POLLUTION PREVENTION FACT SHEET

Pollution Prevention Program - Federal Programs Division

Fact Sheet #14: Alternatives to Halon & Other Halocarbon Fire Extinguishing Agents

This Pollution Prevention Fact Sheet is one in a continuing series prepared under the Pollution Prevention Program of the Federal Programs Division of Environment Canada, Ontario Region. This Program is intended to help federal organizations in Ontario become model environmental citizens by managing beyond compliance. This Fact Sheet describes:

- Fixed fire extinguishing systems;
- Fire classifications;
- Halocarbon fire extinguishing agents; and
- New & innovative halocarbon-free fire extinguishing agents.

This P2 Fact Sheet provides an overview of both halocarbon-based and innovative halocarbon-free fire extinguishing agents for fixed fire extinguishing systems. Please consult with fire protection experts to ensure that any replacement extinguishing agents and systems fulfill your fire protection needs.

Fixed Fire Extinguishing Systems

A total flooding, fixed fire extinguishing system (FES), is a fire protection system which is integrated into a building, other structure or a means of transport. Both fixed and portable FES which contain halocarbons (such as halons) are subject to the *Federal Halocarbon Regulations* under the *Canadian Environmental Protection Act, 1999*.

Fixed FES may be actuated manually (by release buttons) or automatically (by fire detection systems). Fire extinguishing agents such as water, halocarbons, inert gases, aerosols and dry chemicals are employed in total flooding systems. Ideal agents are effective, fast-acting, electrically non-conducting, economical and “clean”. “Clean Agents” are defined as non-toxic substances that do not harm or damage the people or contents of a protected space and do not leave a residue after discharge. Unfortunately, many existing agents are not considered ideal. For example, conventional sprinkler systems can cause extensive water damage, while powdered aerosols, dry chemicals and foams can leave a chemical residue.

Furthermore, halocarbons may break down to corrosive gases (e.g. hydrogen fluoride) before extinguishing a fire. This presents a potential hazard to human health in addition to the immediate danger and hazard of the fire.

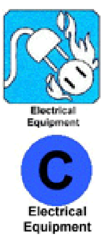
Figure 1: Total Flooding System in Operation

Types of Fires

A fire is classified according to the type of material that is burning:

Class A fires involve fuels that generate an ash residue after combustion, such as paper, wood, cloth, rubber, and certain plastics. Class A fires are extinguished by halocarbon, dry chemical, foam, conventional water, and inert gas systems (including carbon dioxide).

Class B fires involve flammable and combustible liquids or gases such as gasoline, paint thinner, grease, lubricating oils, alcohols, propane or acetylene. Such fires are suspended in the vapour-air mixture over a liquid surface. Class B fires are extinguished by halocarbon, dry chemical, foam, inert gas (including carbon dioxide), and water mist systems.



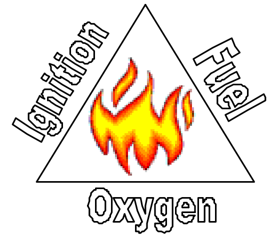
Class C fires involve "live" or energized electrical wiring or equipment (e.g. power outlets, panel boxes, motors, computers). In Class C fires, non-conducting agents are recommended. If electricity is removed from a burning electrical device, a Class C fire will shift to one of the other three fire types. Class C fires are extinguished by halocarbon, dry chemical, and inert gas systems (including carbon dioxide).

Class D fires involve the combustion of exotic metals (e.g. magnesium, sodium, titanium, lithium, zirconium, potassium) and certain organometallic compounds (e.g. alkyllithium and Grignard reagents). Class D fires are fairly uncommon and are usually only a concern to more specialized situations (e.g. airport crash rescue, nuclear plants, machining). Class D fires are extinguished by special dry chemicals, dry powders, foams and inert gas agents. Other extinguishing agents should not be used on Class D fires because of the associated danger of chemical reactions.

