MONTREAL PROTOCOL
ON SUBSTANCES THAT DEPLETE
THE OZONE LAYER

REPORT OF THE
HALONS TECHNICAL OPTIONS COMMITTEE
DECEMBER 2018

TECHNICAL NOTE #2 – REVISION 3
EMISSION REDUCTION STRATEGIES FOR HALONS AND OTHER HALOGENATED GASEOUS FIRE EXTINGUISHING AGENTS

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The opinions expressed are those of the Committee and do not necessarily reflect the views of any sponsoring or supporting organisations.

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Preface

Technical Note #2, *Emission Reduction Strategies for Halons and Other Halogenated Gaseous Fire Extinguishing Agents* replaces the chapters on this subject that have been part of previous Assessment Reports of the UNEP Halons Technical Options Committee (HTOC). Reports beginning with the 2014 Assessment Report contain an abbreviated chapter that briefly introduces the subject of *Emission Reduction Strategies* and refers the interested reader to this document. The HTOC elected to take this approach because much of the information, while important to understand when developing strategies for reducing emissions from halons, has largely been reported in prior editions of Assessment Reports. The *Halon Emission Reduction Strategies* chapter of each edition of past Assessment Reports contained important updates on evolving technologies and procedures, but the updates usually formed only a small portion of the chapter content. As such, it was decided by the HTOC to make the *Emissions Reductions Strategies* a stand-alone document for reference purposes. By this approach those having particular interest in the procedural and technical aspects of *Emissions Reductions Strategies* can access a self-contained document addressing those issues. One final note – the emission reduction strategies apply equally well to the gaseous halogenated fire extinguishing alternatives to halons. The HTOC encourages the readers of both the Assessment Reports and this document to integrate these strategies into their operations, policies, and guidelines when employing all halogenated gaseous fire extinguishing agents including halons, HCFCs, and HFCs. Likewise, the title of this Technical Note has been updated to *Emission Reduction Strategies for Halons and Other Halogenated Gaseous Fire Extinguishing Agents to* reflect the expanded scope.

1.0 Introduction

Releasing gaseous fire extinguishing agents into the atmosphere is fundamental to the process of flame extinction and enclosed space inerting. Historically, less than 5% of all halon emissions have been a result of using halons to extinguish fires. Therefore, these necessary emissions use only a small proportion of the available supply of the agent in any year. While most (it is presumed all) parties have discontinued system discharge testing and discharge of extinguishers for training purposes resulting in emission reductions in most cases of up to 90%, additional and significant reductions of emissions can be realised by improving maintenance procedures, detection and control devices, etc., as outlined in this Technical Note. While there are a number of halon alternatives now available, users are encouraged to minimize emissions from any gaseous halogenated fire extinguishing system for reasons of economics, safety, personnel exposure, and environmental impacts whether replacing an existing halon, hydrochlorofluorocarbon (HCFC) or hydrofluorocarbon (HFC) system or contemplating a new installation.

There are a number of non-technical actions that can be taken which have been shown to be equally important to the aforementioned technical actions. Non-technical steps include development of Codes of Conduct, implementing Awareness Campaigns, workshops, training, policies, and legislating regulations, and ensuring enforcement. Emissions reduction strategies can be a combination of responsible use and regulatory action.

Emission reduction strategies are discussed in detail in the ten following areas:

- Alternative Fire Protection Strategies
- Halogenated Fire Extinguishant Use Minimisation
- Maintenance Programs
- Detection Systems
- Hazard and Enclosure Review
- Personnel Training and Documentation
- Agent Transfers and Storage
- Discharging of Halons and Other Halogenated Gaseous Agents
- Awareness Campaigns and Policies
- Decommissioning, Transportation, and Destruction

2.0 Alternative Fire Protection Strategies

Fire Protection should be based upon three E's:

Engineering: Identify the risks, then apply good engineering principles in a system or facility design.

Education: Educate all organisations involved with the hazard being protected on the function, operation, and maintenance of the fire protection system.

Enforcement: Ensure all standards, codes, and national regulations are applied to the design, installation, operation, and maintenance of the fire protection method selected for the facility or hazard being protected.

Do not use halons in new fire protection applications or new designs of equipment. Alternatives are available for virtually all applications with very few exceptions, i.e., civil and some military aircraft. Alternatives for HCFCs and HFCs also exist but there are more applications where only the original halon or the HCFC or HFC will work, e.g., explosion suppression in cold climates and in crew spaces of armoured vehicles. See Chapter 3 of Volume 1 of the HTOC 2018 Assessment report and Technical Note 1 for more information on alternatives to halons, HCFCs and HFCs. Emissions typically can be reduced if gaseous halogenated agents are no longer employed as the fire extinguishant.

Good engineering practice dictates that, where possible, hazards should be designed out of facilities rather than simply providing protection against them. Active fire extinguishing systems using gaseous agents, should not be considered as the only alternatives. Based on a Risk Assessment, a combination of prevention, inherently safe design, minimisation of personnel exposure, passive protection, equipment duplication, detection, and manual intervention should be considered as follows:

1. Prevention

   Where there is a low probability of fire and that probability can be reduced to acceptable proportions by procedures and diligence, the need for other protection measures can be minimized. Where it is not possible to reduce the chance of fire/explosions sufficiently, then a combination of prevention and other measures such as sensitive fire/gas detection and manual intervention may be considered as acceptable protection.

2. Minimize Area of Protected Hazard

   The fire extinguishing system should be located specifically around the "*hazard being protected*" and the size of the hazard should be minimized. Isolate the hazard where feasible.

3. Review Available Technologies

   Review system and technologies, such as not-in-kind. Other technologies may be cheaper, more available, easier to maintain and still provide the same level of protection.

4. Review Facility / Operations Recovery Plans

   In some applications, automatic fire extinguishing is not necessary such as small telecom units that will be replaced under fire scenarios regardless of having an automatic system.

