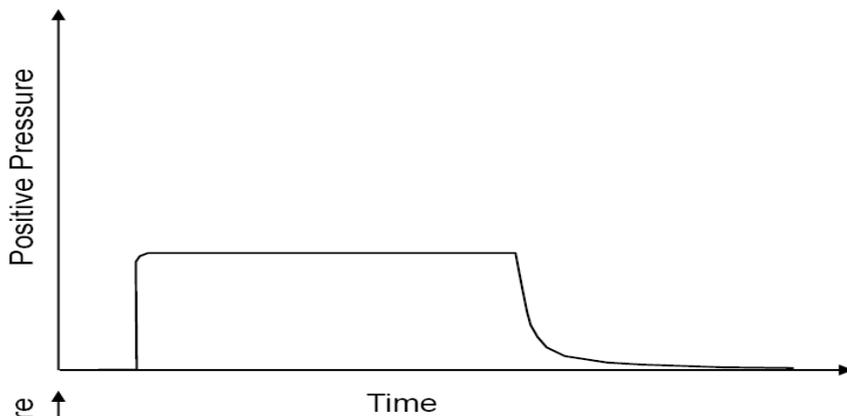
Extinguishant Name	Positive Pressure Created	Negative Pressure Created
FK 5-1-12	Yes	Yes
HFC 125	Yes	Yes
HFC 227ea	Yes	Yes
HFC 23	Yes	No
IG 01	Yes	No
IG 100	Yes	No
IG 55	Yes	No
IG 541	Yes	No
CO2	Yes	No

6.2.1 Pressure graphs

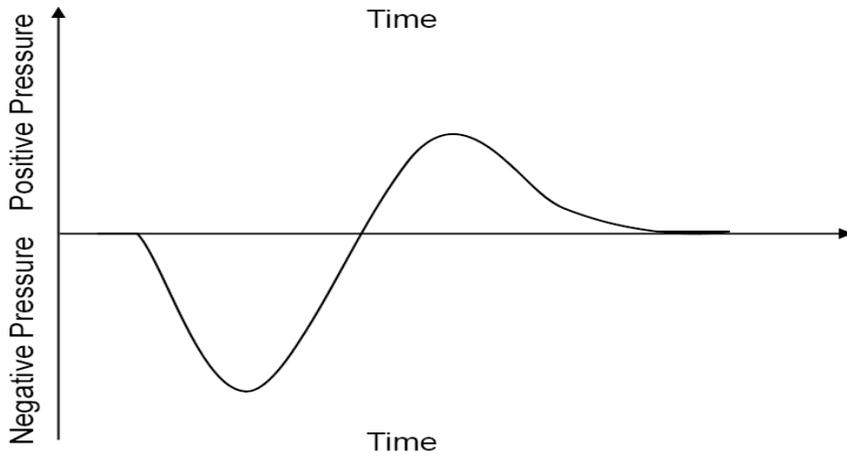
The graphs below illustrate the typical pressure excursions that would occur during discharge.



Inert Gas



Inert Gas (Constant Flow)



Halocarbon Gas

6.3 Enclosure characteristics

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

Our understanding of building strength standards in the UK is that normal (blockwork) construction can withstand 500 pascals, whilst lightweight structures such as stud partitioning can withstand only 250 pascals. 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.

Note : 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.

6.4 Vent paths

It is generally assumed that positive/negative pressure vent paths will lead to/from atmosphere. Positive 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 clause 6.9).

6.5 Types of vents

There are various types of vent which can be used for this application and these vents may fall into the following categories:

6.5.1 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 room pressure change in order to move the vent blades.

This type of vent may provide a free vent area significantly less than the gross 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 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.

6.5.2 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.

Typical vents would be more efficient than gravity flap vents.

6.5.3 Electrically operated vents

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

This type of vent is the 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.

6.5.4 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.

6.5.5 Vent accessories

6.5.5.1 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.

6.5.5.2 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 vent areas.

6.5.5.3 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 vent areas.

6.5.5.4 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 vent areas.