Fires can be categorized as a combination of different classes (e.g. a kitchen fire that involves the combustion of grease and paper is designated as a Class AB fire.

Figure 2: Total flooding systems are commonly used to protect flammable liquid storage areas

Fire Extinguishing Basics



A fire starts when three components come together, namely a fuel, oxygen and a source of ignition. One side of this "fire triangle" must be removed to prevent or extinguish a fire.

Halocarbon Fixed FES

Halocarbons are synthetic organic substances that contain a carbon-halogen chemical bond. The term 'halogen' includes fluorine, chlorine, bromine and iodine. Halocarbon total flooding systems are generally used to protect critical systems that are extremely costly and timely to repair. Examples include computer centers; ground combat vehicles; flammable liquid storerooms; fuel pump rooms; art and historical collections; communication centres; control rooms; shipboard propulsion machinery spaces; aircraft engine nacelles, cargo bays and dry bays; aircraft simulators and aircraft traffic control rooms. Types of halocarbons found in fixed FES include hydrobromofluorocarbons (HBFC - e.g. halon), hydrochlorofluorocarbons (HCFC), hydrofluorocarbons (HFC) and perfluorocarbons (PFC). Each of these classes of halocarbons is regulated under the *Federal Halocarbon Regulations*.

Halocarbons & Environmental Risk

Unfortunately, the release of halocarbons contribute to a number of global environmental problems, such as stratospheric ozone depletion and global warming (climate change). For this reason, it is important to choose fire extinguishing agents that do not contain halocarbons or to shift to less environmentally harmful agents where appropriate.

One can determine how harmful a halocarbon is after it enters the atmosphere by examining its ozone depletion potential (ODP) and global warming potential (GWP). The ODP of a substance reflects its ability to cause ozone depletion relative to an equivalent amount of CFC-11. The GWP of a substance reflects its ability to cause global warming relative to an equivalent mass of carbon dioxide. For example, halon-1301 which has an ODP of 10 and a GWP of 6900 can deplete up to ten times as much stratospheric ozone as CFC-11 (ODP=1), and can cause 6900 times as much global warming as carbon dioxide (GWP=1). The associated environmental risks for various types of halocarbons commonly found in fixed FES are presented in Table 1. For additional information regarding the environmental risks of halocarbons refer to *P2 Factsheet #4: A Halocarbon Management Strategy for Federal Facilities.*

Table 1: Environmental Risk of Halocarbons used in Fixed Total Flooding FES [1]

Trade Name(s)	Extinguishing Agent	ODP	GWP	Atmospheric Life (years)
Agents for Occupied Areas				
BTM	Halon-1301	10	6900	110
NAF S-III	R-595 Blend (HCFC Blend A)	0.05	1600	16
FE-13	HFC-23	0	12100	250
CEA-308	PFC-218	0	8600	>2000
CEA-410	FC-3-1-10, PFC-410	0	5500	2600
FM-200, R-227	HFC-227ea	0	3300	41
Agents for Unoccupied Areas Only				
Trade Name	**Generic Name**	**ODP**	**GWP**	**Atmospheric Life (years)**
Triodide	CF3I	0.008	<1	1.15
FE-24	HCFC-124	0.02	620	5.9
FE-25	HFC-125	0	3800	36
FE-36	HFC-236fa	0	9400	250

1 Values for ozone depletion potential (ODP) and global warming potential (GWP) are taken from various international sources, some of which report different values. The highest value encountered has been included in Table 1.

Regulations Applying to Halocarbons

Actual fire fighting and explosion suppression account for a very small portion of all fire protection-related halocarbon releases. Most halocarbon releases from FES occur due to accidental or deliberate discharges that can be attributed to system malfunctions, system testing, poor equipment maintenance and servicing procedures, and the extinguishing of test fires.

The Montreal Protocol, an international agreement for the protection of the ozone layer, prescribes restrictions on the use and production of ozone depleting substances in an effort to minimize releases. The availability of halons and HCFCs are affected by this Protocol.