5. Evaluate the Hazard

   An evaluation of the hazard may indicate an automatic system is not needed in the main area. For example, the true hazard may be underfloor and obstructed in which case an injection, total flood or local application would be applied to the specific location and not to the entire room.

6. Central Bank with Directional Valves

   In total flooding applications with multiple rooms or enclosures near or adjacent to each other, consider installing a central bank of agent using detection coupled with directional valves.

7. Inherently Safe Design

   It may be possible to eliminate the need for protection by ensuring that either all the equipment in the area is not combustible, or that inventories are sufficiently small such that there is no immediate threat to life or vital equipment before evacuation of the area and manual intervention can take place.

8. Minimisation Of Personnel Exposure

   Where the only threat to life is within the protected area, the need to occupy the area may be minimised by the segregation of the hazardous equipment from the areas requiring access. Similarly, evacuation strategies and routes may be arranged to ensure that personnel can evacuate before a fire reaches a scale which can threaten life.

9. Passive Protection

   Vital equipment may be safeguarded with passive fire protection materials to ensure its survivability, or by location in a protective enclosure. This may not be possible where the inherent risks are within the equipment itself.

10. Equipment Duplication

    Vital equipment may be duplicated so that the loss of one item does not affect the system availability. However, since secondary equipment may also be exposed to hazards, duplication may not protect the total system from all hazards.

11. Detection

    Early detection could allow isolation and manual intervention before a fire reaches a size which can cause major damage or threaten life.

12. Manual Intervention

    Critical examination of the fire hazards may show that, where codes permit, a manual response is acceptable when trained fire teams can react within a short time.

Performing an overall Risk Assessment, taking into consideration fire protection strategies, allowable down time, backup equipment & documentation, backup services, etc., will help in determining the optimum fire protection strategy. A thorough analysis may also provide documentation necessary for obtaining insurance.

3.0 Halogenated Fire Extinguishant Use Minimisation

When protection against fire or explosion hazards with halon or other halogenated gaseous fire extinguishant is considered vital, the following practices should be observed to minimize the use of these systems, and thus reduce emissions potential:

1. Local Application

   Local application systems should be used where the primary fire hazards within an area can be identified and effective protection achieved with less agent than a total flood design would require.

2. Reserve Systems

   Reserve systems should only be installed when:

   - There is a confirmed immediate need to restore fire protection.
   - Recharge supplies are an unacceptable transport time away.

   If it is feasible to do so, consideration should be given to leaving reserve supplies unconnected, which can help avoid unwarranted release of the reserve supply. If possible, keep reserve agent in a single large storage tank to reduce the risk of accidental release and minimize the chance of leaking. Note, if the reserve agent is on site in a system of cylinders rather than a single large storage tank, then the chances of leaking and accidental discharge is increased by approximately the number of cylinders. Where there are no on-site capabilities for the storage and transfer of the agent, or a contractor nearby with the capabilities, then consideration should be given to placing all reserve cylinders in an enclosure closed with caps or plugs installed in the discharge connection and installing an automatic agent-appropriate leak detector with remote and/or local alarms or placing the cylinders on load cells and monitoring them for material loss. Alternate forms of leak detection include pressure or mass monitoring. Further loss prevention can be achieved by performing routine leak checks using suitable hand-held leak detectors.

3. Extended Discharge

   All possible means to maintain extinguishing concentration from an initial discharge, such as stopping air movement, closing openings, installing system-actuated dampers or shutters, etc., should be explored before considering an extended discharge. Extended discharge systems should be considered as a last resort as they normally require more agent than the initial discharge.

4. Zoned Systems

   Where it is technically feasible, protection of several separate zones by a single bank of agent using total or partial discharge should be considered.

4.0 Maintenance Programs

Adherence to maintenance programs can add years to a halon or other halogenated gaseous fire extinguishant banks by reducing emissions from leaks and discharges. This represents money saved in two ways. It minimizes the need to purchase new or recycled agent, and it prolongs the useful life of the existing fire protection system. Once emissions are minimized, funding for system replacement can be planned over longer periods, for example over the life of the program/equipment. Cost payback from maintenance, manufacturer improvements, and more frequent servicing can be realized almost immediately. A maintenance program includes upgrading equipment to utilize improvements and new technology, scheduling equipment replacement, regular maintenance, and regular system checks.

1. Upgrade Equipment

   Upgraded equipment can often minimize leaks, prevent accidental discharges, and minimize false alarms/discharges. In some cases, the same equipment (with minor modifications) can be used for a halon replacement. In most cases, the alarm/detection system can be reused regardless of the method of fire protection. However, upgrades to equipment represent a natural progression in an operation and maintenance program and usually result in lower agent losses. In particular, it has been found that replacing cylinder solenoids on a periodic basis can significantly reduce accidental discharges.

2. Scheduled Equipment Replacement

   A well-developed maintenance program will include scheduled equipment replacement, based on the expected life of the equipment. The equipment life may be based on manufacturer's recommendations, local or national regulations, technical standards or previous history. Planning for replacement provides a basis for forecasting long term funding requirements. The opportunity should be taken ahead of scheduled equipment replacement to determine whether the halon or other halogenated gaseous fire extinguishant system continues to be required. A risk assessment may identify that an alternative agent may be suitable, and the halon, HCFC or HFC system could be replaced.

3. Design and Regular Maintenance

   In some cases, inadvertent discharges represent the largest source of emissions, and they can often be significantly reduced through improved maintenance and/or system redesign.

   Inadvertent discharges are mostly attributed to:

   - Automatic detectors responding to transient changes in environmental conditions (e.g., humidity and airborne dust).
   - Electronic unreliability or poor circuit protection from outside interference, e.g., lightning.
   - Design not conforming to manufacturer’s recommendations or Listing.
   - Irregular and/or inadequate personnel training.
   - Inadequate maintenance procedures and documentation.
   - Accidents during system servicing or testing (see note below).
   - Malice/vandalism

Note: Reductions in accidental releases during maintenance of detection systems have been observed when electrical isolation switches are incorporated into protection system designs. Such devices prevent equipment from being returned to service while still in an alarm condition.