6.5.5.5 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

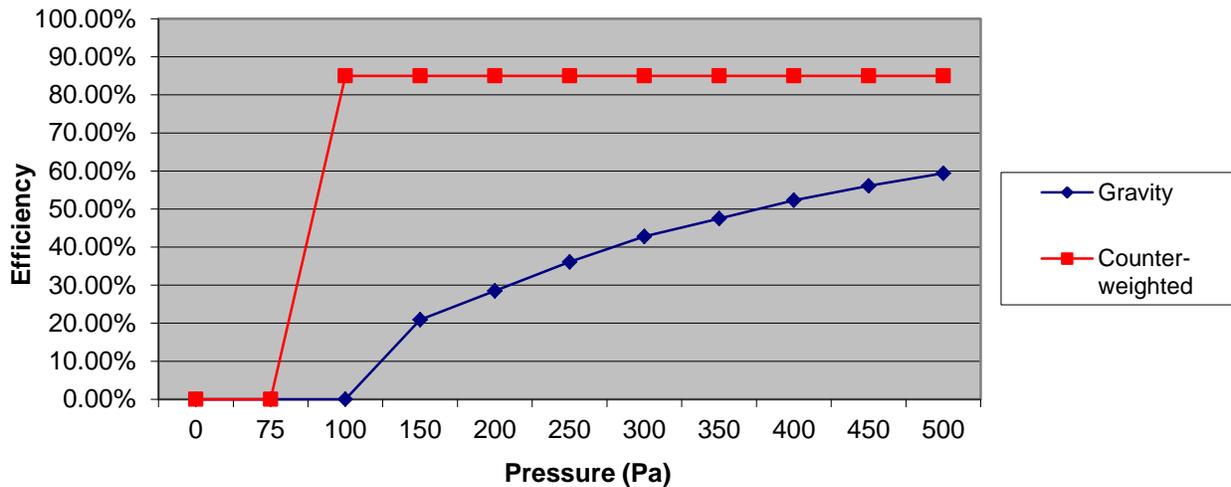
6.6 Vent Characteristics

6.6.1 Vent Efficiency

Pressure relief vents, of whatever type (see section 6.5), 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 vent area of the vent at that pressure. For example, if a vent has a nominal area of 1.0 square metres and an efficiency of 50% at 100 pascals it will provide a free vent area of 0.5 square metres at 100 pascals. The blades of the same vent may open more at higher pressures, perhaps having an efficiency of 80% at 250 pascals and thus provide a free vent area of 0.8 square metres at 250 pascals. It is therefore recommended that vent manufacturers provide free vent areas at no less than three pressures, for example 100, 250 and 500 pascals.

Vent efficiency will be reduced by the addition of other accessories in the vent path, e.g. weather louvres, grilles etc. Whilst it would be impossible for vent manufacturers to test their vents with every variety of accessory available (manufacturer, style etc.), they should be able to provide a safe assessment of the potential effect based on the free vent area of the accessory proposed.

Efficiency of Pressure Relief Vents



6.6.2 Minimum Opening Pressure

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

6.6.3 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 pascals.

6.6.4 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.

6.7 Vent location and mounting

6.7.1 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 fire fighting 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 fire fighting system causes rich streams of extinguishant to be liberated 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.

6.7.2 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 is 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 manufactures. 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 must 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.

6.8 Total vent area calculations

6.8.1 Total vent area requirement (non liquefiable gases and CO₂)

The area 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).

$$A = \frac{M * S}{\sqrt{P * S_H}}$$

A = Total vent area (square metres)

M = mass flow of extinguishant (kgs/second)

S = specific vapour volume of extinguishant (cubic metres/kg)

P = maximum room strength (pascals)

S_H = specific vapour volume of homogenous mix (cubic metres/kg)

Where

$$S_H = \frac{C * S}{100} + \left(\frac{100 - C}{100} \right) * S_{AIR}$$

C = design concentration (%)

S_{AIR} = specific vapour volume of air given by :-

S_{AIR} = K1 + K2 * T

K1 = 0.773824

K2 = 0.002832967

T = Temperature in degrees C

Where

$$Q_R = \left(\frac{S_R}{S} \right) * \ln \left(\frac{100}{100 - C} \right)$$

S_R = specific reference volume of extinguishant at the reference filling temperature and at 1.013 bar (cubic metres/ cubic metres)

Q_R = the quantity in cubic metres of extinguishant required at the reference temperature and at a pressure of 1.013 bar.

Example Calculations for Inert Gases (values taken from BS EN 15004)

Note : in these examples peak discharge percentage relates to the stored quantity of gas

IG-55 @ 20°C

Temperature

20°C

S (IG-55)

0.7081 m³/kg

S_{AIR}

0.8305 m³/kg

S_H	0.7752 m ³ /kg
P	500 Pa
Volume	260m ³
Design Concentration	45.2%
Flooding factor	0.8494 kg/m ³
Amount of gas required	220.84 kg
Number of containers holding 32.09kg (80 litre 300 bar)	7
Actual gas flowing	224.63 kg

Total vent area required assuming vent co-efficient of 1:

1. Peak discharge at 3%, 60 second discharge (6.74 kg/s) 0.243 m²
2. Peak discharge at 1.5%, 120 second discharge (3.37 kg/s) 0.122 m²
3. Constant discharge, 60 second discharge (3.744 kg/s) 0.135 m²

IG-100 @ 5°C

Temperature	5°C
S (IG-100)	0.8143 m ³ /kg
Design Concentration	40.3%
S_{AIR}	0.7880 m ³ /kg
S_H	0.7986 m ³ /kg
P	250 Pa
Volume	530m ³
Flooding factor	0.6335 kg/m ³
Amount of gas required	335.73 kg
Number of containers holding 24.88kg (80 litre 300 bar)	14
Actual gas flowing	348.32kg

Total vent area required:

1. Peak discharge at 4%, 60 second discharge (13.93 kg/s) 0.803 m²
2. Peak discharge at 2%, 120 second discharge (6.97 kg/s) 0.402 m²
3. Constant discharge, 60 second discharge (5.80 kg/s) 0.334 m²

IG-541 @ 35°C

Temperature	35°C
S (IG-541)	0.7416 m ³ /kg
Design Concentration	39.9%
S_H	0.8206 m ³ /kg
S_{AIR}	0.8730 m ³ /kg
P	350 Pa
Volume	435m ³
Flooding factor	0.691 kg/m ³
Amount of gas required	300.79 kg
Number of containers holding 57.39kg (140 litre 300 bar)	6
Actual gas flowing	344.34kg

Total vent area required:

1. Peak discharge at 2.5%, 60 second discharge (8.61 kg/s) 0.376 m²
2. Peak discharge at 1.25%, 120 second discharge (4.3 kg/s) 0.188 m²
3. Constant discharge, 60 second discharge (5.74 kg/s) 0.252 m²

Carbon Dioxide at 0°C

Temperature:	0°C
S (CO ₂)	0.505 m ³ /kg
Design Concentration	34%
S _H	0.6824 m ³ /kg
S _{AIR}	0.7738 m ³ /kg
P	100 Pa
Volume	375m ³
Flooding Factor	0.8 kg/m ³
Amount of gas required	300 kg
Number of containers holding 50kg	6
Actual Gas Flowing	300 kg

Total Vent Area Required:

Constant discharge, 60 second discharge (5 kg/s)	0.306 m ²
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6.8.2 Total vent area requirements (liquefiable gases)

The US based Fire Suppression Systems Association (FSSA) have issued a “Guide to Estimating Enclosure Pressure and Pressure Relief Vent Area for Applications Using Clean Agent Fire Extinguishing Systems”. This guidance has been based upon experimental data attained via collaboration with various industry participants, including a number of multinational organisations.

The FSSA work is by far the most in-depth investigation to-date, on the estimation of enclosure pressure and total vent area requirements.

Due to the unique status of the FSSA Guidance at this juncture, together with the backing of appropriate experimental data, the same calculation methodology for halocarbon extinguishants is used within this FIA guidance document. It should be noted, that the form of the equations have been consolidated into a single expression and to represent SI units.

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 vent area.

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

Parameter	Unit	Definition
+vePE	Pa	Positive Pressure Excursion
-vePE	Pa	Negative Pressure Excursion
TotalVentArea	m ²	the sum of the free vent area and the natural leakage area
Volume	m ³	Protected enclosure volume
Conc	%	Suppressant concentration used in the protected enclosure
t _d	s	Gaseous fire fighting system discharge time
%RH	%	Relative humidity within the enclosure
+veEPL	Pa	Enclosure positive pressure limit
-veEPL	Pa	Enclosure negative pressure limit
+veFVA	m ²	Positive free vent area required to ensure that the positive pressure excursion is below the enclosure positive pressure limit (+veEPL)
-veFVA	m ²	Negative free vent area required to ensure that the negative pressure excursion is below the enclosure negative pressure limit (-veEPL)

CAUTION: The magnitude of both +veEPL and –veEPL for each extinguishant have limits of applicability. The calculation methodology is based on experimental data and therefore the prediction of the calculation tool must 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.

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

- 6s ≤ t_d ≤ 10s
- 4.2% ≤ Conc ≤ 6.0%
- 20% ≤ RH% ≤ 80%
- +veEPL ≤ 240Pa
- veEPL ≤ -1200Pa

Pressure Excursion for FK-5-1-12

$$+vePE = 0.042649 * \left(\frac{TotalVentArea}{Volume} * \frac{t_d}{Conc} \right)^{-1.0334} * \left(0.81 + 0.51 * \frac{\%RH}{100} \right) \quad \text{Equ. 1}$$

$$-vePE = 0.32170 * \left(\frac{TotalVentArea}{Volume} * \frac{t_d}{Conc} \right)^{-1.0318} * \left(1.68 - 1.79 * \frac{\%RH}{100} \right) \quad \text{Equ. 2}$$

Total Vent Area for FK-5-1-12

$$\begin{matrix} \text{Positive} \\ \text{Total Vent Area} \end{matrix} = 0.04678 * \left(\frac{Conc}{t_d} \right) * Volume * \left(\frac{+veEPL}{0.81 + 0.51 * \frac{\%RH}{100}} \right)^{-0.9677} \quad \text{Equ. 3}$$

$$\begin{array}{l} \text{Negative} \\ \text{Total Vent Area} \end{array} = 0.34309 * \left(\frac{\text{Conc}}{t_d} \right) * \text{Volume} * \left(\frac{-veEPL}{1.68 - 1.79 * \frac{\%RH}{100}} \right)^{-0.9692} \quad \text{Equ. 4}$$

HFC-227-ea : Limits of applicability:

- 6s ≤ t_d ≤ 10s
- 6.25% ≤ Conc ≤ 10.5%
- 20% ≤ RH% ≤ 80%
- +veEPL ≤ 380Pa
- veEPL ≤ -1000Pa