The Kyoto Protocol, is an international agreement that targets the reduction of greenhouse gas emissions, which contribute to global climate change. Carbon dioxide, HFCs and PFCs are among these gases. Fire extinguishing agents are not exempted under this protocol.

In support of these agreements, Canada has implemented two federal regulations to control all stages of the halocarbon lifecycle (production, import, export, use).

The ***Federal Halocarbon Regulations*** target end-uses of halocarbons on federal and aboriginal lands and by federal works and undertakings (refrigeration, air conditioning, solvent and **fire extinguishing applications)**.

Equipment owners for these applications are subject to specific reporting, permit, installation, servicing, disposal and record-keeping requirements.

The FHR strictly prohibits:

- the release of halocarbons to extinguish fires deliberately caused for the purposes of training; and
- new installations of halon FES without a permit, which will only be granted if no viable alternatives exist.

The FHR also requires the reporting of releases of halocarbons in excess of 10 Kg to Environment Canada (see Compro #20: Federal Halocarbon Regulations).

The ***Ozone-depletion Substances Regulations*** (ODSR) target the manufacture, sale, offer for sale, import and export of ozone depleting substances and products containing ozone depleting substances throughout Canada. These Regulations do not specifically address end-uses such as fire extinguishing systems, however phase-out schedules for ozone-depleting substances will undoubtedly influence their future availability and cost.

Halon Production

Canada began importing Halons around 1965; they have never been produced in Canada. North American production of halons ceased in 1994. All halon currently available in Canada is from recycled stock.

More complete descriptions of the FHR and ODSR can be found in *COMPRO #20: Federal Halocarbon Regulations*. Also refer to *COMPRO #11: Ontario*

Regulations for Halon Fire Suppression Systems for a description of additional provincial requirements.

Properties of Halocarbon Agents

Halocarbon systems protect against Class A, Class B and Class C fires. In general, all halocarbons undergo a similar process to extinguish fires. As a halocarbon gas approaches a fire, it absorbs large amounts of heat energy from combustion and lowers surface temperatures of combustibles below the ignition point. During this process, they also release highly reactive halogen ions which combine with free hydrogen (a secondary fuel source) which is released during a hydrocarbon fire. The elimination of free hydrogen also helps to prevent the fire from spreading, in addition to cooling temperatures at the heat source.

The toxicity of a halocarbon fire extinguishing agent determines whether it is suitable for use in occupied areas (i.e. areas containing people) or solely in unoccupied areas (i.e. areas that do not contain people).

Hydrobromofluorocarbons: Halon-1301 has traditionally been viewed as the best available clean fire extinguishing agent for use in fixed FES (in Canada, Halon-1211 is used almost exclusively for streaming agents in portable FES). It was used extensively as a total flooding agent in fixed FES in North America. Halon-1301 is approved for use in occupied (and unoccupied) areas.

Many facilities have already replaced existing halon-1301 systems with more environmentally acceptable alternatives. Many of these replacements are also halocarbons that are linked to ozone depletion and global warming (see Table 1). Therefore, in time, these halocarbons will likely be subject to strict legislative controls (most halocarbon replacement agents should be viewed as temporary or interim replacements for halon).

There are no true "drop-in" replacements for halon-1301. Alternatives may require the installation of new chemical distribution systems (e.g. cylinders, piping, sprinkler heads) or require major modifications to an existing system.

Consideration should be given to the particular class of fire hazard when determining alternatives to halons. Like halon, each of these alternatives can be associated with specific strengths and weaknesses. For example, most replacements require a greater quantity of chemical to achieve the same fire fighting capability as halon-1301. This may be disadvantageous wherever weight and space is a constraint. In addition, some agents do not deplete stratospheric ozone, but are significant climate changing gases. Alternative halocarbon agents may also leave behind dangerous levels of acid residual when they contact fire.

