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

Lignes directrices et recommandations relatives à la conception, à la sélection et à l'installation d'évents pour préserver l'intégrité structurelle des enceintes protégées par des systèmes d'extinction d'incendie à gaz

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 firefighting*, Subcommittee SC 8, *Gaseous media and firefighting systems using gas.* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 191, *Fixed firefighting systems*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition cancels and replaces the first edition (ISO/TS 21805:2018), which has been technically revised.

The main changes are as follows:

— subclause 7.8.3 has been amended to cross-reference ISO 6183 for vent area calculations for CO_2;

— Annex A has been added, providing guidance on how testing in order to derive the agent-specific formulae;

— Annex B has been added, providing guidance on the procedure for developing coefficients for any new agents in the ISO 14520 series.

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.

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Introduction

The guidance presented in this document is based on the results of a joint research programme conducted in 2006 and 2007 by several fire protection system manufacturers and interested parties. The programme 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 formulae in cases where the discharge of the agent results in cooling the air temperature below its dew point. 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 formulae 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 analyses indicate 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 can 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 programme 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 a 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. To limit the rate of gas exchange, the enclosure boundary should have a high degree of integrity. To put it another way, the 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 the extinguishant discharge.

The addition of a gaseous firefighting extinguishant to an enclosure having a 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,

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ceiling. Conversely, if the enclosure has too much pressure-relief vent area then gas exchange with the ambient atmosphere will occur rapidly, leading to a 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 formulae contained in this document. Please refer to the text and notes that follow them.

The information in this document does not supersede the manufacturer's guidance. The information contained in this document is presented as being 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.

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

1 Scope

This document gives guidelines for fulfilling the requirements contained in ISO 6183:2022, 6.4.1 and 7.4.1 and ISO 14520-1:2023, 5.2.1 h) and 5.3 h), in respect to over- and under-pressurization 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 terminology databases for use in standardization at the following addresses:

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

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

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

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

3.2
gross pressure-relief vent area
total area of the pressure-relief vent

3.3
negative pressure
pressure in the protected room which is lower than the pressure immediately outside the enclosure boundary

3.4
peak pressure
maximum pressure (positive and negative) generated within an enclosure caused by the discharge of the gaseous agent

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3.5
positive pressure
pressure in the protected room which is higher than the pressure immediately outside the enclosure boundary

3.6
enclosure strength
specified differential pressure limit for the protected enclosure

3.7
pressure-relief area
sum of the free pressure-relief vent area and the enclosure leakage area

3.8
pressure-relief vent
device that provides a flow path through an enclosure boundary to limit the pressure therein

3.9
authority
organization, office or individual responsible for approving equipment, installations or procedure

4 Symbols and abbreviated terms

A	pressure-relief vent area (m^2)
A_N	pressure-relief vent area to limit negative pressure to a specified P_N (cm^2 or in^2)
A_P	pressure-relief vent area to limit positive pressure to a specified P_P (cm^2 or in^2)
A_T	total pressure-relief vent area (m^2)
C	agent design concentration (vol. %)
$E_{p,P}$	positive pressure excursion
$E_{p,N}$	negative pressure excursion
f_F	flooding factor (m^3/m^3)
H	relative humidity within the enclosure (%)
$L_{e,p,P}$	enclosure positive pressure limit
$L_{e,p,N}$	enclosure negative pressure limit
m	minimum design quantity of agent (kg)
M_{AGT}	molecular weight of the agent (kg/mol)
M_{AIR}	molecular weight of air (0,029; kg/mol)
M_H	is the mixture molecular weight of the agent (kg/mol)
P	pressure (Pa or psf)
P_{max}	maximum room strength (Pa)
P_N	negative pressure (Pa or psf)
P_P	positive pressure (Pa or psf)

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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

Q_R quantity of agent required at reference temperature of 20 °C (m^3)

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

S specific volume of the agent at the design temperature (m^3/kg)

S_{AIR} specific volume of air (m^3/kg)

S_R specific volume of the agent at the reference temperature (m^3/kg)

t discharge time (s)

t_d gaseous firefighting system discharge time (s)

T temperature (K)

V volume of the protected space (m^3)

V_A specific volume of the agent at the design temperature (m^3/kg)

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

V_V specific vapour volume of extinguishant (m^3/kg)

w maximum mass flow rate of the agent

ρ_H agent-air mixture density

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.

Other trades and services are involved in the complete system and this document is limited to providing the guidance outlined in the Scope.

After applying the enclosure peak pressure and pressure-relief vent area analysis of this document, the user can potentially conclude that an enclosure can require additional pressure-relief vent areas 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, which can be specified and selected by use of this document.

The maximum pressure developed in an enclosure on the 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 clauses contains correlation formulae that are specific to the agent type and manufacturer's hardware. The formulae can be used to make estimates of the following:

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

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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 use in 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 formulae application limits

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

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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 for preventing the possibility of failure of structural integrity. This is essential for mitigating 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 the atmosphere or another area not necessarily protected. Safety issues can arise due to exposure to the extinguishants themselves or products of combustion and/or extinguishant breakdown products. Also, any hazards arising from the operation of the over/under pressurization 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 can withstand.

A room integrity test can be used to determine the equivalent leakage area, or simply the "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 the discharge of a clean agent system. If 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 the development of pressure upon system discharge to an acceptable value.