Pressure Excursion for HFC-227-ea

$$+vePE = 48.359 * \left(4.2 * \ln \left(\frac{\text{Volume} * \text{Conc}}{\text{TotalVentArea} * t_d} \right) - 27.922 \right) * \left(0.81 + 0.51 * \frac{\%RH}{100} \right) \quad \text{Equ.5}$$

$$-vePE = 46.444 * \left(9.41 * \ln \left(\frac{\text{Volume} * \text{Conc}}{\text{TotalVentArea} * t_d} \right) - 62.76 \right) * \left(1.68 - 1.79 * \frac{\%RH}{100} \right) \quad \text{Equ. 6}$$

Total Vent Area for HFC227-ea

$$\begin{array}{l} \text{Positive} \\ \text{Total Vent Area} \end{array} = 0.00130 * \left(\frac{\text{Conc}}{t_d} \right) * \text{Volume} * \exp \left(\frac{-0.00497 * +veEPL}{0.81 + 0.51 * \frac{\%RH}{100}} \right) \quad \text{Equ. 7}$$

$$\begin{array}{l} \text{Negative} \\ \text{Total Vent Area} \end{array} = 0.00127 * \left(\frac{\text{Conc}}{t_d} \right) * \text{Volume} * \exp \left(\frac{-0.00222 * -veEPL}{1.68 - 1.79 * \frac{\%RH}{100}} \right) \quad \text{Equ. 8}$$

HFC-23 : Limits of applicability:

- 6s ≤ t_d ≤ 10s
- 18% ≤ Conc ≤ 30%
- 20% ≤ RH% ≤ 80%
- +veEPL ≤ -1400Pa

Pressure Excursion for HFC-23

$$+vePE = 0.08827 * \left(\frac{\text{TotalVentArea} * t_d}{\text{Volume} * \text{Conc}} \right)^{-1.165} * \left(0.81 + 0.51 * \frac{\%RH}{100} \right) \quad \text{Equ. 9}$$

Total Vent Area for HFC-23

$$\begin{array}{l} \text{Positive Total} \\ \text{Vent Area} \end{array} = 0.12384 * \left(\frac{\text{Conc}}{t_d} \right) * \text{Volume} * \left(\frac{+veEPL}{0.81 + 0.51 * \frac{\%RH}{100}} \right)^{-0.8587} \quad \text{Equ. 10}$$

HFC-125 : Limits of applicability:

- 6s ≤ t_d ≤ 10s
- 8.0% ≤ Conc ≤ 10.5%
- 20% ≤ RH% ≤ 80%

+veEPL ≤ 480Pa

-veEPL ≤ -480Pa

Pressure Excursion for HFC125

$$+vePE = 0.045349 * \left(\frac{\text{TotalVentArea}}{\text{Volume}} * \frac{t_d}{\text{Conc}} \right)^{-1.037} * \left(0.81 + 0.51 * \frac{\%RH}{100} \right) \quad \text{Equ. 11}$$

$$-vePE = 0.03949 * \left(\frac{\text{TotalVentArea}}{\text{Volume}} * \frac{t_d}{\text{Conc}} \right)^{-1.039} * \left(1.68 - 1.79 * \frac{\%RH}{100} \right) \quad \text{Equ. 12}$$

Total Vent Area for HFC125

$$\begin{aligned} \text{Positive} \\ \text{Total Vent Area} \end{aligned} = 0.050 * \left(\frac{\text{Conc}}{t_d} \right) * \text{Volume} * \left(\frac{+veEPL}{0.81 + 0.51 * \frac{\%RH}{100}} \right)^{-0.964} \quad \text{Equ. 13}$$

$$\begin{aligned} \text{Negative} \\ \text{Total Vent Area} \end{aligned} = 0.04589 * \left(\frac{\text{Conc}}{t_d} \right) * \text{Volume} * \left(\frac{-veEPL}{1.68 - 1.79 * \frac{\%RH}{100}} \right)^{-0.9622} \quad \text{Equ. 14}$$

Example Calculation 1:

Protected Enclosure	Volume = 125m ³ Air Conditioned – 50%RH Room Strength = 500Pa Total Vent Area = 0.042m ²
Extinguishing System	Agent = HFC227ea Concentration = 8.5vol% System Discharge time = 9.2s

