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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.

Dedication

Since the last Assessment Report three members of the Halons Technical Options Committee passed away. This report is dedicated to the memory of.

David Ball

Takkaki Konno

Arthur Lim

Acknowledgements

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1. Executive Summary

1.1 Introduction

The following sector summaries show the remarkable progress that has been made to significantly reduce the need for halons and discuss the current state of cooperative or individual arrangements to ensure adequate stocks of halons to meet future needs:

1.2 Military

The military sector has shown leadership in, and devoted considerable effort to, the identification, development and testing of suitable halon alternatives, with much of the benefit transferring to the civilian and commercial sectors. As a result of this effort, much progress has been made and HTOC is unaware of any new facilities or new designs of military equipment that now require the use of the halons. The conversion of systems in existing, in-service equipment is more challenging, but conversion programmes are underway or completed for several important applications. In other cases, very significant technical, economic and logistical barriers to conversion remain. To maintain Parties' levels of national security, and the safety of military personnel, halon systems may need to continue in service for the remainder of the operational life of the equipment concerned. Halon use by the sector is well managed. Many organisations have established dedicated halon storage and recycling facilities to support Critical Use equipment for as long as is necessary. Future Essential Use production of additional quantities of any halon for the military sector should therefore not be necessary.

1.3 Civil Aviation

The aviation industry continues the search for acceptable replacements for halon, and in the meantime has eliminated or reduced emissions in testing, training, maintenance operations and use in ground facilities. Progress has been achieved and for some applications, including systems for lavatory waste receptacles and portable fire extinguishers, approved replacements are available. However, for the majority of in-flight applications, including systems for engine nacelles and cargo compartments, progress has been slow due to a combination of factors. These range from industry and government reluctance to incur additional risk or expense associated with new systems, to the need for extensive training of personnel. An active programme of work to find suitable approaches for these remaining areas continues, co-ordinated for the commercial aviation industry by an International Aircraft Systems Fire Protection Working Group open to all interested parties. Until these projects reach successful conclusions, aircraft will continue to require halon for their fire protection and Airworthiness Certification. To meet the needs of new and existing airframes certified with protection systems based on halon, recycling, conservation and banking of halon, will be necessary for their minimum expected life of some thirty years. It is strongly recommended that commercial airlines and other aviation users continue to implement discharge minimisation procedures and individually or collectively establish measures to meet their long-term needs for recycled halons.

In existing aircraft, changeover to approved halon free lavatory waste receptacle fire protection systems and portable fire extinguishers should be implemented in a timely manner.

Given the important technical considerations, logistical needs and financial implications, and to ensure the safety of the aircraft crew and passengers, the International Civil Aviation Organisation (ICAO) would be an appropriate body to co-ordinate the development of a timely plan of action to eliminate the need for use of halon on new airframes. Certifying Agencies, Airframe Manufacturers and Operators will likely wish to participate in this effort. Aircraft Operators may also wish to consider asking ICAO for assistance in developing a coordinated program to put in place and manage an assured supply of halon to meet the ongoing needs of existing airframes certified on the basis of halon fire protection.

1.4 Merchant Shipping

The status of halons in merchant shipping must be viewed in two different contexts: existing ships already equipped with halons and new ships that are not permitted to employ halons. At the centre of this halon subject is the International Maritime Organization (IMO), which has been the cohesive force to address the halon issue in both contexts. In that regard, IMO

- enacted an international ban on the use of halons aboard new ships on international voyages, nearly 2 years before the halt of production of halons in non-Article 5 countries.
- developed and published approval guidelines and test methods for the systems using halon alternatives on shipboard applications.
- developed recommended procedures for ships with discharged / depleted halon systems to safely move from one port to another where system replenishment is possible.
- established, distributed and has maintained an international listing of halon agent replenishment sources for ships needing a system recharged.

It is important that the marine industry closely monitors the change in availability of replenishment halon around the world. This is a dynamic situation and it will only be through pre-planning that owners and authorities can prepare for the eventuality of a future halon shortage. Parties to the Montreal Protocol, in conjunction with the International Maritime Organization, may wish to consider specific programs directed to owners of vessels to emphasize the need for continued international cooperation to prepare for this potential problem.

1.5 Oil and Gas Production

The use of halon 1301 systems in this industry for explosion prevention (inertion) has been focused on inhospitable locations such as the Alaskan North Slope in the United States and the North Sea in Europe where facilities have had to be enclosed due to the harsh climatic conditions. The process areas in the production modules and the pumping stations face a constant threat from methane gas and crude oil leaks that can lead to potentially explosive atmospheres. Halon 1301 has been the agent of choice for mitigating this threat. When reviewing protection measures brought about by the phase out of halon there are two distinct cases to consider, existing facilities and new facilities. Halon supplies are only a consideration for existing facilities, as new facilities are not being designed to use halon.

In regions/countries where regulatory actions have forced the decommissioning of halon 1301 systems, companies are either stockpiling the resulting surplus (if permitted) or are relying on government/private halon 'banks' to supply their ongoing needs. In some cases, regulations require a company to submit their halon requirements to a 'critical use' review board to determine whether or not they can obtain necessary supplies.

In regions/countries without regulatory controls on halon use, there currently appears to be no compelling reasons to stockpile halon as demand is being met from recycled supplies. Companies are making opportune buys as halon comes to market at reasonable cost, and larger corporations are generally maintaining stocks at the 3 to 5 year level. However, the industry should plan for the long term to ensure that supplies of recycled halon are available to it for as long as will be needed.

1.6 Explosion Suppression

In the past, halons were used to suppress explosions in industries such as Aerosol Fill Rooms, Grain Silos, Paper Production and Milk Powder Processing plants. Halon 1301, halon 1211 and halon 1011 have all been used as explosion suppression agents. For all known applications alternatives have been developed and tested. As a result all new explosion suppression systems no longer rely upon halons.

Explosion suppression systems for Aerosol Fill Rooms are a special case. In the past, halon 1301 was the standard suppression agent used in North America, whereas aqueous systems were employed in Europe. Since approximately 1996, the standard agent for new systems in North America has been water. Retrofit activity from halon 1301 to water in North America has occurred but only to a limited extent, and significant conversion has not been undertaken. This is due to the very high cost of replacement of the entire existing system in the facility with a new aqueous based system.