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7.2 Extinguishant characteristics

7.2.1 Positive and negative pressurization

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

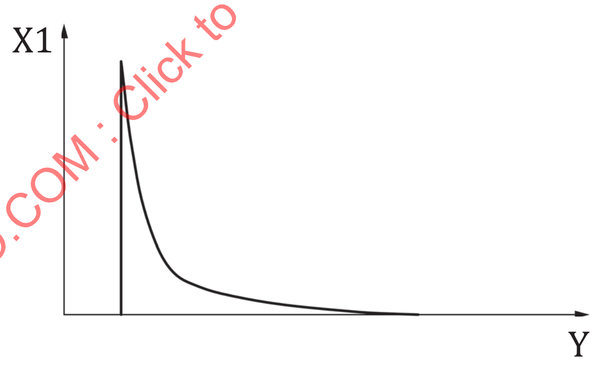
Table 2 — Pressure effects of gaseous extinguishant

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[a]

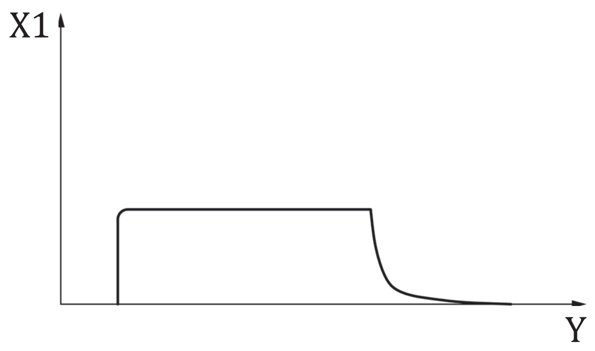
[a] Negative pressure has been observed, with adverse effects. It can occur in certain cases where large quantities of CO_2 are released into a space having low leakage to ambient.

7.2.2 Pressure graphs

The graphs shown in Figure 1 illustrate the typical pressure excursions that would occur during discharge within the protected area.



a) Inert gas



b) Inert gas (constant flow)

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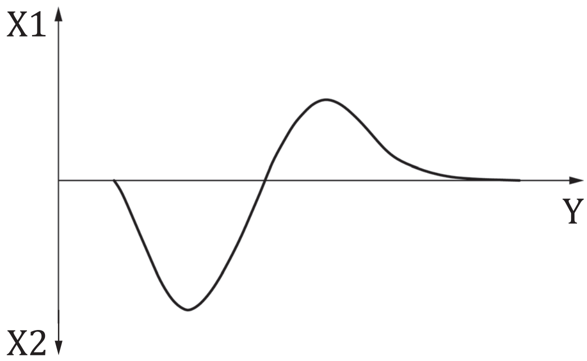

c) Halocarbon gas

Key

X1 positive pressure

X2 negative pressure

Y time

Figure 1 — Typical pressure excursions

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7.3 Enclosure characteristics

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

It is generally accepted that normal masonry construction can withstand 500 Pa, while lightweight structures such as stud partitioning can withstand only 250 Pa. Both figures assume fixings at the top and bottom. Certain structure types can 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. If the client does not make clear the allowable pressure the enclosure will withstand, it is necessary to obtain their acceptance of the figures used.

Due to issues related to enclosures utilizing 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 the atmosphere. Positive pressure-relief vent paths will assist in the safe transfer of the displaced air/extinguishant volume to the atmosphere in the most efficient, uncomplicated manner as well as ensuring air/extinguishant contaminated with fire by-products also finds a safe route to the outside air.

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

Under certain circumstances, it can 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 a transit path to the atmosphere. Under the circumstances described in the latter option, special venting considerations can be required to ensure the pressure condition is not simply transferred to that adjacent space (see 7.9).

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7.5 Types of pressure-relief vents

7.5.1 General

There are various types of pressure-relief vents, which are normally closed to preserve the integrity of the enclosure and which then open to relieve a pressure impulse and close again. These pressure-relief vents can fall into several categories, which are described in the following subclauses.

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 to move the vent blades.

This type of vent can provide a free pressure-relief vent area significantly smaller 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 loss 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 can avoid compromising the enclosure fire rating. See Figure 2.

Figure 2 — Gravity vent

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7.5.3 Counterweighted flap vent

This type of vent is configured with the hinge located just off from 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.

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7.5.4 Electrically-operated vents

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

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 can be dependent on the sequence of activation and the time allowed for the vent to open fully.

See Figure 3.

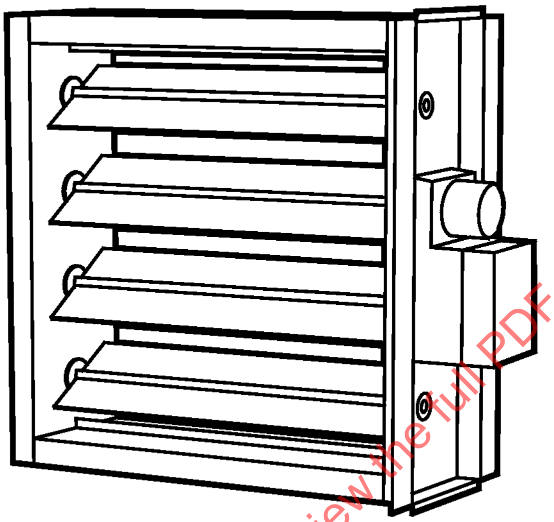

Figure 3 — Electrically-operated vent

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7.5.5 Pneumatically-operated vent

Pneumatically operated vents are actuated by pressure, normally that of gas flowing through the pipework or 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 a low level it is feasible that the client will have some concerns regarding forced entry. Therefore, it is likely that security bars can be fitted across the aperture to retain the building security.

7.5.6.2 Insect screen

If there is concern that insects can potentially penetrate the building through the vent it can be necessary to specify insect screens. However, these are made of fine mesh and can 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 can penetrate the opening even with the vent in the closed position. In this case, a weather louvre can be fitted externally. However, this can have a significant impact on the free pressure-relief vent areas.

See Figure 4.

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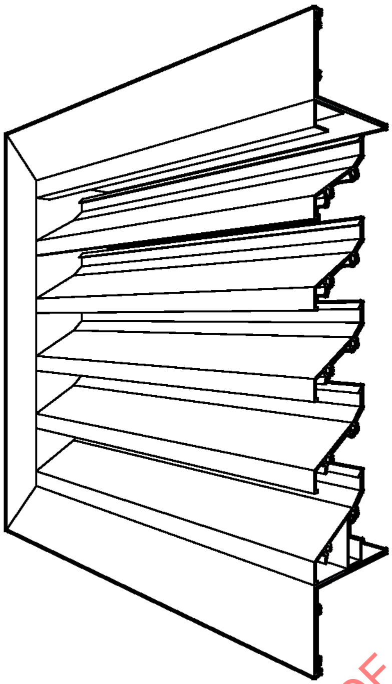

Figure 4 — Louvres

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7.5.6.4 Decorative grilles

A decorative grille can be used to cover the inner face of the vent assembly. However, this can have a significant impact on the free pressure-relief vent areas.