HCFCs: Two hydrochlorofluorocarbons are currently marketed as clean alternatives for halon-1301. An HCFC-blend known as NAF S-III contains HCFC-22, HCFC-124, HCFC-123 and organic compounds in the following proportions: 82%, 9.5%, 4.75% and 3.75%. NAF S-III is used in both occupied and unoccupied spaces. FE-24 (HCFC-22) is toxic to human life and therefore is used only in unoccupied areas.

Although HCFCs generally have low ODPs (having little effect on ozone depletion), their high GWPs categorize them as strong climate changing gases. The ODSR, in concert with the Montreal Protocol, prescribe a phase-out schedule for HCFCs leading to a production and import ban in 2020. Like halons, HCFCs are also likely to undergo substantial price increases once availability becomes limited.

HFCs: Hydrofluorocarbon alternatives for halon-1301 include HFC-23, HFC-227ea, HFC-236fa and HFC-125. The HFC-23 (trifluoromethane) agent known as FE-13 requires a high pressure system for proper discharge and dispersion. FE-13 is viewed as an ideal agent where very rapid extinguishing is essential. It is used in both occupied and unoccupied spaces. HFC-227ea (trade name FM-200) and HFC-236fa (trade name FE-36) are used in both occupied and unoccupied areas. The HFC-125 (trade name FE-25) is toxic to human life and is therefore only permitted for used in unoccupied areas.

HFCs do not deplete ozone (i.e. ODP=0) but are known to have a long atmospheric life and a strong ability to contribute to climate change (i.e. high GWP). Therefore these agents should only be considered acceptable alternatives for halon-1301 where other alternatives are not technically feasible.

PFCs: Two types of perfluorocarbon alternatives exist for halon-1301. PFC-410 or FC-3-1-10 (trade name CEA-410) and PFC-218 (trade name CEA-308) are used in both occupied and unoccupied spaces.

Like HFCs, PFCs do not deplete ozone, but contribute to climate change. In fact, PFCs are associated with the highest GWPs of any halocarbon. Although no restrictions exist to prohibit or phase-out the use of PFCs in fire protection equipment, other alternatives should be considered wherever possible.

Powdered Aerosols: Different types of powdered aerosol systems include gelled halocarbon/dry chemical suspensions such as PGA. These extinguishing agents are not clean agents and may have varying degrees of environmental risk, depending on the halocarbon used in its formulation. These powdered aerosols are used to protect unoccupied areas.

Water-Based Systems

The most common water-based systems are roof-mounted sprinklers. These systems are time-tested, reliable and non-toxic. However, these systems are not effective in all types of fires. For example, in an oil fire a sprinkler system would not be suitable. One also has to be concerned about the potential for water damage.

There have been several innovations in water-based systems. In the past, organizations have been reluctant to use water with electronic equipment. Now there are system interlocks that shut down electrical equipment before the water is released. Once the fire is extinguished, one simply waits for the equipment to dry out.

Another innovation is the water mist fire suppression system. This works by releasing a fine water mist that, in contact with a heat source, turns to steam. The steam then displaces oxygen and the fire is extinguished. Water mist systems are discussed further below.

Carbon Dioxide

Carbon dioxide is a traditional fire extinguishing agent. It is a colourless, odourless, clean agent. It extinguishes a fire by displacing oxygen, making it unavailable for the combustion process. Carbon dioxide systems are not recommended for occupied spaces because the concentration of CO_2 used is toxic and may be fatal.

New & Innovative Technologies

Water mist and inert gases represent two categories of new and innovative halocarbon-free agents that are available for use in total flooding systems. Traditional installations such as water sprinklers, carbon dioxide systems, and chemical foam systems may also provide an adequate means of fire protection for particular situations.