1.7 Countries with Economies in Transition (CEIT)

The same technical issues and current status of selected uses of halons outlined in this Report also apply to all CEIT from a technical point of view. However, the difference is in the higher economic cost to retrofit existing halon based fire protection systems with alternatives, in particular in CIS.

The installed capacity of halon 2402 in the Russian Federation is sufficient to assure that enough halon 2402 can be removed and recovered to meet the needs of critical applications. Quantities should be sufficient to meet the critical needs of the Russian Federation and those CIS requiring halon 2402 for critical applications. Parties may wish to encourage the Russian Federation government to allow export of recycled halon 2402 to help meet critical needs in CIS.

There should be no further need for an “Essential Use” exemption for any halon in CIS. However, all CEIT governments should advise their “critical user sectors” to make appropriate efforts to obtain supplies of recycled halons to support their needs. Recovery and recycling of halon 2402 as well as halon 1211 and 1301 is of particular importance in the Russian Federation.

The need for technical training and assistance to CIS to facilitate the transfer of halon based fire protection towards long-term, sustainable fire protection alternative solutions continues.

1.8 Article 5(1) Countries

Halon consumption in Article 5(1) countries has been reduced significantly over the past few years. Based on the current trends, the agreements between the Multilateral Fund (MLF) and Article 5(1) countries, and the halon production figures for the year 2002, it seems certain that production of halon 1211 will stop in China by 2005, and the only remaining 1211 production may be a few hundred tonnes in South Korea. Similarly, total production of halon 1301 in China and South Korea will also be reduced to less than 300 tons from 2005 and until 2009 due to reduced demand.

Three activities have contributed to this accelerated phase-out achievement in Article 5(1) countries. Firstly, halon management and banking projects have substantially reduced the demand for halon in over 35 of the larger halon consuming Article 5 countries. This has been achieved through a combination of awareness creating activities, promotion and transfer of substitute fire protection technologies, training courses for the fire protection industry, and halon recovery and recycling. Based on agreements with the Multilateral Fund, those countries will stop import of new halons by 2005 and will be able to cover future needs for halons through recovered and recycled halons. The second major activity that has enabled the accelerated phase-out of halons in Article 5(1) countries is the China Halon Sector Plan. The financial support provided by the MLF will result in the closure of halon 1211 production by 2005 and will reduce the allowed production of halon 1301 to no more than 150 tonnes annually from 2006 onwards. The third activity is the halon phase-out program for India, which has allowed India to accelerate its halon phase-out. As part of the MLF support to India, both halon production facilities in India have been dismantled.

While the demand for new halons has been reduced to close to zero, it is also necessary to recognize that Article 5(1) countries, like non-Article 5 countries, will be depending on the availability of recycled halons for critical uses after 2005. It is noted that critical uses in Article 5(1) countries are the same as in non-Article 5(1) countries and new technologies are suitable for new installations. As funds for capital expenditures are often scarce in Article 5(1) countries, retrofit of existing halon systems poses a particular challenge. Any assessment of global demand for recycled halons should therefore also include the demand in Article 5(1) countries after 2005. A real or perceived shortage of recycled halons could lead to the need for additional production of new halons.

1.9 Summary of progress

The following table provides a summary of the extraordinary progress that has been made in the development of alternatives, replacements and new fire protection approaches.

Current Status of Selected Uses of Halons		**Halon Type**	**Alternative Availability for Existing Use**	**Impediments to Retrofit of Existing**	**Alternatives Available for Next Generation**	**Impediments to Next Generation**
Military Uses						
Facilities	Command Centre	1301	Alternatives Available	Cost $$	Alternatives Available	None
	Research Facility	1301	Alternatives Available	Cost $$	Alternatives Available	None
	Computer Centre	1301	Alternatives Available	Cost $$	Alternatives Available	None
	Electrical Compartment	1301	Alternatives Available	Cost $	Alternatives Available	None
Airfield	Crash Rescue Vehicle	1211	Potential Alternatives	Technical	Potential Alternatives	Technical
	Flight Line Portables	1211	Potential Alternatives	Technical	Potential Alternatives	Technical
Aircraft	Engine Nacelle	1301, 1211 or 2402	Potential alternatives	Technical	Alternatives Available	None
	Auxilliary Power Unit	1301, 1211 or 2402	Potential alternatives	Technical	Alternatives Available	None
	Dry Bay	1301, 1211 or 2402	Potential alternatives	Technical	Alternatives Available	None
	Cargo Bay	1301	Potential alternatives	Technical	Potential alternatives	Technical
	Fuel Tank Inerting	1301	Potential alternatives	Technical	Alternatives Available	None
	Lavatory Waste Receptacle	1301	Alternatives Available	Cost $	Alternatives Available	None
	Portable Extinguisher	1301 or 1211	Alternatives Available	Cost $	Alternatives Available	None
Combat Vehicle	Engine Compartment	1301, 1211 or 2402	Alternatives Available	Cost $$	Alternatives Available	None
	Crew Compartmnent	1301 or 2402	Potential alternatives	Technical	Potential Alternatives Available	Technical
	Portable Extinguisher	1211 or 1301	Alternatives Available	Cost $	Alternatives Available	None
Surface Vessel	Machinery Space	1301, 1211 or 2402	Potential alternatives	Technical	Alternatives Available	None
	Flammable Stores	1301 or 2402	Potential alternatives	Technical	Alternatives Available	None
	Electrical Compartment	1301 or 2402	Alternatives Available	Cost $$$	Alternatives Available	None
	Command Centre	1301 or 2402	Alternatives Available	Cost $$$	Alternatives Available	None
	Flight Line/Hangar Portable	1211	Potential alternatives	Technical	Potential Alternative	Technical
Submarine	Machinery Space	1301 or 2402	Potential alternatives	Technical	Alternatives available	None
	Diesel Generator Space	1301 or 2402	Potential alternatives	Technical	Alternatives available	None
	Electrical Compartment	1301 or 2402	Potential alternatives	Technical	Alternatives available	None
Merchant Shipping						
Vessels	Machinery Space	1301, 1211 or 2402	Alternatives Available	Cost $$$	Alternatives available	None
Ground Transportation						
Railway	Locomotive Engine Compartment	1301	Alternatives Available	Cost $$	Alternatives Available	None
	Wagons with Occupied Vehicles	1301	Potential alternatives	Technical	Potential Alternatives	Technical
Commercial Aviaton						
Aircraft	Engine Nacelle	1301 or 2402	Potential Alternatives	Technical	Alternatives Available	Regulatory Barrier
	Auxilliary Power Unit	1301 or 2402	Potential Alternatives	Technical	Alternatives Available	Regulatory Barrier
	Cargo Bay	1301 or 2402	Potential Alternatives	Technical	Potential alternatives	Technical
	Lavatory Waste Receptacle	1301	Alternatives Available	Cost $	Alternatives Available	None
	Portable Extinguisher	1211	Alternatives Available	Cost $	Alternatives Available	None
Airfield	Crash Rescue Vehicles	1211 or 2402	Alternatives Available	Cost $$	Alternatives Available	None
	Flightline portable	1211	Alternatives Available	Cost $	Alternatives Available	None
Industrial Uses						
Explosion Prevention	Oil and Gas Pipeline Pumping Stations	1301 or 2402	Potential Alternatives	Technical	Alternatives Available	None
	Enclosed Oil and Gas Production Modules	1301 or 2402	Potential Alternatives	Technical	Alternatives Available	None
	Aerosol Fill Rooms	1301	Alternatives Available	Cost $$	Alternatives Available	None
	General Explosion Suppression	1011 or 2402	Alternatives Available	Cost $	Alternatives Available	None
General Fire Protection	Computer Room	1301	Alternatives Available	Cost $$	Alternatives Available	None