7.5.6.5 Limit switches

If electrically- or pneumatically-operated vents are inadvertently left in the open position they can potentially become either a security risk or endanger the equipment within the space by the infiltration of pollution from external sources. In this case, it can 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 any 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 can open further 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.

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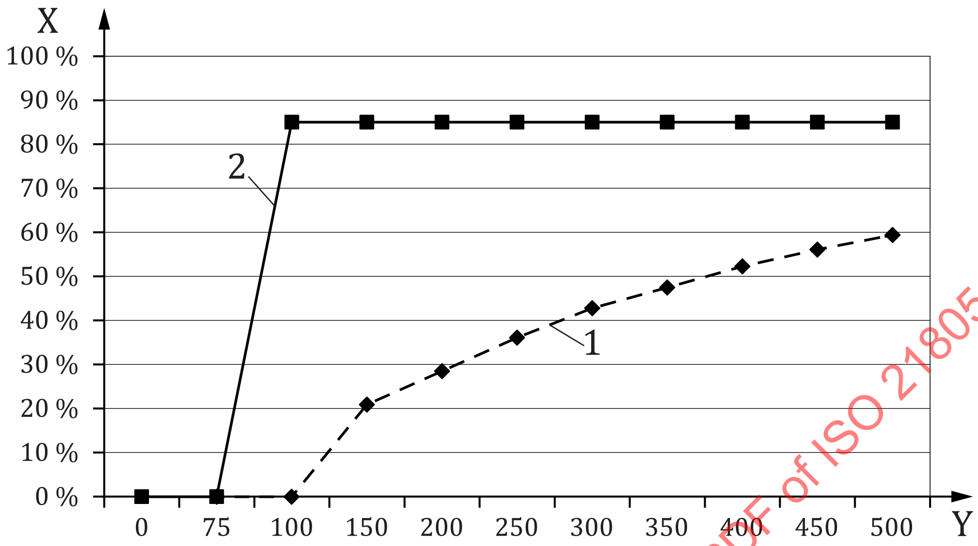
Vent efficiency will be reduced by the addition of other accessories in the vent path, e.g. weather louvres, grilles, etc. Vent manufacturers should provide a safe assessment of the potential effect based on the free pressure-relief vent area of the accessory proposed.

NOTE Vent efficiencies are provided by vent manufacturers.



Key

X efficiency (%)

Y pressure (Pa)

1 gravity

2 counter-weighted

Figure 5 — Efficiency of pressure-relief vents

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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 should 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.

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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 should 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 is those which are of a non-fixed or temporary arrangement, which can impede flow or prevent the vent from functioning correctly. Such items are not necessarily present at the time at which the gaseous firefighting system is designed and ultimately handed over. Examples 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 near nozzles and directly in the path of discharge, can 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 points are provided as general information which can vary between suppliers.

Vents can feature a mounting flange that 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 are required. Additional mounting frames can also need to be utilized where the vents are being fitted in very thin enclosure walls such as glass-reinforced plastic 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 several 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 should 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 are not to 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 are fully tightened, that the vent is free of any distortion and all the blades can freely move such that they can fully open and intentionally 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 building 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.

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7.8 Pressure-relief vent area calculations

7.8.1 Use of agent-specific formulae

To use the agent-specific formulae, the user needs to know the following:

a) volume of the protected enclosure (m^3 or ft^3);

b) agent type;

c) agent design concentration based on an enclosure temperature of 21 °C (vol. %);

d) system discharge time (s)

e) average relative humidity, H, in the protected enclosure (only required for FK-5-1-12, HFC-125, or HFC-227ea);

f) equivalent leakage area of an enclosure (cm^2 or in^2). See 7.8.4.

NOTE This can be determined by a room-integrity (door-fan) test. See ISO 14520-1:2023, Annex E.

g) the specified maximum allowed enclosure pressure, the “pressure limit,” (Pa or psf).

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

1) Determine the enclosure’s positive pressure (P_P) and negative pressure (P_N) limits.

2) Determine the equivalent leakage area using the enclosure integrity test. See ISO 14520-1:2023, Annex E.

3) Use agent-specific formulae and the measured equivalent leakage area, from step 2), to estimate values of P_P and P_N.

4) 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 on the system plans.

5) If the measured equivalent leakage area results in pressure P_P and P_N that exceed the specified enclosure pressure limit, use agent-specific formulae 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 working plans.