4. Regular System Checks

System checks and maintenance should be done on a frequent and regular basis as a minimum in accordance with manufacturer's instructions, recognized technical standards, and local/national legislation. System cylinders should be visually inspected on a monthly basis for obvious damage to the cylinders, valves, leak detectors, etc. The contents of cylinders should be checked at least every six months or more frequently (monthly or quarterly), if feasible to monitor losses. (Note: There are a number of methods for checking the quantity of agent in a cylinder. Check with the manufacturer for the optimum method.) Valves, hoses, manifolds, and fittings should be inspected at the same time using a portable leak detector such as those used to check refrigeration systems for leaks. Cylinders should be replaced if more than 5% by weight of the initial contents has been lost or will be lost by the next service, Minor losses within this 5% can often be tolerated and will minimize unnecessary losses incurred in the process of rectifying such leaks. Indications of corrosion, cylinder or pipe damage, hose deterioration, etc., should also be addressed during these inspections. Bar coding methods have been successfully employed to record and track agent**Error! Bookmark not defined.** quantities and equipment condition. Checks and tests s hould be performed by competent and trained personnel that understand the need to perform such checks. If the check identifies that halon or other halogenated gaseous fire extinguishant contents need to be transferred, discharge to the atmosphere must be avoided during transfer activities. The contents must be safely transferred to a suitable holding pressure vessel by a suitable recovery method. Records of system checks and maintenance should be kept for the life of the system as per manufacturers' instructions and/or local requirements. Defects and condition reports should be made available to those personnel responsible for maintaining the system.

An example of the importance of a maintenance program is illustrated through reports such as the following. The manager of a national halon bank reported that 90% of the halon discharges were a result of "dirty smoke detectors and bad maintenance operations". The experience of HTOC members is this is a typical example seen world-wide. It is imperative in cases where halon or other halogenated gaseous fire extinguishants are being used that considerable effort be given to developing better maintenance methods for the equipment. Improved discharge system reliability is achieved through enhanced maintenance procedures and/or replacement with new technology. Development of a maintenance program should be done in parallel with performing a Risk Assessment of the facility and operations. Once a Risk Assessment has been performed on an operation, the fire protection needs are then determined. In cases where automatic fire detection or extinguishment is determined necessary, maintenance becomes a significant and integral part of the risk management. Maintenance and service activities need to ensure that systems do not accidentally discharge during the maintenance itself.

5.0 Detection Systems

Automatic halon or other halogenated gaseous fire extinguishant systems go hand in hand with sensitive detection systems. Poor design and improper maintenance of sensitive detection systems will almost always result in unwanted fire extinguishant**Error! Bookmark not defined.** releases. It is therefore essential that:

1. Systems components should not be mixed.

   Systems assembled from a mixture of components from different manufacturers should be avoided unless the fire and/or gas control panel manufacturer takes responsibility for the overall system.

2. The fire extinguishant is released only after positive confirmation of fire.

   Automatic release circuits should be designed to operate only after at least two detectors on independent circuits have confirmed a serious incident.

   Where the Authority Having Jurisdiction (AHJ) permits, and in facilities that are occupied continuously by trained personnel, the use of Closed Circuit Television (CCTV) flame detectors will allow trained personnel to remotely, visually confirm the existence of a fire within a predetermined time when alerted by pop-up video. An exception would be if the hazard area contained materials whose flames are of low visibility to CCTV, such alcohol and hydrogen. If no fire exists, then release of the agent can be inhibited. Newer technology called video smoke & fire detection or video smoke detection (VSD) can provide even faster response than CCTV alone as it utilizes computer software to analyse the smoke pattern for quicker identification.

   Where the AHJ permits, in protected areas that are occupied continuously by trained personnel, consideration should be given to manually activated systems rather than automatic.

3. Equipment chosen conforms to internationally or nationally accepted specifications.

   Detection equipment chosen should conform to internationally or nationally accepted specifications incorporating suppression of airborne and electrical interference. For example, BS 7273-1:2006 covers the electrical actuation of total flooding extinguishing systems and was introduced to improve the reliability of control systems to reduce the likelihood of accidental discharges, see reference [1]. One of the major requirements is that the circuit design and equipment construction should be such that the system should not discharge because of the failure of a single component or the short circuiting of two current paths. In addition, the equipment must be protected from EMI (cellular phones, handheld radios, etc.), e.g., EC Directive 2014/30/EC, see reference [2].

4. Existing detection systems are upgraded to take advantage of the latest technology.

   Experts in the field have determined that fires produce different types of stimulation that can be detected by sensors, e.g., gases, condensed-phase aerosols, heat conduction, electromagnetic radiation, and acoustic waves. As a result, there are a number of ways the fire can be detected and an even greater number of detector device types. Fire protection experts should be consulted when selecting the types of detection that is most suitable for a given application based on the hazards present and expected environmental conditions.

An example of upgraded technology in this area would be the use of early warning air sampling smoke detection systems. These types of systems employ a laser based light source, see reference [3] for an example. Owing to particle size discrimination, a laser based light source requires no air intake filter which can clog over time and desensitize the system. In addition, a laser based light source requires no maintenance and no replacement on a periodic basis. This must be balanced against the potential for false alarms due to the ambient environment being protected. For example, historically, these sensors have been susceptible to interference by dust.

Other examples are infrared optical sensors which have an advantage over sensors that depend on sunlight blocking filters or operate in the ultraviolet range because they are less susceptible to service interruptions due to the presence of visible light obscuring substances. Infrared fire sensors are also less likely to produce false alarms in response to sun and artificial lights, as well arc welding and as other common optical sources. Sensors using optical signal processing also achieve very rapid response times compared to thermal and smoke detectors.