1.10 Conclusions

Halon fire extinguishants are no longer necessary in virtually any new installations, with the possible exceptions of engine nacelles and cargo compartments on commercial aircraft and crew compartments of combat vehicles. The very high cost of replacing many existing halon systems with substitutes, replacements or other alternative fire protection measures continues to be a major impediment to eliminating continued use of halons.

Although potential alternatives exist for both engine nacelles and cargo bays of commercial aircraft it is disturbing to report that new airframes are still being designed and certified with halons as the required fire extinguishant due to regulatory requirements. Parties may wish to request the International Civil Aviation Organization (ICAO) to act with the TEAP HTOC as a co-ordinating body in development of a timely plan of action to eliminate regulatory requirements for halons on new airframes. Airframe Certification Agencies and Airframe Manufacturers will want to participate in this effort.

Some Parties have enacted regulations requiring existing halon systems to be decommissioned and the halons from these systems destroyed. Although most halon 1211 and a portion of halon 1301 in inventory will not be required to meet future needs such measures require careful planning to ensure that sufficient stocks of halon 1301 remain available to meet future critical needs of both Article 5(1) and non-Article 5(1) Parties. Users that have critical halon needs should consider making arrangements to ensure a secure supply, either individually or in partnership with other critical users. This effort would likely include obtaining the additional halon necessary to meet their future requirements and expansion of existing or construction of new secure storage facilities that would include necessary leak prevention and monitoring measures.

An alternative to the creation of large halon stockpiles would be a decision to allow Parties to earn credits for destroyed or converted halon by technologies approved by the Parties. These credits would be eligible to be carried forward for possible future critical uses to be approved (Article 1, Paragraph 5 allows credits for the year of destruction and not for future use). Such a provision would be an incentive to collect and destroy halons, would deter emissions from halon banks which may be found surplus to requirements, and could help eliminate the reluctance to retrofit of existing applications that results from the current oversupply of halon. A bolder strategy to achieve these objectives could be, through market-based approaches, such as trading in credits to be obtained by destruction of halons or allowing such credits to be used for essential/critical uses of other ODS.

The HTOC will invite TEAP and its other TOCs to consider the potential advantages and disadvantages of such an approach to other ODS use sectors.

In 2003, the Halon Technical Options Committees will further explore options to reduce halon emissions.

2 Halon Usage and Replacement in the Military

2.1 Current uses of halons in the military sector

Prior to the agreement of the Montreal Protocol, the halons found widespread use by military organisations throughout the world, because of their effectiveness against the wide range of fire hazards that existed.

As in the civilian sectors, the halons were used in headquarters and other buildings, in computer rooms and communications facilities, and at research and equipment test facilities. Many of these halon systems have now been converted to HFC, inert gas or carbon dioxide alternatives, though some remain in facilities such as flight or weapon simulators, underground command and control centres and hardened aircraft shelters. In a significant number of cases, improved procedures, changing requirements and alternative fire protection strategies have allowed the removal of the halons without their replacement by an in-kind alternative. Nearly all halon portable extinguishers have been replaced with conventional alternatives such as dry chemical, foam, carbon dioxide or water extinguishers.

However, the most important military uses of halon systems and, to a smaller extent, portable extinguishers, have been to protect personnel and the operational capability of front-line weapons platforms (aircraft, naval vessels and vehicles) from fires caused by mechanical or electrical failures or by hostile actions. Some of these hazards, and some of the difficulties that must be overcome in order to replace the halons, are unique to the military sector.

The need for effective fire protection for military personnel and their front-line equipment is universal. However, the hazards involved, and the methods used to counter them, vary with each type of equipment. Where the halons have been used, the choice of halon, whether 1211 or 1301 (or 2402 in eastern European countries[1]), and the design of the agent delivery system, may also vary. The difficulties of finding and implementing acceptable alternatives have proven to be formidable in many cases, and the defence forces of all nations therefore continue to use the halons in front-line fire protection applications. Although the number and types of different halon applications in front-line equipment vary from nation to nation, some or all of the following Critical Uses may be found in any current combat or peacekeeping force.

In military armoured fighting vehicles, engine compartments are protected by fixed, total flooding, halon 1301, halon 1211 or halon 2402 systems designed to extinguish any fires caused by the ignition of leaked fuel, lubricant or hydraulic fluids. The crew compartments of many vehicle types are also fitted with halon 1301 or 2402 systems intended to prevent explosions and fires that may be caused by hostile action. The crew compartment systems are designed to discharge the halon in a few tens of milliseconds to prevent or suppress the ignition of any fuel vapourised by an incoming round that has penetrated a fuel tank on its way to the compartment. Vehicles may also be equipped with portable halon 1211, 1301 or 2402 extinguishers for crew use on interior or exterior

[1] Some examples of older equipment in Europe and USA remain in service with halon 1011, 1202 or 2402 and methyl bromide fire protection systems. These are normally replaced with halon 1211 or 1301 upon discharge or during system maintenance programmes.

electrical or other equipment fires. There are a few other examples of halon systems in communication and control vehicles or other mobile facilities.