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

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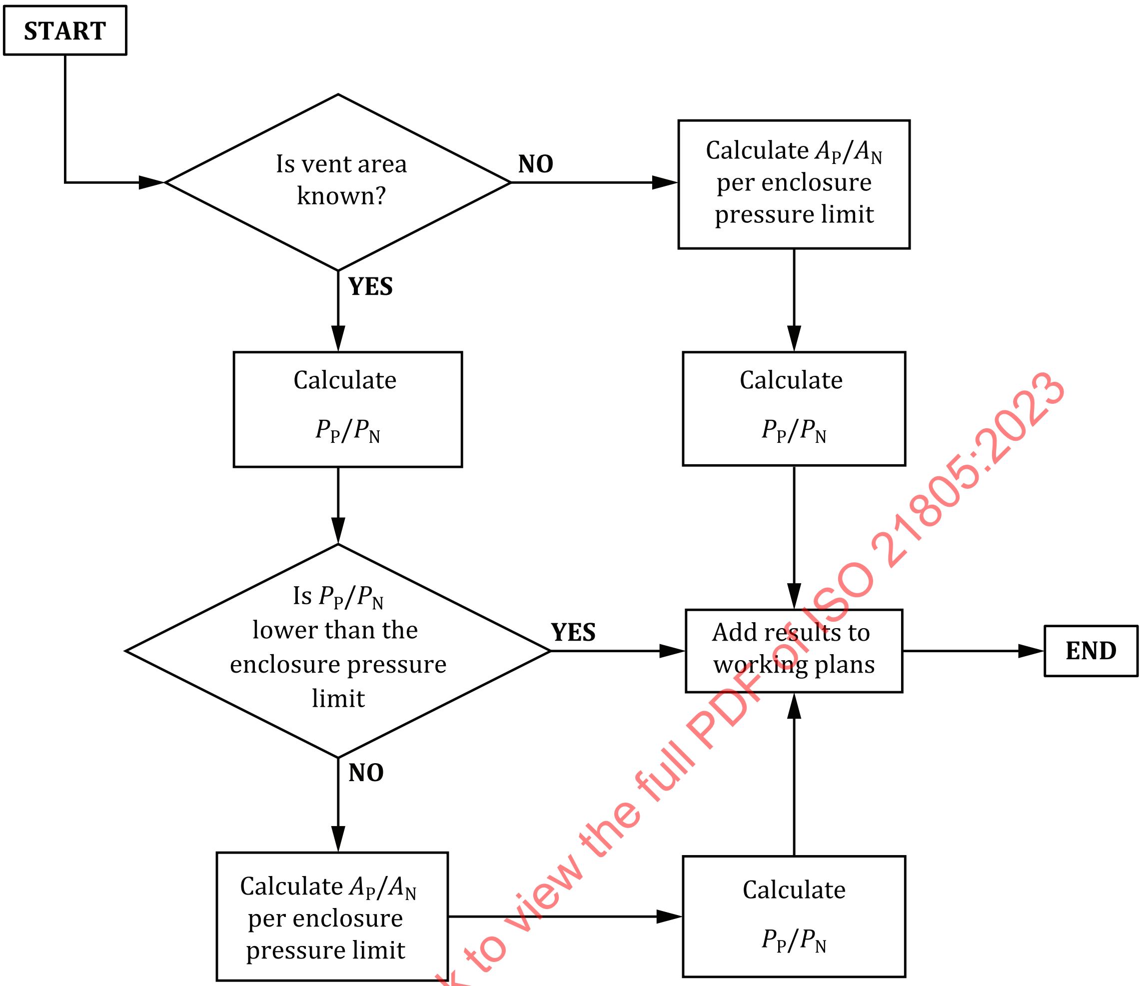

Figure 6 — Sequence of steps to follow to calculate P_P and P_N

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7.8.2 Vent area requirement (non-liquefiable gases)

7.8.2.1 General

The manufacturer's system flow calculations are used to determine the maximum agent flow rate. The required pressure-relief vent area depends on the maximum mass flow rate of the agent, *w*, measured in kg/s. The maximum mass flow rate of the agent, *w*, depends on the discharge time, *t*, the minimum design quantity of agent, *m*, and the design of the discharge valve. The maximum mass flow rate of the agent can be approximated as follows:

a) Constant discharge rate: $w = m/t$, (kg/s).

b) Initial discharge rate of *x* % per second: $w = (x/100)\ m$, where *x* is determined by the system manufacturer and *m* is determined according to Formula (1):

$$m = \frac{V}{V_A} \ln\left(\frac{100}{100 - C}\right) \tag{1}$$

where

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

V_A is the specific volume of the agent at the design temperature (m³/kg);

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

7.8.2.2 Vent area

The total pressure-relief vent area, A_T, is calculated using Formula (2), where a value of 1,0 has been assumed for the co-efficient of resistance of the flow through an opening.

$$A_T = \frac{w \times V_V}{\sqrt{P_{max} \times V_H}} \quad (2)$$

where,

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

w is the maximum mass flow rate of the agent (kg/s);

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

P_{max} is the maximum room strength (Pa);

V_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, ρ_H, is calculated using Formula (3):

$$\rho_H = \frac{P \times M_H}{R \times T} \quad (3)$$

where the mixture molecular weight, M_H, is calculated using Formula (4):

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

and Formula (5):

$$V_H = {}^{1}\!/_{\rho_H} \quad (5)$$

where

ρ_H is the agent-air mixture density (kg/m^3);

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

M_{AGT} is the molecular weight of the agent (kg/mol);

M_{AIR} is the molecular weight of air (kg/mol);

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

P is the pressure (Pa);

T is the temperature (K).

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7.8.2.3 Example calculations for inert gases (values taken from ISO 14520-1)

7.8.2.3.1 Introduction

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.

7.8.2.3.2 IG-55 at 20 °C, 1,013 bar(a) (atmospheric pressure)

Temperature	20 °C
V_A (IG-55)	0,708 1 m^3/kg
S_{AIR}	0,830 5 m^3/kg
V_H	0,775 2 m^3/kg
P	500 Pa
V	260 m^3
C	45,2 %
f_F	0,849 4 kg/m^3
Amount of gas required, calculated as follows: {m = (260 / 0,708) × ln[100 / (100 – 45,2)]}	220,84 kg
Number of containers holding 32,09 kg (80 litre, 300 bar)	7
Actual gas quantity	224,63 kg

NOTE 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm^2.

The pressure-relief vent area required assuming vent coefficient of 1 is:

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

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

7.8.2.3.3 IG-100 at 5 °C

Temperature	5 °C
V_A (IG-100)	0,814 3 m^3/kg
C	40,3 %
S_{AIR}	0,788 0 m^3/kg
V_H	0,798 6 m^3/kg
P	250 Pa
V	530 m^3
f_F	0,633 5 kg/m^3

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Amount of gas required, calculated as follows {m = (530/ 0,814) × ln[100 / (100 – 40,3)]}	335,73 %
Number of containers holding 24,88 kg (80 litre, 300 bar)	14
Actual gas quantity	348,32 kg

The pressure-relief vent area required is:

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

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

7.8.2.3.4 IG-541 at 35 °C

Temperature	35 °C
V_A (IG-541)	0,741 6 m^3/kg
C	39,9 %
S_{AIR}	0,820 6 m^3/kg
V_H	0,873 0 m^3/kg
P	350 Pa
V	435 m^3
f_F	0,691 kg/m^3
Amount of gas required, calculated as follows {m = (350 / 0,741) × ln[100 / (100 – 39,9)]}	300,79 kg
Number of containers holding 57,39 kg (140 l, 300 bar)	6
Actual gas quantity	344,34 kg

The vent area required is:

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

2) 0,188 m^2 for a 120-s 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.