Addressable detectors and control panels should be employed wherever possible. Such systems enable exact location of the fire event to be made resulting in faster attendance with first responder firefighting. Addressable systems are now no more expensive than earlier conventional systems. More sophisticated systems are also available where a combination of analogue detectors and control equipment can, in addition to identifying event location, compensate for detector deterioration and advise when sensor maintenance is required, or the system is tending towards a false alarm. This can be either automatically corrected or manually through the service company, see reference [4].

5. Trained service personnel are employed.

   User and service company personnel should be fully familiar with the system operation and the equipment fitted and should have undergone product/system training with the supplier.

6.0 Hazard and Enclosure Review

Monitor and control the hazard. Check for enclosure modifications or changes to the configuration of the protected space. Ensure that the enclosure integrity is intact and that any operable openings such as HVAC dampers or mechanisms to hold doors in the open position are integrated into the fire system and fully close before system discharge. Halon or other halogenated gaseous fire extinguishant system removal or redesign will likely be required where walls have been repartitioned, moved, the contents of the enclosure have been changed significantly, etc. During these types of changes, it is also important to review impacts to the fire protection system which may include changes in the environmental control system. It is usually necessary to modify the fire protection system when heating, ventilation and/or air conditioning systems (HVAC) are added to the protected zone. Check with local/national fire regulations and manufacturers' recommendations for specific requirements, which will include requirements to connect controls of the fire protection system into the HVAC system for automatic shutdown where the HVAC is not dedicated to the protected enclosure.

7.0 Personnel Training and Documentation

Where on-site maintenance will be performed, it is essential that the personnel performing the service be properly trained. Training records should be kept demonstrating training and competence to the appropriate level to perform the maintenance and service activity.

It is equally important that the system user be competent in the proper operation of the system and aware of activities that could result in an unwanted discharge. Any individual who could potentially cause a discharge should be educated on ozone depletion and climate change issues and the impact of halogenated gaseous fire extinguishing agent releases, as well as the restrictions on future supplies.

Where on-site maintenance personnel are not available, the user should take out a maintenance contract. Whether on-site personnel are utilized or a maintenance servicing contract, always insist on competent and licensed service personnel. Maintenance personnel should be properly trained for servicing system cylinders and hand-held extinguishers such that moisture and other contamination are not introduced (essential to prevent cylinder corrosion and/or loss of agent due to contamination).

Risk Management includes establishing good system documentation and maintenance procedures. Ensure there is documentation to follow in performing system maintenance and system checks, and all maintenance activities are logged. Review it thoroughly and periodically to see that it correctly addresses the specific equipment on-site and is not a generic copy. Install proper warnings, labels, and instructions on-site, for example post signs on the walls of areas protected by halon or other gaseous fire extinguishant systems stating, “This area is protected by XXX, Contact YYY prior to performing modifications to this enclosure”. Track quantities of fire extinguishing agents in service, storage, and emitted to determine areas where emissions can be reduced, as well as to identify future recharge needs. Where large quantities of agent(s) are in service, utilize a computer database for tracking quantities and component failures.

8.0 Agent Transfers and Storage

The component of emissions related to agent transfers can be substantially reduced by the use of approved filling rigs. Recovery / transfer equipment, vacuum pumps, pressure vessels, storage tanks, pipework, etc., need to be regularly maintained and checked for fitness of purpose and leak free. Procedures should be in place to prevent overfilling and over pressurization. Calibrated scales should be used, and agent weights documented during the transfer process to determine recovery efficiencies.

Any operation relating to a high pressure gas must conform to the appropriate safety standards in line with all relevant local, national, and international regulations. Where available, the equipment used must be certified by a recognized standards organisation and be compatible for the agent(s) use.

Environmental and operator safety dictates that all filling procedures should be conducted by trained, and preferably licensed personnel. Filling operations should be carried out in a well-ventilated area and consideration should be given to safely capturing emissions from safety relief valves and/or other points of release. All equipment, particularly flexible connections, should be checked at monthly intervals for signs of deterioration. One of the reasons that halogenated gaseous fire extinguishants are widely used is their non-corrosive characteristics when free from moisture. Therefore to avoid corrosion problems, it is essential that water must not be allowed to come into contact with these agents. The water content needs to be kept to an absolute minimum[1] to prevent corrosion occurring due to hydrolysis of the agent inside extinguishers or system cylinders. Corrosion could impact system operability (potential to affect dip tubes and valves), as well as the risk of corrosion of the asset being protected, e.g., if the system is discharged in applications that rely on the operability of electrical or electronic equipment.

The filling rig must be tested in accordance with local/country regulatory requirements and constantly monitored for leaks during the filling operation. During filling and recovery operations, overall loss of agent should be minimized and under no circumstances should it exceed 5%.

It is recommended that all new portable fire extinguishers or system cylinders be leak tested at all welds, valves, fill points, fittings, burst discs and other cylinder closures before and after being filled with agent. Any units that show signs of leaking should be connected immediately to a recovery rig and the contents transferred into the recovery container. The cylinder/valve should be rebuilt and the leak located and eliminated. Newly filled cylinders should not be accepted unless they are certified as having total leak rates below 0.5% by weight per annum (according to typical industry standards) of the initial fill.

Most safety standards require that portable extinguishers be emptied and refilled at regular intervals (or disposed of at the end of a specified period, e.g., in the U.S. Occupational Safety and Health Administration (OSHA), in 29 Code of Federal Regulations (CFR) 1910.157) limits single-use dry chemical and halon extinguishers to a 12-year life). This permits the operation of the appliance to be checked and allows the cylinder to be inspected for signs of corrosion and to be subjected to pressure testing. In the past, frequently the halon was

[1] Typical specifications are for water content to be less than 10 ppm by weight.

released to the atmosphere. Clearly such practices are discouraged, and all discharging should be accomplished using approved recovery rigs.