On military aircraft the halons are used to protect the engine nacelles and, on larger aircraft, auxiliary power units, from fires caused by fuel leaks or other engine failures. Larger aircraft with more than one occupant are also fitted with portable halon 1211 or (to a lesser extent) 1301 extinguishers. On some transport aircraft, especially those based upon civilian airliners, cargo bays are protected by halon 1301 systems designed to contain any fire for up to several hours. As in the civilian sector, aircraft lavatories may have small fixed systems to extinguish fires in waste receptacles. On a few aircraft and helicopters designed for missions with a high risk of attack by opposing forces, dry bays (the compartments surrounding fuel tanks) are protected by rapid response automatic explosion suppression halon 1301 systems. These are intended to suppress any explosion caused by the ignition of fuel ejected from a fuel tank by an incoming round. On a couple of US-designed aircraft types, halon 1301 systems are installed to prevent explosions from whatever cause by the pre-emptive inerting of the empty space (ullage) in their fuel tanks. These latter are emissive systems where the halon cannot be recovered once the systems are activated. However normal policy in the countries that use the aircraft is that the systems are activated by the pilot only when facing hostile action. On airfields, some forces continue to use halon 1211 in portable extinguishers in flight line applications and on crash rescue vehicles.

Naval vessels, whether surface ship or submarine, have a number of fixed halon systems designed to extinguish fires caused by equipment failure or hostile action. These protect engine rooms, main and auxiliary machinery spaces, gas turbine and diesel engine enclosures and flammable liquid storerooms from flammable liquid fires. On some vessels, compartments containing electrical equipment will also have dedicated halon systems. Some aircraft carriers and smaller vessels carrying aircraft also have available for their crew halon 1211 units or portable extinguishers to fight fires on flight decks and in hangar bays.

2.2 Alternative fire extinguishants and fire protection methods

The military organisations of Parties to the Montreal Protocol have committed themselves to reducing and eventually eliminating the use of the halons in military equipment and facilities, wherever this is technically and economically feasible. These efforts have included:

- The design of new weapons platforms such that halon systems are no longer required;
- The replacement of the halons in existing equipment with alternative means of fire protection; and
- The introduction of measures and procedures to reduce halon emissions from the applications that remain in service.

The military community continues to devote considerable effort and resources towards the assessment and implementation of alternative extinguishants and fire protection technologies.

The task is often complex and challenging. Effective fire protection in front-line military equipment is essential to protect personnel and to maintain and enhance the operational capability and survivability of the weapons platform. In all cases, front-line equipment is characterised by use that demands performance at the limits of capability, in potentially extreme or hostile environments. A variety of fuels and potential explosives will likely be present in a compact design where weight and space are critical. Ensuring the safety of personnel who occupy this equipment is particularly challenging: maintaining continuity of operations is paramount, especially under combat conditions, and evacuation of personnel is often not possible.

2.2.1 New designs of equipment

The long lead-times in military equipment development and procurement programmes mean that some equipment, being built to an established design, is still being procured with halon systems on board. This is especially true for aircraft. However, extensive research and development work and laboratory-scale to full-scale performance testing have all but eliminated the need for the halons in new designs of military equipment.

In a few cases, such as the UK variant of the Typhoon aircraft, weapons platforms are being developed with enhanced passive fire protection and fire control features such that an active fire suppression system is no longer considered to be necessary. Elsewhere, acceptable solutions for new equipment include traditional extinguishants such as foams, dry chemical powders and carbon dioxide, the newer halocarbon alternatives, and new technologies such as water mist/fine water spray, fine particulate aerosols and inert gas generators. Specific examples that are now being implemented include:

- In <u>armoured fighting vehicles</u>, HFC-125, HFC-227ea, an inert gas (nitrogen) or dry chemical powder are being used for the engine compartments of Challenger 2 and Warrior vehicles being manufactured in the UK, Leopard 2 vehicles in Germany and Stryker and AAAV vehicles in the US. A hybrid HFC-227ea/dry powder system is about to be introduced for crew compartment explosion suppression on the Stryker, AAAV and Crusader vehicles. The US Army is adopting CO2 extinguishers to replace the halon 1301 portables installed in its vehicles.

- In <u>military aircraft</u>, HFC-125 is being used for engine nacelles on the Nimrod maritime patrol aircraft in the UK and the F-22 Raptor fighter and pyrotechnic inert gas generators protect the V-22 Osprey tilt-rotor aircraft in the USA; on-board inert gas generating systems or explosion suppression foams are being used for the inerting of fuel tank ullage spaces in the US-designed F/A-18E Super Hornet.

- In <u>naval vessels</u>, HFC-227ea, fine water spray, hybrid HFC-227ea/fine water spray, foam or carbon dioxide are being used for the main machinery and other spaces of new vessels of the UK Royal Navy and US forces.

In many cases, particularly where the scope for fundamental changes in equipment design has so far been limited, the acceptance of these alternatives has not been without some trade-off. This can include a weight or space (and hence platform performance) penalty, a reduced – but still acceptable – level of fire extinguishant performance, or an additional toxicity hazard that must be managed. If foams or powders have been selected, there are implications for the decontamination of protected areas after a system has been discharged. In all cases, operational and maintenance procedures must be changed and personnel suitably trained.

2.2.2 Existing, in-service, equipment

Conversion of halon systems in existing military equipment is usually more difficult than accommodating alternative fire protection solutions in new weapons platforms. This is primarily because the scope for any post-construction alterations to the platform is more limited, and because the conversion programmes must be accommodated without adversely affecting the operational availability of the equipment. Not infrequently, the original design of the weapons platform was predicated on the use of halon and its high level of effectiveness. In some cases, it is not technically feasible to replace the halons with any of the current range of alternatives whilst retaining an acceptable level of fire protection.