Water Mists

The *1996 NFPA 750 - Standard on Water Mist Fire Protection Systems* sets a standard for the design and use of water mist technologies (NFPA is the National Fire Protection Association in the United States). NFPA defines water mist as "water spray for which 99% of the total volume of water is in droplets with a diameter less than 1000 microns at the minimum design operating pressure of the water mist nozzle." Water mist systems are usually installed to protect against Class B fires. They are generally not a recommended for use in areas where Class A, Class C or Class D fire protection is required.

Water mist is much more effective at extinguishing fires than conventional sprinkler systems because mists occupy a larger surface area per unit volume of water in comparison to the larger water droplets of sprinkler systems. Water mist extinguishes a fire by rapidly removing heat energy from a fire as it changes to water vapour. Mists scatter radiant heat and wet combustible surfaces to minimize the possibility of adjacent flammables from igniting. Water mist also displaces available oxygen as it expands approximately 1650 times at the base of a fire (i.e. as it changes from a liquid state to a vapour state - as steam).

Figure 3: Water Mist System

Fine water sprays use specially designed nozzles that combine air and water to generate a fine water mist, under low, medium or high pressures. The use of air to generate mist (versus small orifices), prevents nozzles from clogging. Some water mist systems can connect to facility water and air supplies, eliminating the need for water tanks, bottles and cylinders. Self-contained systems are available if existing water and air supplies are unavailable or unreliable. Each nozzle in a water mist system discharges approximately 4.9 L of water per minute, much less water than traditional water-spray systems. As a result, post-discharge water build-up and resultant damage after a fire is negligible and cleaning time is kept to a minimum.

Water mist systems are suitable for use in both occupied and unoccupied areas. Unlike many gaseous fire protection systems, water mists have also been proven effective in non-air tight spaces and enclosures. Water mist systems permit electrical equipment to continue operating without failure. The risk of electrical shock from electricity conducting through the mist is very low. Water mist helps to improve the quality of breathable air (and minimize the amount of smoke-related damage) during a fire event by "scrubbing" smoke and other combustion-related products from the air.

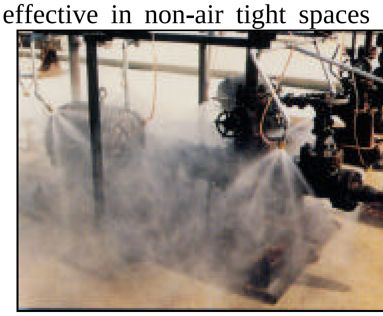


Figure 4: Water Mist System in Operation

Applications where water mist systems are commonly employed include gas turbines, diesel generators, transformer vaults, steam turbine bearings, fuel and lubricating oil tanks and pumps, oil filled electrical power equipment, oil cellars, flammable liquid storage, paint mixing and spray booths, internal combustion engine test cells, compressors, wet benches, machinery spaces, and sheet metal coating equipment. Fine water mist systems have also been installed on small boats and amphibious craft with small volume engine compartments. However, these systems tend to be less effective in large ship engine rooms with high overheads and numerous obstacles.

Inert Gases

Inert gases refer to noble gases (i.e. Group 8 elements of the Periodic Table) which are unreactive or only slightly reactive with other chemical substances. Fire extinguishing agents using the trade names Inergen, Argonite or Argon contain the noble gas argon in varying concentrations. Although carbon dioxide is sometimes referred to as an inert agent, it is not by strict definition (i.e. it is not a noble gas).

Composition of Inert Gas Fire Extinguishers

"Inergen" is composed of 52% nitrogen, 40% argon and 8% carbon dioxide. It is being used in both occupied and unoccupied areas.

"Argonite" is composed of 50% nitrogen and 50% argon. Argonite is used solely in unoccupied areas.

"Argon" is composed of 100% argon gas. It is only used in unoccupied areas.

Inert gases are colourless, odourless, non-corrosive clean agents that do not contribute to ozone depletion or climate change. Constituents of inert gases are extracted from the Earth's atmosphere. Although Inergen contains carbon dioxide, a global warming gas, Inergen's GWP is zero because this gas is simply being returned to the environment when released, (i.e. there is no net change in the amount of atmospheric carbon dioxide).