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

Select the HFC227ea equation (Equ.5) for positive pressure excursion (+vePE)

$$+vePE = 48.359 * \left(4.2 * \ln \left(\frac{\text{Volume} * \text{Conc}}{\text{TotalVentArea} * t_d} \right) - 27.922 \right) * \left(0.81 + 0.51 * \frac{\%RH}{100} \right) \quad \text{Equ. 15}$$

$$+vePE = 48.359 * \left(4.2 * \ln \left(\frac{125 * 8.5}{0.042 * 9.2} \right) - 27.922 \right) * \left(0.81 + 0.51 * \frac{50}{100} \right) \quad \text{Equ. 16}$$

$$+vePE = 48.359 * (4.2 * \ln(2750) - 27.922) * (1.065) \quad \text{Equ. 17}$$

$$+vePE = 48.359 * (4.2 * (7.919) - 27.922) * (1.065) \quad \text{Equ. 18}$$

$$+vePE = 48.359 * (5.339) * (1.065) \quad \text{Equ. 19}$$

$$+vePE = +275 \text{ Pa} \quad \text{Equ. 20}$$

Select the HFC227ea equation (Equ. 6) for negative pressure excursion (-vePE)

$$-vePE = 46.444 * \left(9.41 * \ln \left(\frac{\text{Volume} * \text{Conc}}{\text{TotalVentArea} * t_d} \right) - 62.76 \right) * \left(1.68 - 1.79 * \frac{\%RH}{100} \right) \quad \text{Equ. 21}$$

$$\text{-vePE} = 46.444 * \left(9.41 * \ln \left(\frac{125 * 8.5}{0.042 * 9.2} \right) - 62.76 \right) * \left(1.68 - 1.79 * \frac{50}{100} \right) \quad \text{Equ. 22}$$

$$\text{-vePE} = 46.444 * (9.41 * \ln(2750) - 62.76) * (0.785) \quad \text{Equ. 23}$$

$$\text{-vePE} = 46.444 * (9.41 * (7.919) - 62.76) * (0.785) \quad \text{Equ. 24}$$

$$\text{-vePE} = 46.444 * (11.758) * (0.785) \quad \text{Equ. 25}$$

$$\text{-vePE} = -429\text{Pa} \quad \text{Equ. 26}$$

Example Calculation 2:

Protected Enclosure	Volume = 7500m ³ Air Conditioned – 50%RH Room Strength = 500Pa
Extinguishing System	Agent = HFC227ea Concentration = 7.9vol% System Discharge time = 9.6s

Calculate the expected required free vent area following the discharge of the extinguishing system: Select the HFC227ea equation (Equ. 7) for positive total vent area such that the enclosure positive pressure limit is not exceeded. A key point here, is that the limit of applicability for the +veEPL must be adhered; for HFC227ea this limit is 380Pa and so this is entered into the calculation even though the enclosure can withstand 500Pa.

$$\begin{aligned} \text{Positive Total Vent Area} &= 0.00130 * \left(\frac{\text{Conc}}{t_d} \right) * \text{Volume} * \exp \left(\frac{-0.00497 * +\text{veEPL}}{0.81 + 0.51 * \frac{\%RH}{100}} \right) \end{aligned} \quad \text{Equ. 27}$$

$$\begin{aligned} \text{Positive Total Vent Area} &= 0.00130 * \left(\frac{7.9}{9.6} \right) * 7500 * \exp \left(\frac{-0.00497 * 380}{0.81 + 0.51 * \frac{50}{100}} \right) \end{aligned} \quad \text{Equ. 28}$$

$$\begin{aligned} \text{Positive Total Vent Area} &= 0.00130 * (0.8229) * 7500 * \exp(-1.773) \end{aligned} \quad \text{Equ. 29}$$

$$\begin{aligned} \text{Positive Total Vent Area} &= 1.363 \text{ m}^2 \end{aligned} \quad \text{Equ. 30}$$

Select the HFC227ea equation (Equ. 8) for negative total vent area such that the enclosure negative pressure limit is not exceeded.

$$\begin{aligned} \text{Negative Total Vent Area} &= 0.00127 * \left(\frac{\text{Conc}}{t_d} \right) * \text{Volume} * \exp \left(\frac{-0.00222 * -\text{veEPL}}{1.68 - 1.79 * \frac{\%RH}{100}} \right) \end{aligned} \quad \text{Equ. 31}$$

$$\begin{aligned} \text{Negative Total Vent Area} &= 0.00127 * \left(\frac{7.9}{9.6} \right) * 7500 * \exp \left(\frac{-0.00222 * 500}{1.68 - 1.79 * \frac{50}{100}} \right) \end{aligned} \quad \text{Equ. 32}$$

$$\begin{aligned} \text{Negative Total Vent Area} &= 0.00127 * (0.8229) * 7500 * \exp(-1.414) \end{aligned} \quad \text{Equ. 33}$$

$$\begin{aligned} \text{Negative Total Vent Area} &= 1.906 \text{ m}^2 \end{aligned} \quad \text{Equ. 34}$$