The extent to which conversion programmes for existing equipment have been started or completed varies from country to country. Important factors are the unique characteristics of each nation's forces, the wide range in the technical difficulty of possible solutions, the strength of political will to finance the conversion programmes when there are always competing priorities, and the prevailing legislative position. In some cases, in Europe and Australia for example, legislation has driven changes to certain halon systems that would not be considered acceptable to military organisations elsewhere.

The technical and economic constraints on conversion of existing front-line equipment can prove to be formidable. The alternatives identified for new equipment may not be technically and economically feasible for use in existing equipment. The commercially available alternatives have an inferior intrinsic performance, higher toxicity or questionable environmental characteristics, or a combination of these properties. Whilst these disadvantages may be managed by the careful design of new equipment to ensure that the fire protection *system* is effective and safe, there is more limited opportunity within the constraints of existing equipment. The toxicity of halon alternatives is especially important to the military sector because there is a significant risk that personnel will be exposed to extinguishing concentrations of the agents or high levels of their breakdown products in operational situations.

The feasibility of conversion of in-service systems will depend significantly on whether the work can be accomplished during routine maintenance periods or whether a separate programme, entailing the withdrawal of equipment from service, is necessary. If conversion requires major modifications to a protected enclosure, the work will only be technically and economically feasible at times of major equipment refit or upgrade, such as mid-life updates. Deployment of equipment and associated maintenance, refit and upgrade schedules are often planned many years ahead and cannot readily be changed, even in peacetime. Thus, even if it is technically feasible to convert a particular type of equipment, it may not be economically justifiable, or practically acceptable, in the short term. Conversion programmes can therefore often be lengthy and any unforeseen operational commitments will potentially delay their completion.

Despite all these difficulties, good progress has been made in some areas and by some countries:

- The use of halons in protecting the engine compartments of existing armoured fighting vehicles is diminishing as many nations implement conversion programmes. The UK has identified HFC-227ea and a dry chemical as the preferred alternative extinguishant and has planned a fleet conversion programme with completion expected by 2006. The US Army has converted its Bradley and MLRS (Multiple Launch Rocket System) vehicle engine systems to HFC-227ea. A dry chemical powder has been selected for the Abrams vehicles, which are being converted during scheduled maintenance programmes. The engine compartments of Germany's Leopard armoured fighting vehicles are now protected by an inert gas and the armed forces of Denmark and the Netherlands are adopting the same solution. Sweden, in collaboration with a number of countries, is evaluating HFC-236fa for both crew and engine compartments in its variants of the Leopard and Canada is evaluating HFC-125 for the engine compartment of its vehicles. The armies of the US, the Netherlands and Australia have replaced most of their vehicle portable extinguishers with carbon dioxide equivalents and the UK has replaced portable extinguishers mounted on the outside of its vehicles with dry powder alternatives.

- On existing naval vessels, a number of conversion programmes are being considered or are underway for the smaller, normally unoccupied, spaces such as engine rooms or diesel or turbine modules. In these applications, carbon dioxide or HFC extinguishants have been found acceptable. The US Army has converted machinery spaces in over 60 of its watercraft to use an HFC-227ea/water spray hybrid system. Australia and Germany began conversion programmes to replace main machinery space halon systems with HFC-227ea and carbon dioxide respectively. However, in both cases, difficulties were experienced with ensuring adequate fire extinguishing performance without adverse consequences for platform capability and crew safety and the design process for further conversions is on-going. In Denmark, where HFCs are not acceptable as fire extinguishants because of their high global warming potential, nitrogen systems are being installed to protect the engine compartments of surface ships.

- The opportunity for conversion of existing aircraft halon systems, whether military or civilian, remains very limited, though a number of studies are underway and considerable investment in potential alternatives continues. In some circumstances, slight changes to a fire protection system design could result in significant improvement in the performance of an extinguishant, such that a less effective agent might be acceptable with little or no weight penalty. Several aircraft engine nacelle conversions are being evaluated in the US and UK. In the lavatory waste receptacle application, current halon systems have been found to be an over-engineered solution; an HFC alternative probably represents one of the very few examples of a potential "drop-in" solution, though HTOC is not aware of any conversion programmes that are underway. An opportunity for modification of these systems would certainly present itself when the halon systems were discharged. Otherwise, the best time to consider a conversion programme would be during periods of major equipment upgrade or modification.

Generally, with the exception of the examples described above, very significant technical, economic and logistical barriers to conversion remain. To maintain Parties' levels of national security, and the safety of military personnel, halon systems may need to continue in service for the remainder of the operational life of the equipment concerned.

2.3 Responsible management – minimisation of halon use and emissions

For the applications where an acceptable alternative for in-service equipment has not yet been implemented, operational and maintenance procedures and training have been improved to minimise emissions to atmosphere and to conserve the limited supplies of recycled and recyclable materials that are available. These changes were implemented rapidly and had a significant impact. Thus emissions from most military uses are now small relative to the size of the installed base. The stocks available from converted and decommissioned systems and extinguishers, both from within military organisations and from the open market, have been banked by many nations to support their critical military uses for which alternatives are not available or have not yet been implemented. The reliance upon these stocks will continue for at least the next thirty years to support equipment that cannot be converted and which has a long anticipated service life. Of course, the quantities and range of equipment involved will steadily reduce in magnitude. It is not envisaged that any further production will be required to support military equipment.

2.4 Military-sponsored research into halon alternatives

Because of the need for additional solutions to enable the conversion of in-service Critical Uses where current alternatives are not feasible, military organisations continue to sponsor short, medium and longer-term studies of novel fire extinguishants.

One example is the US Department of Defence's Next Generation Fire Suppression Technology Programme (NGP). This programme continues to deliver increased understanding of flame suppression processes and chemistry and is evaluating novel fire suppressants and agent delivery techniques. Originally envisaged as developing and demonstrating feasible, retrofittable, fire protection solutions to replace halon 1301 in aircraft, ships, land combat vehicles and support facilities by 2005, its scope has now narrowed to concentrate on more practical fire protection solutions for new and existing aircraft applications. The current status of the programme and a summary of its outputs so far can be viewed on the NGP website[2].

