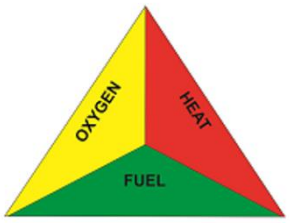
Loss Prevention Standards

Gaseous Fire Extinguishing Systems

Introduction

In simple terms fire needs three elements to be present for it to be sustained and these are:

- Heat/ignition source
- Oxygen
- Fuel



This is often referred to as the fire triangle or combustion triangle.

The earth's atmosphere normally contains approximately 21% oxygen, 78% nitrogen, and 1% other gases (by volume), principally argon. To sustain flaming combustion, the oxygen level in the atmosphere must be at least 15%; for smoldering combustion this can reduce to around 3% oxygen.

The minimum oxygen concentration in the air permissible for human breathing is 19.5%. However, humans in good health and fitness can generally survive for a period on as low as 12% oxygen (with some side effects) and for a time as low as 8%.

Gaseous extinguishing systems are designed to extinguish a fire by:

- Reducing the oxygen concentration (displacement or substitution)
- Interrupting the chemical decomposition reaction mechanism, that is fire
- Reducing the temperature of the fire/fuel to a point where fire can no longer continue. Of the three mechanisms this provides much less of an impact than the other two and significantly less than water-based fire suppression or extinguishing systems. This is primarily associated with high-pressure carbon dioxide systems

There are various types of gaseous extinguishing systems available with different extinguishing mechanisms, therefore it is important to discuss the nature of a proposed installation with your Insurance or Risk Management providers.

Gaseous fire extinguishing systems are usually either inert or chemically based. Typically, they are normally designed to protect areas where there may be an enhanced business concern or fire risk or where there may be concerns around the deployment of extinguishing water (understanding in a fire, most manual fire-fighting activities will use water).

Typical examples include:

Control rooms & within control cabinets	Electrical substations & generators
Computer data rooms/halls	Engine compartments, test cells', etc.
Data/tape & film stores	Industrial ovens & oil quench tanks
Archive & document stores	Printing presses, dip tanks & paint spray booths

Risk Assessment

The area to be protected should be risk assessed by a specialist to assess if gaseous extinguishment protection is required and what would be the most appropriate extinguishing media/mechanism.

It is recommended that your Insurance/Risk Management advisers and Insurers are consulted as part of this assessment.

System Design

Gas extinguishing systems can be designed as total/full flooding systems or as localised/spot protection systems and based on deep seated or surface fires.

Total/full flooding systems are designed to discharge into an enclosure or room. The system design is for a predetermined gas concentration level to be achieved within the enclosure, within a given time from discharge for a set time frame. The nature of this coverage and concentration profile is dependent on the type of extinguishing gas used.

The gas concentration must remain in the room for long enough, without a significant loss of concentration, to extinguish the fire and hopefully prevent reignition. Typically, the gas is held for at least 10 minutes (up to 60 minutes for some gases in certain circumstances), therefore the enclosure must be appropriately sealed, or the gas discharge time/stored volume managed to maintain this requirement.

Note: With some gases, sealing an enclosure can also increase the exposure of over-pressurisation upon gas discharge. This needs careful management.

Local or spot protection is used to protect a specific hazard or piece of equipment. The design takes into consideration the physical arrangements and discharges of a volume of gas over a period, to maintain a concentration of the gas or displace ambient air to an appropriate level, to extinguish a fire and hopefully prevent re-ignition.

Note: Historically and generally, Carbon Dioxide is the main extinguishing gas used for local protection systems.

Extinguishing Gases

Examples of gases typically used as extinguishing agents are:

Carbon Dioxide (CO_2) is a naturally occurring gas; a by-product of air separation and manufacturing processes and is relatively cheap to produce. It is a non-conductive, colourless and odourless gas which is a heavier than air. Protection systems can come in both low-pressure bulk systems and as cylindered high-pressure systems.

National Fire Protection Association (NFPA) standard 12 requires a minimum soak period of at least 20 minutes for some deep-seated fires. For other areas this can be increased to at least 30 or 60 minutes.

CO_2 makes up 390 ppm of the Earth's atmosphere (approximately 0.04% by volume). The Occupational Safety and Health Administration's (OSHA) maximum safe level is 3% (30,000 ppm); lethal concentration (death in 30 minutes) is 10% (100,000 ppm).

To effectively extinguish a fire, CO_2 requires high levels of concentrations to be discharged, normally between 30% and 50% concentration, and sometimes up to 75% in the most extreme situations. At any of these levels, this is lethal to life and therefore CO_2 is generally used to protect unoccupied areas.

For life safety considerations, attention needs to be given to gas discharge; gas flow and potential sneak paths; gas evacuation/ventilation after an event, etc. Whenever proposed or used, it requires careful risk assessment and all employees to be suitably trained and made aware of the risks associated with CO_2.