Inert gas systems extinguish a fire by reducing the oxygen content below the combustion level of most materials. Unlike Argonite and Argon (not used in occupied spaces), Inergen elevates room concentrations of carbon dioxide to help stimulate deep breathing in the human body to ensure acceptable levels of oxygen intake (low oxygen levels below may slow respiration to dangerous levels making it difficult for people to evacuate a burning room).

Figure 5: Inergen Storage Cylinders

In contrast to carbon dioxide, halon, some halon replacements, and water mist systems (that cool air and generate a fog that may impede evacuation procedures), inert gas systems do not impair visibility. Inert gases are generally used to combat Class A, Class B, Class C and sometimes Class D fires. Inert gas installations are often used to protect data processing centres, communication rooms, flight simulators, air traffic control centres, laboratories, power generating equipment, bank vaults, archives, and medical diagnostic rooms.

Recharge costs for inert gases are approximately 80% less than that for alternative halocarbon agents. However, larger amounts of inert gases are required to achieve the same level of fire protection as halon. For this reason, storage cylinders are generally larger and heavier. However, in building applications, cylinders can be positioned in remote areas that are more than 100 m away from the fire protected area. In other situations, where space or weight are critical and there is no opportunity for equipment displacement, specialized high pressure storage tanks, cylinders and piping can be used.

Further Sources of Information:

For additional information on regulations, ozone depletion, climate change and alternatives for halocarbon fire extinguishing agents, please see the following references:

Canadian Environmental Protection Act (CEPA), Federal Halocarbons Regulations, Canada Gazette, Part II, July 1999
Web site: *http://www.ec.gc.ca/ozone/tocregs.htm*

Canadian Environmental Protection Act (CEPA), Ozone-Depleting Substances Regulations, 1998, Canada Gazette, Part II, December 1998.
Web site: *http://www.ec.gc.ca/ozone/tocregs.htm*

Code of Practice on Halons, Report EPS 1/RA/3E, Environment Canada, July 1996.
Tel: (819) 997- 2800

Environment Canada Stratospheric Ozone Website
Information and links about the ozone layer and ODS.
Web site: *http://www.ec.gc.ca/ozone*

Environment Canada Climate Change Website
Web site: *http://www.ec.gc.ca/climate*

Pollution Prevention Fact Sheet #4: A Halocarbon Management Strategy for Federal Facilities. Federal Programs Division, Environmental Protection Branch, Environment Canada.
Website: *http://www.on.ec.gc.ca/epb/fpd*

COMPRO #11: Ontario Regulations for Halon Fire Suppression Systems. Federal Programs Division, Environmental Protection Branch, Environment Canada.
Website: *http://www.on.ec.gc.ca/epb/fpd*

COMPRO #20: Federal Halocarbon Regulations. Federal Programs Division, Environmental Protection Branch, Environment Canada.
Website: *http://www.on.ec.gc.ca/epb/fpd*

Environment Canada ODS Alternatives & Suppliers List
Web site:
http://www.ec.gc.ca/ozone/altlist/download/altliste.pdf

US Environmental Protection Agency - SNAP List
Lists of Substitutes for Ozone-Depleting Substances
Web site:
http://www.epa.gov/ozone/title6/snap/lists/index.html#halons

Ansul
Inergen Clean Systems Tel: 1-800-TO-ANSUL
Web site: *http://www.ansul.com*

Securiplex Inc. Fire-scope 2000 Fine Water Spray
Tel: (514) 633-1000
Web site: *http://www.securiplex.com*

Reliable Fire Equipment Company
Water Mist & Inergen Suppression Systems
Tel: 708-597-4600
Web site: *http://www.reliablefire.com*

Dupont
Fire Extinguishing Agent, Properties Data
Web site: *http://www.dupont.com/fire/techinfo/feprop.html*

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