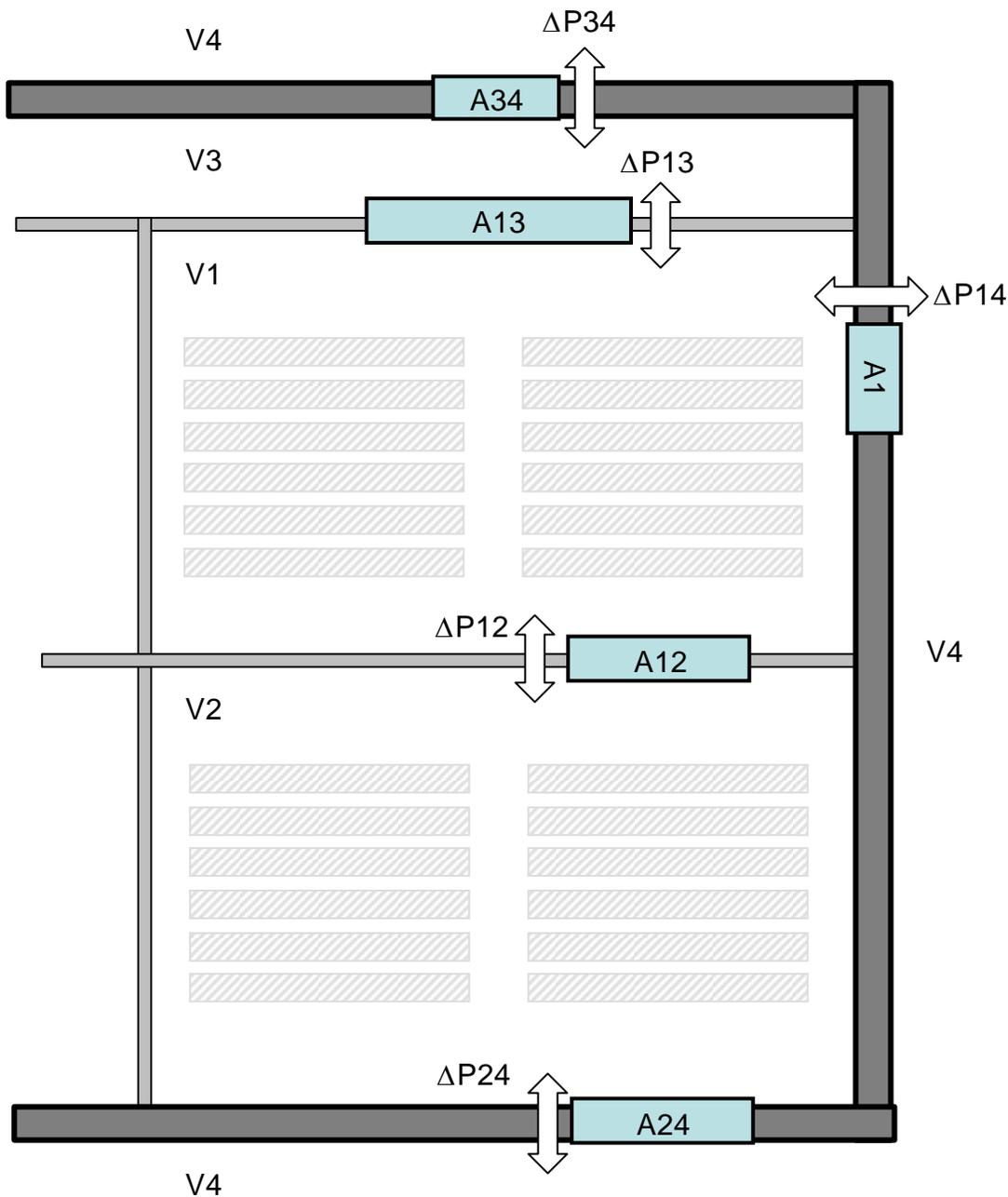
6.8.3 Natural leakage

When determining the overall vent area required, it may be acceptable to take into account the natural leakage area. This natural leakage area is the equivalent leakage area (ELA) as determined by the room integrity test.

NOTE : When the integrity test is conducted with doors held open in adjacent rooms to the room under test, there could be less natural leakage available than may have been assumed from the ELA value. In such cases, if natural leakage is to be used for pressure relief, the protected enclosure must be assessed and judgement applied in deciding what proportion of the ELA is used as a contribution to the total vent area

6.9 Cascade venting calculations

Where the over-pressure venting for a gaseous fire fighting 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:



All volumes are in m^3 , all free 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 vent area if the protected enclosure vented directly to atmosphere V4.

A12 – free vent area from the protected enclosure V1 into the adjacent enclosure V2.

A24 – free vent area from enclosure V2 to atmosphere V4.

A13 – free vent area from the protected enclosure V1 into the adjacent enclosure V3.

A34 – free vent area from the enclosure V3 to atmosphere V4

ΔP_{14} – pressure differential between V1 and V4. With V4 representing atmosphere, this will be equivalent to the maximum allowable pressure in V1

ΔP_{12} – pressure differential between V1 and V2.

ΔP_{14} – pressure differential between V1 and V4.

ΔP_{13} – pressure differential between V1 and V3.

ΔP_{34} – pressure differential between V3 and V4.