Recovery rigs should be operated so as to avoid contaminating agent supplies. Cylinders containing halon or other halogenated gaseous fire extinguishants should be emptied by pressurising with dry nitrogen or by use of positive displacement pumps. Vapours should be recovered if possible. Different agents should never be mixed as this would significantly limit recycling possibilities. Halon 1211 type recovery systems with an efficiency of >98% and halon 1301 type recovery systems with efficiencies >96% are readily available today, see reference [5]. Table 8.1 provides an up-to-date list of available halon or other halogenated gaseous fire extinguishants recycling and reclamation equipment manufacturers known to the HTOC.

Table 8.1: Halogenated Gaseous Fire Extinguishing Agent Recycling and Reclamation Equipment Manufacturers

Agent	Product Information	Manufacturer	Country
Halon 1211 Halon 1301 HCFC Blend B HFC-227ea HFC-236fa FK-5-1-12	Halon 1211 Recovery System HFC-227ea Recovery/Recycle System: Compatible with HFC-125, Halon 1301, and FK-5-1-12 Halotron I/FE-36 Recovery System NOVEC 1230 Recovery/Recycle System	Getz Equipment Innovators 2320 Lakecrest Drive Pekin, IL 61554 Tel: +1 888 747 4389 Fax: +1309 382 0625 URL: www.getzequipment.com	U.S.
Halon 1211 Halon 1301 HCFC Blend B HFC-227ea HFC-236fa	Recovery System	Hydro-Test Products, Inc. 85 Hudson Road Stow, MA 01775 Tel: +1 800 225 9488 Tel: +1 978 897 4647 URL: www.hydro-test.com	U.S.
Halon 1211 Halon 1301 HFC-227ea HFC-236fa	Neutronics Halon 1301 Recycling Machine, Part number A7-06-3100-02-0 Unit also capable of recycling/reclamation of HFC-227ea and HFC-125	Neutronics, Inc. 456 Creamery Way Exton, PA 19341 Tel: +1 610 524 8800 Fax: +1 610 524 8807 URL: www.neutronicsinc.com https://refrigerantid.com	U.S.

Note: the use of trade names in the is table is to solely to allow ease of reference to the Manufacturers' Products

Where backup systems are not necessary, they should be removed from service and the agent recovered. The proliferation of relatively inexpensive, high efficiency recovery systems makes it easier to increase the longevity of agent banks. Good practice dictates that halon or other halogenated gaseous fire extinguishants should not be stored in system size cylinders if possible and should never be placed or stored in cylinders not intended for their use. The manager of a national halon bank reported finding halon stored in improper cylinders resulting in slow leaks. By recovering all on-site agent that is not in use for fire protection purposes, the risk of accidental discharge or agent leakage is minimized. The agent can be recovered into large storage tanks and the tanks monitored for leaks.

The following practices for fire extinguishing agents including halons and other halogenated gaseous agents should be observed:

- Only trained personnel should be permitted to handle and store agents.
- Safety Data Sheets should be available and accessible.
- Handle agents with care to prevent accidental discharges.
- Agent cylinders not in service should be made safe to avoid accidental discharge.
- Store agent reserves in suitable storage containers.
- Implement a leak detection regime for agent in storage.
- Recover surplus agents from systems and appliances.
- Transfer and Store agent in system cylinders, extinguishers, and storage cylinders designed for agent use.
- Appropriately label agent cylinders.
- Inspect and test (where appropriate) all cylinders prior to filling with agent.
- Provide good storage conditions for both in service systems/cylinders and backup systems or bulk agent and install leak detection for storage atmospheres.

9.0 Discharging of Halons and Other Halogenated Gaseous Agents

The discharging of halon systems and portable fire extinguishers for testing, training, and other non-fire related procedures is a cause of unnecessary emissions that can easily be avoided. The HTOC believes that discharge testing using halons has been eliminated in all countries; however, several parties did not respond to HTOC requests for information, and therefore their policies regarding halon management are unknown.

1. Systems

   Do not perform discharge tests using halon under any circumstances. The Committee recommends that any existing regulations which mandate such tests should be amended. A principal emission control measure adopted by the fire protection community was the elimination of halon 1301 (now applicable to all halogenated gaseous fire extinguishants) full discharge tests by utilising several alternative procedures to ensure operational readiness of a system. These procedures are incorporated in the most recent edition of NFPA 12A, *Halon 1301 Fire Extinguishing Systems*, see reference [6] and NFPA 2001 for clean agent halon alternatives, see reference [7]. The reasons for discharge tests using halon 1301 were to check enclosure integrity, distribution and concentration of agent, movement of piping supports and piping, and detector/control device functions.

   To address enclosure integrity a test, known as a "door fan" test, is conducted. The test uses air pressure, developed with a fan and measured with calibrated gauges, to determine the ability of an enclosure to hold the agent concentration. The calculations to interpret the gauge readings into agent hold time are usually performed with a small computer.

   To address the other items, fire protection equipment standards play an important role. For example, UL 1058, *Standard for Halogenated Agent Extinguishing System Units*, provides an indication of the level of reliability for the proper operation of detector/control devices, guidelines for the proper installation of nozzles to achieve sufficient agent distribution, and a test for verifying a manufacturer's flow calculation methodology, see reference [8]. Only systems with complex piping arrangements should require additional agent distribution testing. If testing is required, the use of a surrogate gas is recommended.

   Although the exact decrease in emissions caused by the reduction in discharge testing using halon 1211, halon 2402, or halon 1301, is not known, it was estimated through the modelling of emissions and inventories to exceed 3500 MT per annum. The Committee therefore believes that eliminating discharge testing on a global basis should continue to be enforced for halon and encouraged for all in-kind halon alternatives. This change in practice has not shown to cause a major impact on fire protection system integrity.

2. Portable Fire Extinguishers

   Do not discharge manually operated halon or other halogenated gaseous agent fire extinguishers for training purposes.