The Advanced Agent Working Group (AAWG), a US/UK industry and government collaboration, is aiming to find and characterise an alternative to halon 1301 for use with existing halon system hardware. This work is focussing primarily on bromine-containing tropodegradable halocarbons that are effective extinguishants that degrade rapidly in the lower atmosphere, thereby minimising their ozone depletion and global warming

[2] www.bfrl.nist.gov/866/ngp

potentials. The UK Ministry of Defence is funding participation in the AAWG by QinetiQ with a study of phosphorus-containing compounds.

Military organisations are also working closely with airframe manufacturers and regulatory authorities to identify and certify halon alternatives for aircraft applications. Much of this collaboration builds upon earlier work on halon alternatives for military aircraft engine nacelles that was undertaken by the US Air Force.

The UK MOD is actively investigating the feasibility of using pyrotechnically generated aerosols for fire protection of naval vessel main machinery spaces, high voltage electrical spaces and prime mover enclosures. Real scale tests have given a much better understanding of the design and performance criteria for these systems. Currently, the engineering issues associated with implementing such systems are being examined.

2.5 Summary

The military sector has shown leadership in, and devoted considerable effort to, the identification, development and testing of suitable halon alternatives, with much of the benefit transferring to the civilian and commercial sectors. As a result of this effort, much progress has been made and HTOC is unaware of any new facilities or new designs of military equipment that now require the use of the halons. The conversion of systems in existing, in-service equipment is more challenging, but conversion programmes are underway or completed for several important applications. In other cases, very significant technical, economic and logistical barriers to conversion remain. To maintain Parties' levels of national security, and the safety of military personnel, halon systems may need to continue in service for the remainder of the operational life of the equipment concerned. Halon use by the sector is well managed. Many organisations have established dedicated halon storage and recycling facilities to support Critical Use equipment for as long as is necessary. Future Essential Use production of additional quantities of any halon for the military sector should therefore not be necessary.

Table 2-1 Continuing uses of halons and implemented alternatives in the military sector

Application	Protected Space	Protected Risk	Halon	Implemented Alternatives	
				Existing Equipment	New Designs of Equipment
Military (Armoured Fighting) Vehicle	Engine Compartment	Class B	1301 1211 2402	HFC-227ea Dry Powder Inert gas	HFC-227ea Dry Powder
	Crew Compartment	Class B Explosion	1301 2402	None	Water mist, HFC-236fa HFC-227ea/dry powder (hybrid system)
	Portable Extinguisher	Class A, B, Electrical	1211	CO2 Dry powder (external)	CO2 Dry powder (external)
Military Aircraft	Engine nacelle	Class B	1301 1211 2402	None	HFC 125 IGG
	APU	Class B	1301 1211 2402	None	HFC 125 IGG
	Dry Bay	Class B (Explosion)	1301 2402	None	IGG
	Cargo Bay	Class A (Deep seated)	1301	None	None
	Fuel Tank Inerting	Class B (Explosion)	1301	None	OBIGGS
	Portable Extinguisher	Class A, B Electrical	1211 1301	None	CO2 HFC
	Lavatory	Class A	1301	None	None
Naval vessel (Surface Ship)	Main Machinery Space (normally occupied)	Class B	1301 2402	HFC227ea CO2	HFC-227ea CO2 Water mist
	Engine Space/Module (normally unoccupied)	Class B	1301 1211	HFC-227ea Dry Powder, CO2 HFC-227ea/water spray (hybrid system)	HFC-227ea Dry Powder CO2
	Flammable Liquid Storeroom	Class B	1301 2402	None	HFC-227ea/water spray (hybrid system)
	Electrical Compartment	Class A Electrical	1301 2402	None	HFC-227ea
	Fuel Pump Room	Class B	1301	None	HFC-227ea Foam
	Command Centre	Class A Electrical	1301 2402	None	None
	Flight Line/Hangar	Class B	1211 2402	Foam Dry Powder	None
Naval vessel (Submarine)	Machinery Space	Class B	1301 2402	None	None
	Diesel Generator Space	Class B	1301 2402	None	None
	Electrical Compartment	Class A Electrical	1301 2402	None	None
Military Facilities (Buildings)	Command Centre	Class A	1301	CO2, HFC-227ea Inert gas	Sprinkler CO2, Inert gas
	Research Facility	Class A, B	1301	CO2, HFC-227ea Inert gas	Sprinkler CO2, Inert gas
	Computer Centres Electrical Compartments	Class A Electrical	1301	CO2, HFC-227ea Inert gas	Sprinkler CO2, Inert gas
Military Airfield	Hardened Aircraft Shelter	Class B	1301 1211	Foam	Foam
	Crash Rescue Vehicles	Class B	1211	Dry Powder Foam	Dry Powder Foam
	Flight Line Portables	Class B	1211	Dry Powder, Foam CO2	Dry Powder, Foam CO2

3. Civil Aviation

3.1 Introduction

Although the incidence of in-flight fires is low, the consequences in terms of loss of life are potentially devastating, and the use of halon to help guard against such events has been extensive. Aviation applications of halons are amongst the most demanding uses of the agents, and require every one of their beneficial characteristics. Particularly important are dispersion and suppression effectiveness, which must be maintained even at the low temperatures encountered at high altitude, to exercise duty of care with minimal toxic hazard to the health and safety of ground maintenance staff and also of passengers and flight crew, who could be exposed to the agent and any decomposition products for periods as long as several hours; and the weight and space requirements of the agent and associated hardware.

Also significant are short and long term damage to structure or contents resulting from the agent or from its potential decomposition products in a fire; avoidance of clean-up problems; suitability for use on live electrical equipment, effective on the hidden fire; installed cost of the system and maintenance cost over its life. It is no surprise, therefore, that it is in an area which is proving technically difficult to satisfy - it is for these reasons many aviation applications are generally accepted as “critical” in accordance with the terms of Decision VII/12 by reference to the criteria set out in Decision IV/25 and European Union Regulation 2037 - Annex VII.

In 1993, the USA - Federal Aviation Administration, UK - (Civil Aviation Authority), Europe - (Joint Aviation Authority), Canada - (Transport Canada), Aviation established a working group which included all sectors of the Commercial Aviation Industry to evaluate the effectiveness of halons and revaluate alternative fire suppression agents. It was agreed that a number of task groups would be formed to develop minimum performance standards for the following risks; Engines nacelles (including APU’s), cargo compartments, lavatory waste bins and hand-held extinguishers. Each task group had to do research and identify three alternative agents with a potential to replace halons 1211, 1301 and 2402. Recently the focus of this group has been expanded to include all aircraft fire protection systems research and development.