7.8.3 Vent area requirement carbon dioxide

The vent area for CO_2 systems can be determined in accordance with ISO 6183.

7.8.4 Vent area requirements (liquefiable gases)

7.8.4.1 General

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

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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 the 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 (see Table 3).

Table 3 — Expected pressure excursion

Parameter	Definition	Unit
$E_{p,P}$	Positive Pressure Excursion	Pa
$E_{p,N}$	Negative Pressure Excursion	Pa
A	Pressure-relief vent area	m^2
V	Volume of the protected space	m^3
C	Agent design concentration used in the protected enclosure	%
t_d	Gaseous firefighting system discharge time	s
H	Relative humidity within the enclosure	%
$L_{e,p,P}$	Enclosure positive pressure limit	Pa
$L_{e,p,N}$	Enclosure negative pressure limit	Pa
A_P	Positive free pressure-relief vent area required to ensure that the positive pressure excursion is below the enclosure positive pressure limit (+*ve*EPL)	m^2
A_N	Negative free pressure-relief vent area required to ensure that the negative pressure excursion is below the enclosure negative pressure limit (−*ve*EPL)	m^2

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.

See Annex A which provides guidance on the methodology used to develop the agent-specific coefficients.

See also Annex B which provides guidance on the procedure used to develop coefficients for any new agents in the ISO 14520 series.

7.8.4.2 FK-5-1-12

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

$6\ s \le t_d \le 10\ s$

$4{,}2\ \% \le C \le 6{,}0\ \%$

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$20\ \% \leq H \leq 80\ \%$

$L_{e,p,P} \leq 240$ Pa

$L_{e,p,N} \leq -1\ 200$ Pa

7.8.4.2.2 Pressure excursion for FK-5-1-12

The pressure excursion for FK-5-1-12 can be calculated using Formulae (6) and (7):

$$E_{p,P} = 0{,}042\,649 \times \left(\frac{A}{V} \times \frac{t_d}{C} \right)^{-1{,}033\,4} \times \left(0{,}81 + 0{,}51 \times \frac{H}{100} \right) \quad (6)$$

$$E_{p,N} = 0{,}321\,70 \times \left(\frac{A}{V} \times \frac{t_d}{C} \right)^{-1{,}031\,8} \times \left(1{,}68 - 1{,}79 \times \frac{H}{100} \right) \quad (7)$$

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

The total pressure-relief vent area for FK-5-1-12 can be calculated using Formulae (8) and (9):

$$A_P = 0{,}046\,78 \times \left(\frac{C}{t_d} \right) \times V \times \left(\frac{L_{e,p,P}}{0{,}81 + 0{,}51 \times \frac{H}{100}} \right)^{-0{,}967\,7} \quad (8)$$

$$A_N = 0{,}343\,09 \times \left(\frac{C}{t_d} \right) \times V \times \left(\frac{L_{e,p,N}}{1{,}68 - 1{,}79 \times \frac{H}{100}} \right)^{-0{,}969\,2} \quad (9)$$

7.8.4.3 HFC-227ea

7.8.4.3.1 HFC-227ea: Limits of applicability

$6\ \text{s} \leq t_d \leq 10\ \text{s}$

$6{,}25\ \% \leq C \leq 10{,}5\ \%$

$20\ \% \leq \%\ H \leq 80\ \%$

$L_{e,p,P} \leq 380$ Pa

$L_{e,p,N} \leq -1\ 000$ Pa

7.8.4.3.2 Pressure excursion for HFC-227ea

The pressure excursion for HFC-227ea can be calculated using Formulae (10) and (11):

$$E_{p,P} = 48{,}359 \times \left[4{,}2 \times \ln \left(\frac{V \times C}{A \times t_d} \right) - 27{,}922 \right] \times \left(0{,}81 + 0{,}51 \times \frac{H}{100} \right) \quad (10)$$

$$E_{p,N} = 46{,}444 \times \left[9{,}41 \times \ln \left(\frac{V \times C}{A \times t_d} \right) - 62{,}76 \right] \times \left(1{,}68 - 1{,}79 \times \frac{H}{100} \right) \quad (11)$$

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

The total pressure-relief vent area for HFC-227ea can be calculated using Formulae (12) and (13):

$$A_P = 0{,}001\,30 \times \left(\frac{C}{t_d}\right) \times V \times \exp\left(\frac{-0{,}004\,97 \times L_{e,p,P}}{0{,}81 + 0{,}51 \times \frac{H}{100}}\right) \quad (12)$$

$$A_N = 0{,}001\,27 \times \left(\frac{C}{t_d}\right) \times V \times \exp\left(\frac{-0{,}002\,22 \times L_{e,p,N}}{1{,}68 - 1{,}79 \times \frac{H}{100}}\right) \quad (13)$$

7.8.4.4 HFC-23

7.8.4.4.1 HFC-23: Limits of applicability

$6 \text{ s} \leq t_d \leq 10 \text{ s}$

$18\ \% \leq C \leq 30\ \%$

$20\ \% \leq H \leq 80\ \%$

$L_{e,p,P} \leq 1\,400 \text{ Pa}$

7.8.4.4.2 Pressure excursion for HFC-23

The pressure excursion for HFC-23 can be calculated using Formula (14):

$$E_{p,P} = 0{,}088\,27 \times \left(\frac{A}{V} \times \frac{t_d}{C}\right)^{-1{,}165} \times \left(0{,}81 + 0{,}51 \times \frac{H}{100}\right) \quad (14)$$