Inert gases are naturally occurring and include:

Argonite (IG55) has a mix of 50% Argon (IG01) and 50% Nitrogen (IG100). The gas is non-corrosive, non-conductive, colourless, odourless and tasteless and is stored as a compressed high-pressurised gas. Typically, the design concentration of this gas within a room/enclosure is between 37.9% and 42.7%.

Inergen (IG541) which is the trade name, is a mix of three inert gases normally around 52% Nitrogen, 40% Argon and 8% CO_2. The gas is colourless, odourless, electrically non-conductive and is similarly stored as IG55. Typically, the design concentration of this gas within a room/enclosure is between 34.2% and 38.5%.

IG100 is 100% Nitrogen which is naturally present in the atmosphere. It is chemically non-conductive, colourless, odourless and tasteless and similarly stored as IG55.

Chemical agents include:
HFC227ea – trade name is **FM-200** which is a synthetic gas made from a mix of chemicals that are odourless, colourless, non-conductive and is similarly stored as IG55. Typically, the design concentration of this gas within a room/enclosure is between 6.7% and 7%.

FK-5-1-12 – trade name is **Novec 1230** or dodecafluoro-2-methyl pentan-3-one - $CF_3CF_2C(O)CF(CF_3)_2$. It is colourless and odourless and electrically non-conductive. Typically, the design concentration of this gas within a room/enclosure is between 4.5% and 4.7%.

HFC-125 – Pentafluoroethane CF_3CHF_2 is a mix of carbon, fluorine and hydrogen. HFC-125 is odourless, colourless, non-conductive and is similarly stored as IG55. Typically, the design concentration of this gas within a room/enclosure is between 8.7% and 9%.

Over-Pressurisation

As total/full flooding designed systems are based on an enclosure holding the extinguishing gas for a given time and most systems are designed on a high-pressure basis, when the gas is released this increased pressure is realised within the protected enclosure. This is dependent on the type of gas used, the stored pressure, the release rate and discharge requirements, and required hold time. As a result, and to protect the enclosure, it is possible that pressure relief or over-pressurisation vents may be needed. These need to be designed and installed in a way to protect the room and/or equipment from the high-pressures, maintain the design basis of the system and not create any additional exposures to life safety.

Note: False ceiling tiles may need to be fixed to prevent movement caused by room pressurisation.

Enclosure Integrity (Door Fan Test) and Gas Hold Time

It is important with total/full flooding systems to maintain the enclosure's integrity and to ensure the correct gas concentration is held for the designed amount of time. The actual time needed to be held is based on the occupancy, the nature of the fire and the gas being used. This differs for each arrangement.

As part of the ISO 14520, NFPA and BFPSA Codes of Practice for Gaseous Fire-Fighting Systems, integrity testing should be undertaken in a protected area, to determine whether leakage could impact upon the extinguishant performance. This should be completed when the system is first installed and then regularly as part of the routine maintenance, i.e. once a year. A completion certificate should be issued and posted to indicate the date tested and the hold time achieved.

In addition, testing should also be completed following any enclosure changes as part of the Management of Change process.

Piping Acceptance Tests

While each code of design and installation will have their own requirements for piping system acceptance tests, the following minimum practices should be adhered to:

- Pneumatic testing to 150% of the expected pressure in the system
- If possible, full agent discharge and concentration testing across the protected enclosure

Note: In many instances pipe fittings have failed during discharge acceptance tests or in a fire situation. This was primarily due to the piping network only being tested with a 'puff' test and not a pressure test.

Spare Cylinders, Connected Reserve and Double Shot

Ideally, regardless of the design philosophy, when a gaseous extinguishing system is installed it should incorporate a spare set of fully charged cylinders with the required volume for the protected enclosure. This may be commonly known as a 'double shot'. If this is not provided and only a single volume of gas is provided this is commonly called a 'single shot'.

Preferably, this should be designed as a connected reserve with a pipework header arrangement and automatic change-over solenoid diverter valves. There are many benefits to this, such as:

- If there is a fire and it is extinguished by the discharge of the primary set of cylinders, there is no impairment of the fire protection system. It will instantly remain active and provide protection to the enclosure, providing assurance to continue operational activities with a live protection system. There is no need to wait for new cylinders to be delivered and installed
- Due to the nature of gaseous extinguishing systems; the hold time; compromises in compartment integrity and the provision or not of appropriate interlocks; once the extinguishing media falls below its design concentration, the root cause of the fire may still exist and any latent faults, energised equipment or hot surfaces may still present a fire exposure. As a result, the fire may re-ignite/re-flash. A connected reserve ensures a more robust system

Storage Cylinder Pressure Testing

Dependent on the country and local statutory safety regulations, storage cylinders will require safety inspection and testing to be completed and certificated. The frequency of this can vary but for good loss prevention practices a minimum of 10 years return frequency is recommended. Prior to this occurring it is important to discuss this with your Insurers and any local authorities.