There are five general types of fire and explosion protection applicable to aircraft, these are: total flood fire extinguishment, total flood fire suppression, explosion suppression, inertion against explosions and fires requiring streaming fire extinguishment.

In total-flood applications, an extinguishing agent is discharged into an enclosed space to achieve a concentration sufficient to extinguish or suppress an existing fire. The agent concentration that a system/agent combination is designed to produce is termed the “design concentration.” Total-flood extinguishment usually uses fixed systems (e.g. nonportable systems attached to a protected structure) with either manual or automatic activation. Automatic systems detect a fire and automatically discharge the extinguishing agent. Total-flood applications include protection of enclosed spaces such as aircraft cargo compartments.

In streaming applications, an agent is applied directly onto a fire or into the region of a fire. This is usually accomplished using manually operated wheeled or portable extinguishers. Hand-held portable extinguishers provide fire protection in aircraft passenger compartments in the same manner.

It is important to note that the aviation industry has significantly improved control measures in place since 1992 this has made halon almost none emissive except for fire suppression use.

3.2 Environmental

Although airworthiness regulations do not require the use of a particular fire suppression agent, halons have been the agents of choice of airframe manufacturers. For all practical purposes, production of halons has ceased under the provisions of the Montreal Protocol. The primary environmental characteristics to be considered in assessing alternative chemical options to halons are Ozone Depletion Potential (ODP), Global Warming Potential (GWP), and Atmospheric Lifetime. The agent selected should have environmental characteristics in harmony with international laws and agreements, as well as applicable national, state, and local laws. An agent that does not have a zero or near zero ODP and the lowest practical GWP and Atmospheric Lifetime may have problems of international availability and commercial longevity.

3.3 Toxicology

The toxicological acceptability of a chemical option to halons is dependent on its use pattern. As a general rule, the agent must not pose an unacceptable health risk for workers during installation, maintenance, or operation of the extinguishing system. In areas where passengers or workers are present, or where leakage could cause the agent to enter the passenger compartment, at no time should the cumulative toxicological effect of the agent, its pyrolytic breakdown products, and the byproducts of combustion pose an unacceptable health risk during probable normal and failure conditions.

There are a number of desirable characteristics for replacement agents. They must have acceptable global environmental characteristics (low ODPs, low GWPs, and low atmospheric lifetime) and an acceptable toxicity. A continuing debate on acceptable levels for these characteristics is expected. The primary reason for using halocarbons, rather than such alternatives as foams and dry chemicals, is that halocarbons are clean, volatile, and electrically nonconductive. Finally, the agent must be effective. This needs to have the same effectiveness as the present halons.

3.4 Commercialised Halocarbon Replacements

The term commercialised is used to refer to materials now being marketed or which are planned to be marketed in the near future. Most of the commercialised agents are Physical Action Agents (PAAs) -hydrochlorofluorocarbons (HFCs), hydrofluorocarbons (HFCs), or perfluorocarbons (FCs or PFCs). The only Chemical Action Agent (CAA) now being commercialised is CF3I.

HCFCs currently face an eventual regulated production phase out. Some restrictions are already in place in parts of Europe. The European Union in many cases has accelerated phase-out dates.

The USA EPA has applied narrowed use limits to the use of perfluorocarbons. PFCs are fully fluorinated compounds, unlike HCFCs or HFCs, and have several attractive features. They are nonflammable, have low toxicity, are exempt from federal volatile organic hydrocarbons regulations, and do not contribute to stratospheric ozone depletion. The environmental characteristics of concern, however, are their high global warming potentials (approximately 5,000 to 10,000 times that of CO2, for commercialised halon replacements) and their long atmospheric lifetimes (approximately 5,000 to 7,000 years for commercialised replacements). As the time horizon increases, the GWP for these compounds also increases, making these compounds particularly undesirable. Although the actual contributions to global warming depend upon the quantities emitted, the long lifetimes make the warming effects of PFCs virtually irreversible.

HFCs are attractive as replacements for ozone depleting substances for three reasons: (1) they are usually volatile and many have low toxicities, (2) they are not ozone depleting as are the HCFCs and because they have lower atmospheric lifetimes than PFCs, they are likely to receive less regulatory action than HCFCs or PFCs, and (3) they have properties similar to those of halocarbons that have been used in the past. This does not, however, mean that HFCs are not receiving scrutiny from environmental organisations. A recent study by the National Institute of Public Health and Environmental Protection, The Netherlands, has projected a significant increase in greenhouse gas emissions due to use of HFCs to replace CFCs and HCFCs. Denmark has announced they plan to phase out all hydrofluorocarbons (HFCs) within the next 10 years due to global warming. Other European countries such as Austria, Norway, and Sweden, are considering regulatory HFC use.

3.5 Technical Requirements

The candidate agents must meet the following requirements. The requirements imposed by the specific threat or application are additional to these requirements. A discussion of requirements or possible requirements by application has been published by the various regulatory authorities.

a. The agent must be suitable for the likely Class of fire. It should be recognised by a technical, listing, or approval organisation - National Fire Protection Association, Underwriters Laboratories, Factory Mutual Research Corporation, EU and ISO Standards - as a suitable agent for the intended purpose.

b. It should be compatible with construction materials in the areas where fires may occur and with materials used in the extinguishing systems. There should be, at most, minimal corrosion problems due to extinguishment, either from the neat agent or from likely decomposition products. This is particularly important for aircraft engines and for areas where contact with electronic components could occur.

c. It should comply with the provisions of the Montreal Protocol. It must have a near zero ozone depleting potential. Low Global Warming Potential (GWP) and atmospheric lifetime are desirable, but presently there are no generally accepted requirements. Nevertheless, GWP and atmospheric lifetimes need to be considered in these analyses.

3.6 Engine and APU Compartment

Airworthiness Regulations require a fire protection system to be fitted to engines and auxiliary power units of commercial air transport aircraft; the use of halon is not mandated, but in practice all such aircraft are protected in this way. A copious fuel supply, high airflows and low temperatures render many non-halon agents adequately ineffective.