7.8.4.4.3 Total pressure-relief vent area for HFC-23

The total pressure-relief vent area for HFC-23 can be calculated using Formula (15):

$$A_P = 0{,}123\,84 \times \left(\frac{C}{t_d}\right) \times V \times \left(\frac{L_{e,p,P}}{0{,}81 + 0{,}51 \times \frac{H}{100}}\right)^{-0{,}858\,7} \quad (15)$$

7.8.4.5 HFC-125

7.8.4.5.1 HFC-125: Limits of applicability

$6 \text{ s} \leq t_d \leq 10 \text{ s}$

$8{,}0\ \% \leq C \leq 10{,}5\ \%$

$20\ \% \leq H \leq 80\ \%$

$L_{e,p,P} \leq 480 \text{ Pa}$

$L_{e,p,N} \leq 480 \text{ Pa}$

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7.8.4.5.2 Pressure excursion for HFC-125

The pressure excursion for HFC-125 can be calculated using Formulae (16) and (17):

$$E_{p,P} = 0{,}045\,349 \times \left(\frac{A}{V} \times \frac{t_d}{C} \right)^{-1{,}037} \times \left(0{,}81 + 0{,}51 \times \frac{H}{100} \right) \quad (16)$$

$$E_{p,N} = 0{,}039\,49 \times \left(\frac{A}{V} \times \frac{t_d}{C} \right)^{-1{,}039} \times \left(1{,}68 - 1{,}79 \times \frac{\mathrm{H}}{100} \right) \quad (17)$$

7.8.4.5.3 Total vent area for HFC-125

The total vent area for HFC-125 can be calculated using Formulae (18) and (19):

$$A_P = 0{,}050 \times \left(\frac{C}{t_d} \right) \times V \times \left(\frac{L_{e,p,P}}{0{,}81 + 0{,}51 \times \frac{H}{100}} \right)^{-0{,}964} \quad (18)$$

$$A_N = 0{,}045\,89 \times \left(\frac{C}{t_d} \right) \times V \times \left(\frac{L_{e,p,N}}{1{,}68 - 1{,}79 \times \frac{H}{100}} \right)^{-0{,}9622} \quad (19)$$

7.8.4.6 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 % H 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).

$$E_{p,P} = 48{,}359 \times \left[4{,}2 \times \ln\left(\frac{V \times C}{A \times t_d} \right) - 27{,}922 \right] \times \left(0{,}81 + 0{,}51 \times \frac{H}{100} \right)$$

$$\begin{aligned} E_{p,P} &= 48{,}359 \times \left[4{,}2 \times \ln\left(\frac{125 \times 8{,}5}{0{,}042 \times 9{,}2} \right) - 27{,}922 \right] \times \left(0{,}81 + 0{,}51 \times \frac{50}{100} \right) \\ &= 48{,}359 \times [4{,}2 \times \ln(2750) - 27{,}922] \times (1{,}065) \\ &= 48{,}359 \times (5{,}339) \times (1{,}065) \\ &= +275\ \mathrm{Pa} \end{aligned}$$

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

$$E_{p,N} = 46{,}444 \times \left[9{,}41 \times \ln\left(\frac{V \times C}{A \times t_d} \right) - 62{,}76 \right] \times \left(1{,}68 + 1{,}79 \times \frac{H}{100} \right)$$

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$$E_{p,N} = 46{,}444 \times \left[9{,}41 \times \ln\left(\frac{125 \times 8{,}5}{0{,}042 \times 9{,}2} \right) - 62{,}76 \right] \times \left(1{,}68 + 1{,}79 \times \frac{50}{100} \right)$$
$$= 46{,}444 \times [9{,}41 \times \ln(2750) - 62{,}76] \times (0{,}785)$$
$$= 46{,}444 \times [9{,}41 \times (7{,}919) - 62{,}76] \times (0{,}785)$$
$$= 46{,}444 \times (11{,}758) \times (0{,}785)$$
$$= -429 \text{ Pa}$$

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

Protected enclosure	Volume = 7 500 m^3 Air-conditioned – 50 % *H* 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 $L_{e,p,P}$ should adhere; for HFC-227ea this limit is 380 Pa and so this is entered into the calculation even though the enclosure can withstand 500 Pa.

$$A_P = 0{,}001\,30 \times \left(\frac{C}{t_d} \right) \times V \times \exp\left(\frac{-0{,}004\,97 \times L_{e,p,P}}{0{,}81 + 0{,}51 \times \frac{H}{100}} \right)$$

$$A_P = 0{,}001\,30 \times \left(\frac{7{,}9}{9{,}6} \right) \times 7\,500 \times \exp\left(\frac{-0{,}004\,97 \times 380}{0{,}81 + 0{,}51 \times \frac{50}{100}} \right)$$
$$= 0{,}001\,30 \times (0{,}822\,9) \times 7\,500 \times exp \times (-1{,}773)$$
$$= 1{,}363 \text{ m}^2$$

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

$$A_N = 0{,}001\,27 \times \left(\frac{C}{t_d} \right) \times V \times \exp\left(\frac{-0{,}002\,22 \times L_{e,p,N}}{1{,}68 - 1{,}79 \times \frac{H}{100}} \right)$$

$$A_N = 0{,}001\,27 \times \left(\frac{7{,}9}{9{,}6} \right) \times 7\,500 \times \exp\left(\frac{-0{,}002\,22 \times 500}{1{,}68 - 1{,}79 \times \frac{50}{100}} \right)$$
$$= 0{,}001\,27 \times (0{,}822\,9) \times 7\,500 \times \exp(-1{,}414)$$
$$= 1{,}906 \text{ m}^2$$

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7.8.5 Leakage

When determining the overall pressure-relief vent area required, it has become common 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, however, this is not a common practice.

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

If enclosure leakage is to be used for pressure relief, an integrity test should be conducted with doors of adjacent rooms closed. The ELA from this test is used in the vent area calculations.

NOTE An integrity test is normally conducted with doors held open in adjacent rooms to the room under test to give a worse-case outcome for hold time 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 to vent to the atmosphere, the vents in the enclosure boundaries should be determined as follows (see Figure 7).