Prior to any cylinders being removed, full replacement cylinders with the correct volume of extinguishing agent will need to be installed. Cylinders should not be removed for testing, unless spare replacement cylinders with 100% of the required gas volume are on site ready to be installed.

Operation and Activation

Regardless of the design philosophy gaseous extinguishing systems should be activated:

- Automatically
- And/or manually

There are various methods used to automatically activate these systems, such as:

- Automatic fire detection
- Temperature probes
- Temperature fusible link or frangible bulb

Ideally automatic activation should be by the action of a single fire detection device. However, to avoid 'unwanted or accidental' release of the gaseous extinguishing agent, particularly when the room may be occupied, activation may be two-stage (double knock) timed activation using two different detection devices.

If a double knock system is proposed, this should be via activation of any two devices in the protected enclosure. The zoning of a number of devices and the activation based on two zones activating should be avoided. In this instance an impairment to one of the zones may render the automatic actuation also impaired.

Interlocks

Prior to the agent discharging, consideration should be given to what is interlocked to shut down to ensure fire extinguishment is maximised and fire re-flash is minimised. This should be based on the design philosophy of the system; the volume of agent stored over what is required; the hold time; etc.:

- Ventilation in the protected enclosure and consider in areas adjacent
    - Even if the ventilation is recirculating, this impacts concentration profile
- Power and natural gas supplies
- Operating equipment
- Fire doors, dampers, etc.

Consideration should be given to providing interlocks, so any operational equipment protected by a gas system cannot operate unless the fire suppression system is in the automatic position. If the room is occupied, gas discharge 'hold-off' buttons are sometimes provided inside the protected enclosure. This can be operated by individuals in the enclosure who may be unable to leave or are investigating the cause of the alarm and will provide a time delay or time reset to the agent discharge.

Time delays are sometimes employed between automatic activation and the agent discharging. Care should be taken to ensure this delay is kept as small as possible and is consistent with the risk.

Regardless of automatic activation, manual activation capability should be provided in at least two 'safe' areas outside of the protected space.

Alarms

Aside from the automatic fire detection associated with the system actuation, the following alarms should be provided for such systems and connected to a constantly attended location:

- System out of automatic
- System trouble/fault
- Agent discharge

Control Panel Key Management

An area of vulnerability that is not managed as required at many locations is the key associated with the system control panel. In many instances this is left in the panel, so the system can be switched from automatic to manual or to isolate/off. This is not acceptable as the key should never be left in the panel and should be part of a formal key management procedure.

Training

As with all machinery and equipment, particularly fire protection systems, it is important that management supervisors and operational staff are suitably trained with a good understanding of any hazards, safety systems and operation of the system. Documented evidence in the use and operation of the gaseous extinguishing system, together with daily toolbox talks and regular refresher training should also be provided.

Inspections/Maintenance

Gaseous extinguishing cylinders need to be inspected at least weekly to ensure the pressure gauge readings indicate that the cylinders are correctly charged.

It is essential that the system is regularly inspected, maintained and tested. This should be at least annually and/or in accordance with the manufacturer's recommendations. In addition, at least annually the following should be formally confirmed:

- Automatic actuation mechanism
- Automatic and manual discharge mechanism (completed with the cylinders disconnected to prevent agent discharge)
- All the alarms associated with the system
- The interlocks/cause & effect

Emergency Response Plan and Team

Any on-site Emergency Response Plan and responding team should incorporate all such systems in their activities.

Understanding the systems; if manual activation is required who is empowered or responsible to activate them; the implications on safety of agent discharge, etc. are all issues that need to be addressed with appropriate training.

Other Issues

Generally, where gas protection is provided then the following should be considered:

- Treat any protected enclosure as a 'sterile' area, aside from the operating equipment, e.g. kept clear of all ordinary combustible materials
    - If required, items should be kept to an absolute minimum and stored in normally closed/locked metal cabinets
    - Routine housekeeping inspections should be completed to enforce this
- Consider how any residual gas will be exhausted from the building after the fire event has finished

Managing Change

With experience, Aviva witnesses many protected enclosures compromised by changes to the enclosure, e.g. cable or pipe penetrations, ventilation systems, doors, floor or ceiling voids, etc. Whenever there is any work proposed in a protected enclosure, then it should also include returning the enclosure to its original state and repeating the room integrity/door fan test, all of which should be carefully managed.

Checklist

A generic Gaseous Fire Extinguishing Systems Checklist is presented in Appendix 1 which can be tailored to your own organisation.