   The Committee believes that it is remains possible to eliminate this source of emissions. A pressurized water extinguisher system has been developed for the U.S. military for fire fighter training. The handling behaviour is similar to a halon 1211 system and interactive video training has also been developed for U.S. military applications and can be developed for most other needs, see reference [9]. The UK military in conjunction with the Civil Aviation Authority has also developed and utilizes interactive video training, see reference [10]. Discussions within the industry also suggest that fire training organisations are only demonstrating the use of portable halon or other halogenated gaseous agent fire extinguishers and have stopped using them during training. Thus, where three or four extinguishers may have been discharged in the past, now none are discharged during training sessions. Therefore, it is reasonable to assume that the use of halon 1211 for training purposes can be virtually eliminated. With the increase in awareness of the environmental problems associated with halons, HCFCs and HFCs, many users are switching to carbon dioxide, dry chemical, fire-fighting foams, water mist, or other acceptable zero or low ozone depleting substance (ODS) agent extinguishers. Thus, the reliance on the use of portable halon or other halogenated gaseous agent fire extinguishers has significantly declined.

Similar to the fixed system cylinders, ISO/TS 11602-1:2010, *Fire protection – Portable and wheeled fire extinguishers*, provides requirements for the construction and performance of portable halon type fire extinguishers, see reference [11].

10.0 Awareness Campaigns and Policies

Non-technical steps can be taken to reduce halon or other halogenated gaseous fire extinguishant emissions. These steps have been shown to be as important as the technical steps discussed in the previous sections of this chapter in achieving emission reductions. The non-technical steps are discussed only briefly in this section; however, references are provided and should be consulted for in depth coverage of each subject. The HTOC, various governments, and the fire protection community have worked diligently to provide guidance documents on all aspects of halon phase-out that will also be applicable in the HCFC phase-out, including the use of the 10year service tail allowance, and the phase-down of HFCs. The value of the references should not be underestimated.

Non-technical actions for emission reduction strategies are discussed in the following order:

- Policies, Regulations, and Enforcement
- Awareness Campaigns
- Standards and Codes of Practice
- Record Keeping

The intent in this section is to trigger some ideas on existing strategies that can be, or have been, demonstrated to enhance country programmes while reducing emissions. It is not possible to provide comprehensive lists or information in this Technical Note as the options are extensive and specific aspects should be tailored to the country-specific conditions and needs.

10.1 Policies, Regulations, and Enforcement

Policies should be in place to meet the party obligations under the Montreal Protocol. Each party has a National Ozone Unit (NOU) tasked with implementing policies, programs, and regulations in support of those obligations under the articles of the Montreal Protocol specific to their country. Some parties have elected to utilize a Steering Group to formulate plans for ODS phase-out, to draft policies and regulations, and to provide periodic oversight. This is especially effective where resources are limited, and actions might otherwise be delayed. It also serves to involve those entities directly affected by the phase-out. It is advisable that a Steering Group be made up of stakeholders from the following sectors, see reference [12]:

- Public fire services
- Fire equipment trade association
- Insurance companies
- Halon (and potentially other halogenated gaseous fire extinguishants) users
- Environmental advocacy groups (NGOs)
- Environment Ministry
- Customs officials
- Defence Ministry

The Steering Group can be tasked to put forward a plan for halon or other halogenated gaseous fire extinguishant management by the NOU or other responsible government agency. The NOU can initiate the revision of regulations to eliminate requirements for discharge testing and provide needed assistance to AHJs, especially in those cases where such testing is mandated by local regulations that are outdated or otherwise unnecessary. The NOU can also introduce regulations requiring the recovery, recycling, and reclamation of the halons or other halogenated gaseous fire extinguishants.

While penalties or fees can increase venting and black-market trading, many halon bank managers have cited lack of enforcement of halon control regulations as limiting the success of their operations. This will likely also be the case for HCFC and HFC fire extinguishant banking in the future. Without enforcement and possibly incentives, national halon or other halogenated gaseous fire extinguishants banking functions, especially those operated by industry or commercial entities, are unlikely to be financially viable. Several national halon bank managers have reported to HTOC members little or no activity in halon recycling which they attributed directly to lack of policies, regulations, and enforcement. In those cases, the bank either completely shuts down or the recycling operators will need retraining in the event decommissioned agents become available. For more information on banking of halogenated gaseous fire extinguishing agents, refer to the HTOC 2018 Assessment Report Volume 3, Global Halon, HCFC, and HFC Banking (December 2018).

10.2 Awareness Campaigns

Emission Reductions can be achieved by implementing a comprehensive Awareness Campaign. This can include any or all of the following: workshops, training, brochures, television or radio commercials, websites, newsletters directly or through fire protection equipment/service providers, fire protection and trade publications, etc.

Broad involvement of the stakeholders, who include the NOU delegate, Ministry of Environment, fire protection system and extinguisher users, code enforcing authority, military branches, maritime and airline industries, research and testing laboratories, and the fire protection community has been shown to be important. In all parties one or more of the following organisations are part of the fire protection community:

- National fire service
- National standards writing organisation
- National building and fire code organisation
- National fire protection association
- Trade association of fire equipment companies
- Fire insurance companies

Awareness Campaigns can include a description of halons and other halogenated gaseous fire extinguishants and their uses, environmental concerns related to the ozone layer and climate system, key goals and deadlines in the Montreal Protocol, country-specific policy and regulations on ODS and Climate Change, recycling requirements, alternatives and options, points of contact in government and the fire protection community, and answers to Frequently Asked Questions such as “what should I do with my halon 1211 extinguisher?”

In those countries where there is still no comprehensive halon management programme, no national halon bank, and no clearinghouse, it is quite likely there are halon installations that are inappropriate for the application and should be replaced with an alternative, see reference [12]. This may be similarly true for HCFCs as well. Workshops and Training are an excellent way to implement an Awareness Campaign while meeting with the fire protection community.