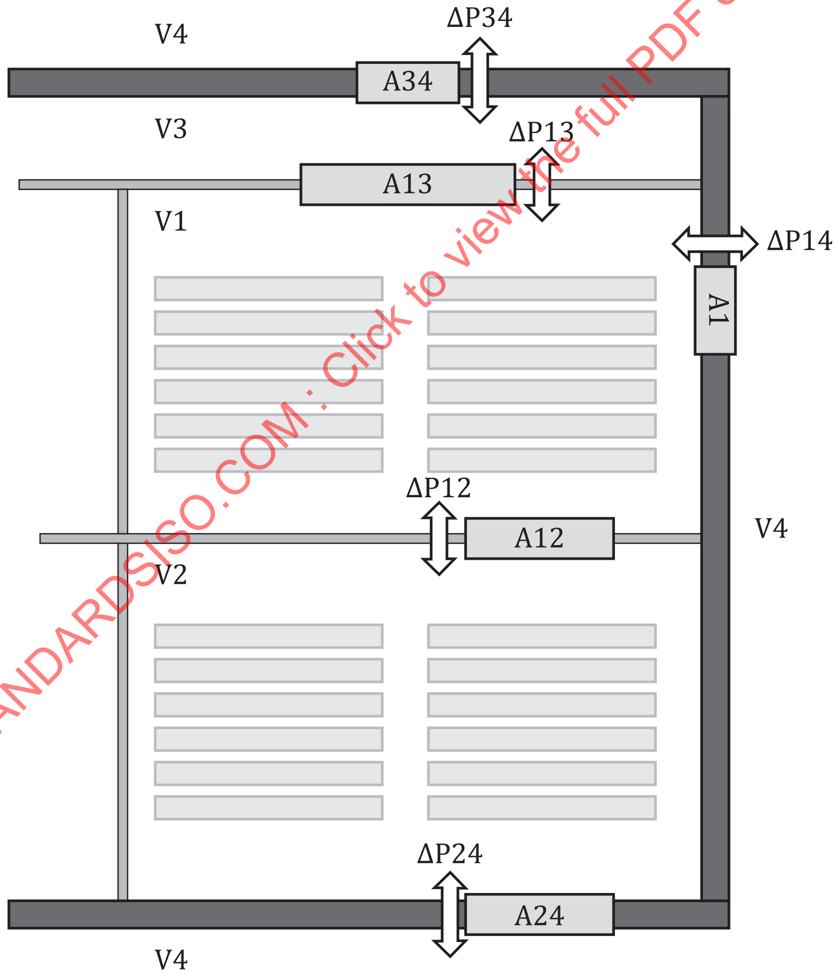

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Figure 7 — Cascade venting

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 the atmosphere.

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A1: free pressure-relief vent area if the protected enclosure vents 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 the 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 = $\sqrt{2}$ × A1. This is because, to achieve the same flow with only half the pressure differential, the area of each vent should be $\sqrt{2}$ × A1 when there are two vents in the flow path. Similarly, the area of each vent should be $\sqrt{3}$ × A1 if there are three equally-sized vents in the flow path, etc.

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: Cascade venting calculations for IG-541 (peak discharge)

Temperature	20 °C
V_A (IG-541)	0,70 m^3/kg
S_{AIR}	0,830 m^3/kg
C	40 %
V_H	0,781 m^3/kg
Enclosure 1	284 m^3
f_F	51 %
IG-541 quantity	204 kg
Peak flow rate	2,5 %
ΔP14 — maximum allowable pressure	500 Pa

Venting directly to the atmosphere (see 7.8.2):

$$A = \frac{M_{AGT} \times V_A}{\sqrt{P \times V_H}}$$

ΔP14 = 500 Pa

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$A1 = 0{,}025 \times 204 \times 0{,}70$

$\sqrt{(500 \times 0{,}781)}$

$A1 = 0{,}182\ m^2$

Cascade venting through adjacent enclosure V2 — Vent size optimized

$\Delta P12 = \Delta P23 = 250\ Pa$

$A12 = A24 = 0{,}025 \times 204 \times 0{,}70$

$\sqrt{(250 \times 0{,}781)}$

$A12 = A23 = 0{,}258\ m^2$; alternatively, A1 can be multiplied by $\sqrt{2}$ in this optimized condition.

Cascade venting through adjacent enclosure V3 — Minimizing size of vent in an outside wall (A34).

$\Delta P13 = 100\ Pa$

$\Delta P34 = 400\ Pa$

$A13 = 0{,}025 \times 204 \times 0{,}70$

$\sqrt{(100 \times 0{,}781)}$

$A13 = 0{,}407\ m^2$

$A34 = 0{,}025 \times 204 \times 0{,}70$

$\sqrt{(400 \times 0{,}781)}$

$A34 = 0{,}204\ m^2$

7.9.2 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.

If the secondary spaces the vent gas will pass through are also protected by their own independent fire protection systems, then consideration should be given to the potential for activation of those systems during the venting process. The route for cascade venting should not be through areas that form a means of escape nor to areas that are not of low fire risk.

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 pressure-relief vent area is calculated with a lateral wall strength of 250 Pa. The intermediate pressure through the flow path is 125 Pa. To allow for this, the pressure-relief vent area calculation needs to be made on 125 Pa to achieve a 250 Pa maximum differential. When calculating pressure losses through ducts pressure loss will change with flows that change with the pressure-relief vent area; 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 the atmosphere. The vent from Area 1 to Area 2, via a pre-opened vent, i.e. electric or pneumatic, to the atmosphere.

2) Protected Area 1 to Protected Area 2 to any further protected area(s) to the atmosphere. The vent from Area 1 to Area 2, and then via pre-opened vents through any further protected area(s) and then to atmosphere.

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3) Protected Area 1 to the atmosphere via ductwork. Ductwork and vents will need to be sized in accordance with maximum lateral pressure and flow requirements.