When venting directly to the atmosphere from the protected space the pressure loss (differential) through the free vent area A1 is ΔP_{14} . When the vent flow has to pass through two vents then the optimum design occurs when the pressure differential is equal, i.e. $\Delta P_{12} = \Delta P_{24}$. As a result $A_{12} = A_{24} = \sqrt{2} \times A_1$. This is because, in order to achieve the same flow with only half the pressure differential, the area of each vent must be $\sqrt{2} \times A_1$ when there are two vents in the flow path. Similarly the area of each vent must be $\sqrt{3} \times A_1$, 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. To prevent flow and pressure oscillations through the enclosures, only one of the vents in the flow path should be a flap type vent; the remainder should be actuated to remain fully open during the venting process.

Example Calculation 3:

Example - cascade venting calculations for IG541 (Peak Discharge)

Temperature	20°C	
S (IG541)		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%	
IG541 Quantity	204 kg	
Peak flow rate	2.5%	
ΔP14 – maximum allowable pressure	500Pa	

Venting directly to atmosphere:

$$\Delta P14 = 500\text{Pa}$$

$$A1 = \frac{0.025 * 204 * 0.70}{\sqrt{500 * 0.781}}$$

$$A1 = 0.182 \text{ m}^2$$

Cascade venting through adjacent enclosure V2 –vent size optimised

$$\Delta P12 = \Delta P23 = 250 \text{ Pa}$$

$$A12 = A24 = \frac{0.025 * 204 * 0.70}{\sqrt{250 * 0.781}}$$

$$A12 = A23 = 0.258 \text{ m}^2 ; \text{ alternatively } A1 \text{ can be multiplied by } \sqrt{2} \text{ in this optimised condition.}$$

Cascade venting through adjacent enclosure V3 – minimising size of vent in outside wall (A34).

$$\Delta P13 = 100 \text{ Pa}$$

$$\Delta P34 = 400 \text{ Pa}$$

$$A13 = \frac{0.025 * 204 * 0.70}{\sqrt{100 * 0.781}}$$

$$A13 = 0.407 \text{ m}^2$$

$$A34 = \frac{0.025 * 204 * 0.70}{\sqrt{400 * 0.781}}$$

$$A34 = 0.204 \text{ m}^2$$

6.9.1 Cascade vent arrangements

Cascade venting is the means to vent from one area through one or more areas.; it is sometimes necessary should the protected area be within another area, e.g. a computer room in the centre of a building rather than located adjacent to an outside wall.

Cascade venting calculations need to determine intermediate pressures generated since these will affect the flow of the exiting gases. This is equally applicable to flow through ducts.

As an example, the intermediate vent area is calculated with a lateral wall strength of 250Pa. The intermediate pressure through the flow path is 125 Pa. In order to allow for this, the vent area calculation needs to be made on 125 Pa to achieve 250 Pa maximum differential. When calculating pressure losses through ducts pressure loss will change with flows that change with the vent area, so an iterative process is required to get a more exact value.

Cascade vent arrangements, for the necessary design calculations and considerations above can be as follows:

1. Protected Area 1 to Protected Area 2 to atmosphere. Vent from Area 1 to Area 2, via a pre-opened vent, i.e. electric or pneumatic, to atmosphere
2. Protected Area 1 to Protected Area 2 to any further protected area(s) to atmosphere. Vent from Area 1 to Area 2, and then via pre-opened vents through any further protected area(s) and then to atmosphere
3. Protected Area 1 to atmosphere via duct work. Duct work and vents will need to be sized in accordance with maximum lateral pressure and flow requirements.

6.9.2 Venting into adjacent enclosures

When a protected enclosure is required to have pressure relief venting fitted, and the vent path is into an adjacent enclosure (i.e. cascade venting) it is important that the volume of the adjacent enclosure is large enough such that the room strength is not compromised. This can be determined by the following methodology and calculation.

V_1 is the volume (m^3) of the enclosure (1) which employs a gaseous fire protection system and has pressure relief fitted which connects it to an adjacent enclosure (2) of volume V_2 . If V_2 is not large enough to act as a reservoir for flow of gas into or out of V_1 during a system discharge, then V_2 will also require pressure relief.

The following two sections detail how to determine the minimum size of V_2 such that pressure relief on V_2 is NOT required.

6.9.2.1 Over-Pressurisation : Determination of adjacent enclosure volume

The basis for this methodology is that at equilibrium the pressure generated by the injection of extinguishant gas into V_1 will balance across the pressure relief vent into V_2 . By taking the volume of extinguishant injected, and calculating what volume is required for that extinguishant to exert +veEPL (differential pressure) over the combined volume of V_1 and V_2 . For all gaseous fire fighting agents, the minimum size of an adjacent volume V_2 , for over-pressurisation can therefore be determined by:

$$V_2 \geq \left(\frac{\text{flooding factor} * V_1 * 101325}{+veEPL} \right) - V_1 \quad \text{Equ. 35}$$

where the flooding factor is in cubic metres/cubic metres (reference BS EN 15004) and +veEPL is the lower of the positive enclosure pressure limits (in Pa) for V_1 and V_2 .

The free vent area between V_1 and V_2 must be calculated as a cascade vent arrangement as described in Section 6.9.