Additional Information

- National Fire Protection Association 12 - Standard on Carbon Dioxide Extinguishing Systems
- National Fire Protection Association 2001 - Standard on Clean Agent Fire Extinguishing Systems
- BS EN 15004: Fixed firefighting systems - Gas extinguishing systems
- BS 7273 -1:2006 Code of Practice for the operation of fire protection measures. Electrical actuation of gaseous total flooding extinguishing systems
- BS 6266:2011 Code of Practice for the Fire Protection for Electronic Equipment Installations
- Health and Safety Executive (HSE) - General Hazards of Carbon Dioxide
  http://www.hse.gov.uk/carboncapture/carbondioxide.htm

Further risk management information can be obtained from Aviva Risk Management Solutions

Please Note
This document contains general information and guidance and is not and should not be relied on as specific advice. The document may not cover every risk, exposure or hazard that may arise and Aviva recommend that you obtain specific advice relevant to the circumstances. AVIVA accepts no responsibility or liability towards any person who may rely upon this document.

Appendix 1 – Gaseous Fire Extinguishing Systems Checklist

Location	
Date	
Completed by (name and signature)	

	Gaseous Fire Extinguishing Systems	Y/N	Comments
1.	Has a risk assessment for the protected area(s) been completed?		
2.	Do you understand the number of systems you have?		
3.	Do you understand the design philosophy of any systems? • Total flooding? • Local? • Single shot? • Connected reserve/double shot?		
4.	Do you understand the extinguishing media and any implications to life safety?		
5.	Do you understand the automatic actuation mechanism of any systems? • Single knock (1 alarming device)? • Double knock (2 alarming devices)? • Time delay from alarm to agent discharge? ○ What is this time delay?		
6.	Are at least two 'safely' located manual actuation devices provided for any systems?		
7.	Aside from any fire alarms, have the following alarms been provided and connected to a constantly attended location: • Out of automatic? • System trouble/fault? • Agent discharge?		
8.	Are any agent gas discharge 'hold off' buttons provided? Are these clearly signed and located in safe locations or adjacent to any exit doors?		
9.	Do you have a key management system for the system panel? Is the panel key normally removed from the control panel? Is the gas system normally kept in automatic mode when the room is unoccupied?		

	Gaseous Fire Extinguishing Systems Contd.	Y/N	Comments
10.	Are there any interlocks so any operational equipment protected by a gas system cannot operate unless the fire suppression system is in the automatic position?		
11.	Are there appropriate interlocks to the gas system so the following shut down before the gas discharges: • Ventilation in the protected enclosure (and consider in areas adjacent)? • Power and natural gas supplies? • Operating equipment? • Fire doors, dampers, etc?		
12.	Has the gaseous extinguishing system(s) been fully commissioned and left operational? • Has the piping been pressure tested? • Has the system been discharge tested?		
13.	For total flooding systems, has the protected enclosure been integrity tested (door fan test)? Is an up to date certificate provided with test date and hold time indicated?		
14.	Does the protected area require any pressure relief vent(s)? If so, are these provided clear of obstructions on both sides of the wall? Does it discharge to a safe area?		
15.	Since the installation of the gas system has the room been altered in any way: • Equipment or occupancy? • Walls or doors? • Ventilation? • Replaced or added new cables, pipes, etc.? • Has the design basis for the protection been revisited to ensure it is not compromised by any changes? • Has a room integrity/door fan test been recompleted?		
16.	Is the protected area regularly inspected as part of routine housekeeping audits?		
17.	Aside from the operational equipment/process, is the protected enclosure sterile? If not, are all combustible items kept to a minimum and stored in a normally closed and locked metal cabinet?		
18.	Is the protected area kept secured with entry restricted to authorised persons?		
19.	Are all entry/exit doors into the protected enclosure fitted with automatically closing and latching doors? If required to be kept normally open, are doors held open on self-closing devices interlocked to the system, so they close and latch prior to agent discharge?		

	Gaseous Fire Extinguishing Systems Contd.	Y/N	Comments
20.	For any in-cabinet or local protection systems, are all equipment enclosure panels in place with no unnecessary openings that may allow the extinguishing gas to escape?		
21.	Are the system pressure gauges visually checked and recorded at least weekly? Are any gas cylinders correctly charged to full, i.e. within the gauge green zone?		
22.	Is the gas system inspected, maintained and tested in accordance with the manufacturer's recommendations? Does this include at least annual tests of all: • Fire detection devices? • Discharge mechanisms? • Interlocks? • System alarms?		
23.	Are any pressure cylinders tested at least every 10 years?		
24.	Is there an Emergency Response Plan and trained Emergency Response Team that: • Can quickly respond to an alarm? • Fully understands the functionality of the gas suppression system?		
25.	Where needed are floor tile lifting devices provided in the room to safely access floor voids?		
26.	Are appropriate clean agent portable fire extinguishers provided near to the entrance of the protected room or area?		
27.	Additional comments:		