7.9.3 Venting into adjacent enclosures

7.9.3.1 General

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 for the volume of the adjacent enclosure to be 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 firefighting 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 the flow of gas into or out of V_1 during a system discharge, then V_2 will also require pressure relief.

The following subclauses provide guidance on how to determine the minimum size of V_2 such that pressure relief on V_2 is not required.

7.9.3.2 Over-pressurization: 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 firefighting agents, the minimum size of an adjacent volume V_2, for over-pressurization can therefore be determined by using Formula (20):

$$V_2 \geq \left(\frac{f_F \times V_1 \times 101\,325}{L_{e,p,P}} \right) - V_1 \tag{20}$$

where

f_F is the flooding factor (m^3/m^3, see EN 15004);

$L_{e,p,P}$ is the lower of the positive enclosure pressure limits (in Pa) for V_1 and V_2.

The free pressure-relief vent area between V_1 and V_2 should be calculated as a cascade vent arrangement as described in 7.9.2.

7.9.3.3 Under-pressurization: determination of adjacent enclosure volume

For gaseous firefighting 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 using Formula (21):

$$V_2 \geq \frac{101\,325 \times A_N \times \sqrt{E_{p,N(V1)} \times S_{AIR}}}{L_{e,p,N(V2)}} \times \frac{t_d}{2} \tag{21}$$

where

A_N is the free pressure-relief vent area (m^2) between V_1 and V_2 based on a cascade arrangement (see 7.9.2);

$E_{p,N(V1)}$ is the negative pressure excursion in V_1 (Pa);

$L_{e,p,N(V2)}$ is the negative enclosure pressure limit for V_2 (Pa).

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7.9.3.4 Example calculation 4

A 248 m^3 enclosure with a positive pressure limit of 500 Pa is protected with an IG-55 inert gas suppression system with an applied design concentration of 46 vol. % at 20 °C (flooding factor — 0,605 7 m^3/m^3):

$$Q_R = \left(\frac{S_R}{S}\right) \times \ln\left(\frac{100}{100-C}\right) = \left(\frac{0{,}696\ 04}{0{,}708\ 12}\right)$$

The over-pressure from this enclosure is to be vented into an adjacent enclosure of 20 000 m^3 with a positive pressure limit of 400 Pa.

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

The free pressure-relief vent area required between the protected area and the adjacent enclosure should be determined under the basis of cascade venting using Formula (20):

$$V_2 \geq \left(\frac{0{,}6057 \times 101\,325 \times 248}{400}\right) - 248$$

$$\geq 37{,}803\ \text{m}^3$$

where V_2 is the minimum volume of adjacent enclosure (m^3).

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.

7.9.3.5 Example calculation 5

An HFC-227ea extinguishing system has been employed to protect a 248 m^3 enclosure with a pressure limit of ±500 Pa at a design concentration of 8,0 vol. % at 20 °C and a discharge time of 9,5 s. The flooding factor is 0,633 5 kg/m^3 multiplied by specific vapour volume at 20 °C of 0,137 4 = 0,087 m^3/m^3. 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 pressure-relief vent area for the negative pressure excursion at 250 Pa is 0,131 m^2 [using Formula (8) and 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 Formula (20) for the over-pressure calculation:

$$V_2 \geq \left(\frac{0{,}087 \times 101\,325 \times 248}{500}\right) - 248$$

$$\geq 4{,}124\ \text{m}^3$$

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

Using Formula (21) for the under-pressure calculation:

$$V_2 \geq \frac{101\,325 \times 0{,}131 \times \sqrt{250 \times 0{,}831}}{500} \times \frac{9{,}5}{2}$$

$$\geq 1{,}817\ \text{m}^3$$

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

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8 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 (in accordance with 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.

In some countries post-discharge ventilation or "purging" systems are required by the relevant authority. Presently, there is not a published International Standard for the design and implementation of post-discharge purge systems. The specifics are typically left to the mechanical engineer of record or general contractor. A post-discharge purge system should be independently ducted and vented to the exterior of the building in a manner that will not cause an additional hazard to personnel and property outside of the building. Do not purge the post-discharge atmosphere using facility ventilation systems intended for heating, ventilating and air-conditioning (HVAC) use. Post-discharge purge systems are designed utilizing forced-draft ventilation activated manually by the municipal fire department, or other authorized personnel, from outside of the protected hazard. Some purge systems incorporate post-discharge time delays that prohibit the operation of the exhaust system until a set agent soak time is achieved. As most clean agents are heavier than air, purge system inlet registers are located low in the hazard.

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9 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.

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

Periodic inspection of installed pressure vents is essential to ensuring protection of the enclosure and the ability to retain the extinguishing atmosphere within for the required hold time. As a minimum, visual and functional verifications should be made every six months. A full-function test should be

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performed in conjunction with any connected building management or agent releasing systems. Where pre- and post-discharge time delays are utilized to open and close dampers, recorded operating times should be compared to that of the system's sequence of operations and commissioning records. A visual inspection should be performed to ensure that both sides of the vent are free from permanent or temporary obstructions and free to open and close in the directions for which it was designed.

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Annex A
(informative)

Development of agent-specific formulae for liquefiable gases

A.1 General

This annex describes the tests which were completed to provide the empirical data used in the formulae given in this document to estimate pressure excursions during the discharge of liquefiable gases (see 7.8.3).

A.2 Principle

The extinguishing agent was discharged into an enclosure having a known pressure relief vent area. The differential pressure across the boundaries of the enclosure was measured during the agent discharge. The peak pressure excursion, positive and negative, was measured for each agent discharge

Multiple tests were run with various pressure relief vent areas. The peak pressures versus ratios of pressure relief area to enclosure volume (A/V) were plotted.

NOTE The quantity "A" is the equivalent leakage area (ELA) in cm^2 measured for the enclosure as described elsewhere in this annex. "V" is the volume of the test enclosure in m^3.

The formulae provided in subclause 7.8.3 of this document are curve fits with the plotted data normalized to a 10 s discharge time.

Example plots for FK 5-1-12 are shown in Figure A.1 and A.2.

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