6.9.2.2 Under-Pressurisation : Determination of adjacent enclosure volume

For gaseous fire fighting agents that generate a negative pressure excursion during discharge (FK-5-1-12, HFC-227ea, HFC-125) the minimum size of an adjacent volume V_2 , can be determined by:

$$V_2 \geq \frac{101325 * -veFVA * \sqrt{-vePE_{V1} * S_{air}}}{-veEPL_{V2}} * \frac{t_d}{2} \quad \text{Equ. 36}$$

where $-veFVA$ is the free vent area (m^2) between V_1 and V_2 based on a cascade arrangement (see Section 6.9), $-vePE_{V1}$ is the negative pressure excursion in V_1 (Pa) and $-veEPL_{V2}$ is the negative enclosure pressure limit for V_2 (Pa).

Example Calculation 4:

A 248 m^3 enclosure with a positive pressure limit of 500Pa is protected with an IG-55 inert gas suppression system with an applied design concentration of 46vol% at 20 degrees C (flooding factor - 0.6057 m^3/m^3)

$$Q_R = \left(\frac{S_R}{S}\right) * \ln\left(\frac{100}{100-C}\right) = \left(\frac{0.69604}{0.70812}\right) * \ln\left(\frac{100}{100-46}\right) = 0.6057$$

The over-pressure from this enclosure is to be vented into an adjacent enclosure of 20,000 cubic metres with a positive pressure limit of 400Pa.

Determine whether or not this volume is of adequate size to ensure that the enclosure pressure limits are not exceeded.

The free vent area required between the protected area and the adjacent enclosure must be determined under the basis of cascade venting,

Using Equ. 35

$$\text{Minimum volume of adjacent enclosure} \geq \left(\frac{0.6057 * 101325 * 248}{400}\right) - 248 \quad \text{Equ. 37}$$

$$\text{Minimum volume of adjacent enclosure} \geq 37,803 \text{ m}^3 \quad \text{Equ. 38}$$

In this instance, the adjacent volume is not adequate on its own, and further pressure relief will be required on the adjacent enclosure, calculated once again under the cascade venting premise.

Example Calculation 5:

An HFC227ea extinguishing system has been employed to protect a 248 m^3 enclosure with a pressure limit of ± 500 Pa at a design concentration of 8.0vol% at 20 degrees C and a discharge time of 9.5 seconds. The flooding factor in cu.m/cu.m is 0.6335 kgs/cu.m multiplied by specific vapour volume at 20 degrees C of 0.1374 = 0.087 cu.m/cu.m. This enclosure is of particularly high integrity and so both under and over pressure relief has been fitted and cascaded into an adjacent enclosure with a volume of 4,200 m^3 and a pressure limit of ± 500 Pa. The free vent area for the negative pressure excursion at 250Pa is 0.131 m^2 (using Equ. 8 and a relative humidity of 50%).

Determine whether or not the adjacent enclosure is of adequate size to ensure that the enclosure pressure limits are not exceeded.

Using Equ. 35 for the over-pressure calculation:

$$\text{Minimum volume of adjacent enclosure} \geq \left(\frac{0.087 * 101325 * 248}{500}\right) - 248 \quad \text{Equ. 39}$$

$$\text{Minimum volume of adjacent enclosure} \geq 4,124 \text{ m}^3 \quad \text{Equ. 40}$$

In this instance, the adjacent volume is of adequate size such that additional cascade venting is not required for the over-pressure event.

Using Equ. 36 for the under-pressure calculation:

$$\text{Minimum volume of adjacent enclosure} \geq \frac{101325 * 0.131 * \sqrt{250 * 0.831}}{500} * \frac{9.5}{2} \quad \text{Equ. 41}$$

$$\text{Minimum volume of adjacent enclosure} \geq 1,817 \text{ m}^3 \quad \text{Equ. 42}$$

In this instance, the adjacent volume is of adequate size such that additional cascade venting is not required for the under-pressure event.

7. System Design - Post discharge venting

In protected enclosures means for prompt natural or forced-draft ventilation of areas after any system discharge should be provided, to safely remove fire by-products and extinguishant (as per EN 15004-1 and ISO 14520-1). Forced draft ventilation will often be necessary. Care should be taken to completely dissipate hazardous atmospheres and not just move them to other locations. It should be noted that most extinguishants are heavier than air.

8. Acceptance

During system handover procedures, checks should be made to ensure vents are :-

- a) properly sited
- b) correctly sized
- c) free to operate
- d) mounted for correct orientation
- e) mounted for correct flow direction
- f) free from internal and external obstructions in the flow path
- g) functionally tested (in the case of electrically and pneumatically operated vents)

Gaseous systems should remain disabled unless and until vents have been fitted and the above checks completed.

9. Service and maintenance

During servicing and maintenance procedures (at least every six months) the following should be checked to ensure vents are:-

- a) free to operate
- b) free from internal and external obstructions in the flow path
- c) functionally tested (in the case of electrically and pneumatically operated vents)

If natural leakage has been used as the means or as a contribution towards the total vent area and if any concerns exist over changes to the natural vent area, a room integrity test should be performed.