10.3 Standards and Codes of Practice

The fire protection community can:

- Adopt or develop technical standards on the design, installation, testing, and maintenance of extinguishers and fire suppression systems both for halons and other halogenated gaseous fire extinguishants.
- Ensure users provide training for the occupants and site manager of a halon and other halogenated gaseous fire extinguishants protected enclosure.
- Develop or adopt a Code of Practice, see references [12–16]:
  - Target groups may include insurance, system manufacturers and distributors, fire protection system operators, service technicians, and State fire services.
  - Enforce the standards and codes. Various methods of enforcement may include command and control measures (e.g., regulations), market-based measures (e.g., taxes or permits) or voluntary agreements. Command and control approaches, the most common approach, require an effective legal framework and enforcement.
  - Incorporate standards and Codes of Practice in regular training. National training workshops can teach and explain the Code of Practice.

The fire protection industry has a goal of reducing the risk to people and property from the threat of fire while minimising non-fire emissions of fire protection agents. With the aim of ensuring both of these goals are achieved, the fire protection industries in many countries have developed or adopted a Voluntary Code of Practice (VCOP) that is intended to focus the industry's efforts on minimising emissions of gaseous fire protection agents, see reference [14]. The VCOP is distributed throughout the fire protection community and members are encouraged to voluntarily follow the emission reduction strategies. The following are typical strategies outlined in a VCOP:

1. <u>Regulations and Standards</u>: Follow applicable technical standards for the agent.
2. <u>Emissions</u>: Minimize emissions during storage, handling, and transfer.
3. <u>Equipment</u>: Utilize equipment appropriate for the agent and maintain it regularly according to step 1.
4. <u>Discharge Testing</u>: Eliminate discharge testing of halon and minimize discharge testing for all replacement agents to "essential" tests only.
5. <u>Decommissioning, Servicing, and Disposal</u>: Prohibit venting or release of agent to the atmosphere. Always recover, recycle, reclaim or destroy agent following manufacturer instructions for operation and maintenance of recovery / recycling equipment, and ensure purity of agent.
6. <u>Technician Training</u>: Require that technicians who test, maintain, service, repair or dispose of halon halons and other halogenated gaseous fire extinguishantcontaining

equipment are trained regarding responsible use to minimize unnecessary emissions, see reference [15]. Training can include:

- Explanation of why training is required (trained technicians prevent emissions).
- Overview of environmental concerns with halons and alternatives (ozone depletion, long atmospheric lifetimes, high GWP, etc.).
- Review of relevant regulations or standards concerning halons and alternatives.
- Specific technical instruction relevant to individual facilities (manufacturer's manuals, training materials, references, and resources available to technicians).

7. Communications and Outreach: Ensure dissemination of information designed to minimize emissions and enable phase-out of halons and HCFCs and phase-down of HFCs.
8. Record keeping and Reporting: Develop a verifiable data tracking system on stockpiles, installed base, transfers, and emissions.

In most countries, fire equipment distributors belong to an industry association or are registered with a government agency. That agency or the government agency responsible for ODS phase-out and HFC phase-down could develop a Code of Practice (COP) and require compliance with the COP, in which case it would not be called voluntary. Requiring compliance would ensure compliance with recognized and acceptable levels of safety and quality, thereby reducing liability concerns and building confidence in the viability of recycled agents. This is very important where international transfers are concerned to ensure compliance with the provisions of the Basel Convention, see reference [17].

There are Codes of Practice available in many countries. It may be that another country's Code of Practice is applicable to your situation and can be translated and adopted. Several parties have successfully used this method.

10.4 Record Keeping

Record keeping can be an integral part of managing halons halons and other halogenated gaseous fire extinguishants from the system user to fire extinguishant banks. Record keeping can include any or all of the following:

- User should have accurate information on site regarding system/extinguisher manufacturer, service provider, drawings, specifications, maintenance schedule, operator manual, etc., see reference [14] for an extensive list.
- Users, service providers, recycling facilities, and fire extinguishant banks can all implement inventory control, maintain detailed transfer records, and emissions data. This provides insight into why leaks or discharges occur, better long range planning for transition to alternatives, proactive capabilities for managing reserves, improved financial planning, and better enforcement of applicable regulations.
- Service providers and fire equipment distributors can keep records of customers' installed base, replenishment rates, and decommissioning plans especially where there is no national physical bank or clearinghouse. This is also a tool to forecast future fire extinguishant needs, surpluses that will become available, and for assisting in the emissions quantifications.

A verifiable data tracking system on the emissions of halons and other halogenated gaseous fire extinguishants can be coordinated across the fire protection industry in each country.

Awareness Campaigns, Codes of Practice, Enforced Policies, and Recordkeeping are all essential tools to prevent further emissions of halons and other halogenated gaseous fire extinguishants. An example of how these are needed was brought to the attention of the HTOC in 2010. *The manager of a national halon bank reported personal knowledge of halon cylinders being vented to make them lighter and easier to handle when decommissioning the systems. The manager emphasized the need to provide information to users, operators, and service technicians explaining the damage that is done to the ozone layer as a result of halon venting and discharges*. Continuing practices such as these are a reminder of the continued need to implement Awareness Campaigns and Policies on Responsible Use of halons and other halogenated gaseous fire extinguishants.

11.0 Decommissioning, Transportation, and Destruction

Decommissioning is the process of removing a fire protection system from service. This must be done in order to recover the fire extinguishant so that it can be made available for other uses. Safety is an important aspect of decommissioning and transportation. Halons and other halogenated gaseous fire extinguishants are pressurized gases. Therefore, the cylinders containing them are under pressure and must be handled with great care. If the pressure is released in an uncontrolled way not only will it result in unwanted emissions, but more importantly it can become a projectile that can cause serious injury or death. Two ways this can occur is damage to the valve or activation of the discharge mechanism. Service technicians should always follow the manufacturer's guidelines for cylinder valve disassembly, see reference [16].

The rate of decommissioning increased significantly as production of halon ceased. As the phase-out of HCFCs and the phase-down of HFCs roceed, there is the potential for a correlating increase in injury and unwanted emissions. Safe decommissioning guidelines are available from numerous sources and are applicable to all users, see references [12, 16]. Decommissioning activities should be undertaken by fully trained and competent personnel. In some parties, e.g., Australia, personnel must be licensed to perform the decommissioning activity.

Transportation of halon and other halogenated gaseous fire extinguishants occurs during decommissioning, servicing, and transfers to other users, vendors, banking facilities, or destruction facilities. Halons and other halogenated gaseous fire extinguishants are dangerous goods as they are pressurized gases and should be transported as per international and national guidelines. It is important to develop procedures and ensure that they are properly followed so that the agent is handled, transported, and stored in such a way that its physical properties are not degradedand it is not emitted. Table 11.1 lists applicable standards for handling, transportation, and storage of most halons and halogenated gaseous fire extinguishing agents.

Table 11.1 Agent Specifications for Handling, Transportation, and Storage

Agent Type	**Chemical name**	**Standard**
Halon 1301	Bromotrifluoromethane (CF3Br)	ASTM D5631-15 [18]
Halon 1211	Bromochlorodifluoromethane (CF2BrCl)	ASTM D7815-17 [19]
Halon 2402	1,2-Dibromotetrafluoroethane ($C_2Br_2F_4$)	Not Known
HCFC Blend B	Blend comprised primarily of 2,2-dichloro-1,1,1-trifluoroethane, (CF_3CCl_2H, Ar, and CF_4)	ASTM D7123-17 [20]
HFC-23	Trifluoromethane (CHF_3)	ASTM D6127-11(2015) [21]
HFC-125	Pentafluoroethane ($C2HF_5$)	ASTM D6268-15 [22]
HFC-227ea	1,1,1,2,3,3,3-Heptafluoropropane (CF_3CHFCF_3)	ASTM D6065-11(2015) [23]
HFC-236fa	1,1,1,3,3,3-hexafluoropropane ($CF_3CH_2CF_3$)	ASTM D6065-11(2015) [23]
FK-5-1-12	Dodecafluoro-2-methylpentan-3-one	Not Known
HBFO-1233xf(B)	2-Bromo-3,3,3-Trifluoro-1-Propene ($CF_3CBr{=}CH_2$), (aka 2-BTP)	ASTM D8061-16 [24]

Destruction of halon and other halogenated gaseous fire extinguishants is a final disposition option that should be considered only if the agents are contaminated and cannot be reclaimed to an acceptable purity. There are several processes that have been identified as suitable for halon, HCFC and HFC destruction by the Parties to the Montreal Protocol and they are discussed in HTOC Technical Note #5 [25], see also reference [15].

12.0 Conclusions

Avoidable halons and other halogenated gaseous fire extinguishing agent releases account for greater emissions than those needed for fire protection and explosion prevention. Clearly such releases can be minimized. In reviewing reduction strategies, the HTOC recommends the following:

- Halon should not be used in new fire protection applications where alternatives exist.
- Other halogenated gaseous fire extinguishing agents should not be used unless a full risk analysis has been performed by a fire professional with expertise in their use and specifications, and the agent was deemed the only viable option taking into consideration safety, efficacy, economics, and environmental effects.
- Take advantage of maintenance opportunities to replace existing halon systems or extinguishers with suitable alternatives where it is technically and economically feasible to do so.
- Encourage the application of risk management strategies and good engineering design to take advantage of alternative fire protection schemes.
- Implement a regular maintenance program.
- In protected areas that are occupied continuously by trained personnel, consider using manually activated systems or automatic systems that are activated via CCTV flame detectors or similar technology.
- Encourage users of automatic detection/release equipment to take advantage of the latest technology that is designed, listed and proven in the intended application. Newer systems have been shown to reduce false alarms that trigger system activation.
- Verify system design and requirements when changes in hazard have occurred.
- Improve maintenance and system configuration documentation.
- Educate and train personnel on system characteristics.
- Introduce the use of recycling equipment to recover all surplus or reusable fire extinguishing agents.
- Utilize well-managed central storage for halon and other halogenated gaseous fire extinguishant reserves and install automatic leak detection.
- Discontinue fire protection system discharge testing using fire extinguishants as the test gas and amend any existing regulations which mandate such testing. If system discharge must be performed, consider using a simulant.
- Discontinue the discharging to the atmosphere of portable halon, HCFC and HFC extinguishers and system cylinders during equipment servicing.
- Discontinue the discharge of portable halon, HCFC and HFC fire extinguishers for training purposes. Live fire training is important but can be adequately done using simulants.
- Enact laws, develop policies, and ensure enforcement to support the managed phase-out of halons and HCFCs and phase-down of HFCs.

- Implement national Awareness Campaigns on all environmental concerns (ODS, GWP, Climate Change).
- Develop or adopt Technical Standards and Codes of Conduct.
- Develop databases and implement record keeping on halon, HCFC and HFC installed base quantities, transfers, and emissions.
- Develop halon, HCFC and HFC fire extinguishing agent management plans including end of useful life considerations.
- Ensure "Responsible Use" of halons and other halogenated gaseous fire extinguishants using the tools from this Technical Note.

13.0 References

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14.0 List of Acronyms and Abbreviations

AFFF	Aqueous Film Forming Foam
AHJ	Authority Having Jurisdiction
BSI	British Standards Institute
CCTV	Closed Circuit Television
COP	Code of Practice
EPA	(United States) Environmental Protection Agency
GWP	Global Warming Potential
HARC	Halon Alternatives Research Corporation
HTOC	Halons Technical Options Committee
HVAC	Heating, Ventilating, and Air Conditioning
NFPA	National Fire Protection Association
NIST	(United States) National Institute of Standards and Technology
NGO	Non-Governmental Organization
NOU	National Ozone Unit
ODS	Ozone Depleting Substance
TEAP	Technology and Economic Assessment Panel
UK	United Kingdom
UL	Underwriters Laboratories Inc.
UNEP	United Nations Environment Programme
U.S.	United States
VCOP	Voluntary Code of Practice
VSD	Video Smoke Detection