Code of Federal Regulation (CFR) Part 25.1195 identifies the requirements for fire suppression systems in aircraft power plants:

1. A fire suppression system is required if other means are not provided to control typical fires, as identified in the CFR.

2. The suppression system must be shown to be effective in quantity of agent, rate of discharge, and distribution by live test during actual or simulated flight conditions.

3. The suppression system must provide adequate, simultaneous protection throughout the compartment.

These requirements apply to all designated fire zones except for combustor, turbine, and tail sections of the turbine engine installations that contain lines or components carrying flammable fluids or gases. These areas are exempted because a fire originating in these sections can be controlled.

An experimental programme has been conducted by the US Air force and overseen by the IFSWG, to evaluate the available alternatives; and additional work is now in progress at the FAA Technical Center. A halocarbon (HFC) was selected; a number of new US military programmes have already adopted this approach, design codes and certification processes have been agreed. However this will incur a significant weight and space (and therefore cost) penalty, making it unlikely to be adopted for retrofit and unattractive compared with recycled halon. There is continued interest in the use of FIC 1311 for this application, but doubts persist regarding its potential toxic impact and how it performs at altitude.

Research test work which took place at the FAA Test Centre on Engine Nacelles have highlighted issues with hot surface ignition. As a result of these findings, revisions have been included in version 3 of the Minimum Performance Standard for Engine Nacelles. There are a number of other technical issues that have not been resolved and work continues in this area. At this time research work to-date state that for commercial aviation there is no alternative to H1301/2402 that will provide the same level of safety with the same weight and space and other essential safety factors to maintain a safe operation for engine nacelles and auxiliary power units.

3.7 Cargo Bays

The majority of cargo bays are located in the lower fuselage beneath the passenger compartment, isolated from it by fixed fireproof liners. In dedicated freight aircraft the main deck is also used for cargo. In ”combi” aircraft, cargo occupies part of the main deck, separated from the passenger accommodation by a movable partition.

Rapid and effective agent dispersion throughout a tightly packed, possibly containerised, cargo bay is a key and demanding consideration. Cargo fires typically involve quantities of Class A (smouldering) combustibles, in some instances it may also be contaminated by small quantities Class B material (flammable liquid), and existing halon systems do not extinguish such fires, but merely suppress them at a level which does not threaten the airframe, flight systems, passengers or crew; aircraft qualified for extended operations may be as much as three flying hours from the nearest adequately equipped airport, and after an initial burst of halon to knock down the fire, a continuing slow discharge is bled into the protected areas to maintain a suppressing concentration against the diluting effects of ventilation and leakage until a safe landing can be achieved. Many of these fires are not easily characterised, but the IFSWG task group has defined and specified a Cargo Compartment Minimum Performance Standard with four different fire test scenarios in order to address the variety of fires.

A cargo compartment fire suppression system must meet the following fire test requirements.

a. The system must suppress a Class A deep-seated fire (bulk-loaded cargo) for at least 30 minutes.

b. The system must suppress a Class A fire inside a cargo container for at least 30 minutes.

c. The system must extinguish a Class B fire (Jet-A fuel) within 5 minutes.

d. The system must prevent, either by fire control or inerting the compartment, the explosion of an explosive hydrocarbon mixture.

The cargo compartments are normally pressurised with a minimum normal pressure corresponding to an altitude of 8,000 feet. In flight, the temperatures are maintained above freezing by several means, including ventilation. Fire in the cargo compartments is detected by smoke, ionization detectors or thermal sensors.

The fire detection system is required to detect and provide visual indication of the fire to the flight crew within 1 minute after the start of a fire. Also, the system must be capable of detecting a fire at a temperature significantly below that at which the structural integrity of the airplane is substantially decreased. Fire detection systems are certified using an FAA-approved fire simulator.

It is desirable for the agent to have the following attributes.

a. Because cargo compartments can be used for transportation of animals, it is desirable that the agent has a low toxicity, and that it not be an asphyxiant at the concentrations required for extinguishment. In addition, no agent can be allowed that could leak into occupied compartments in toxic concentrations. Federal regulations require that "There are means to exclude hazardous quantities of smoke, flames, or extinguishing agent from any compartment occupied by crew or passenger." Airframe manufacturers meet this by design. Typical cargo compartments contain a fibreglass liner, which is tested with a smoke generator for leakage and with burners for flame penetration. Escape of smoke or extinguishing agent in hazardous quantities from cargo compartments of properly maintained aircraft is unlikely.

b. The agent should not impose additional (in addition to system recharge and check-out) departure delay following a false discharge. The present practice is to control ventilation and drafts within the compartment prior to the activation of the suppression system. However, there is a small infiltration into the compartment through the compartment walls (typically fibreglass liner) and leakage out of the compartment through door seals. The general practice is to divert to the nearest airfield on detection of a fire. On long range (overseas) aircraft, suppression is required for up to the maximum diversion time which could be in excess of 200 minutes.

For this range of flight, the agent/system for cargo compartments must also meet the following requirements.

a. The agent/system must be suitable for fires likely to occur. These include Class A and B fires and hazardous materials.

b. The agent/system must be able to provide fire suppression over a period of up to the maximum diversion time, which could be in excess of 200 minutes, depending on the aircraft type and route structure.

The withdrawal of CFC aerosol propellants in favour of propane and butane introduces a further threat of explosive fire resulting from the potential for thermal overpressurisation failure of such aerosol cans in smouldering luggage followed by ignition of the gases released. Livestock may be transported in these bays, and the agent selected should not pose an unacceptable toxic hazard. Finally, although the direction of airflow is designed to be exclusively from the passenger compartment into the cargo bay, reverse leakage is known to occur, and its likelihood is increased by the disruptions associated with a fire; thus traces of agent or of its decomposition products should not pose an unacceptable toxic hazard to passengers.

A Minimum Performance Standard for Cargo Compartment Gaseous Fire Suppression Systems has been developed and published. The FAA has test data now available on the performance of Halon 1301, HFC 125, HFC-227EA, PGA and water mist. MPS requirements for a 2,000 ft^3 cargo compartment is as outlined in the table below.

Table 3-1. Acceptance Criteria for a 2000-cubic foot Cargo Bay

Fire Scenario	Maximum Temperature °F (°C)	Maximum Pressure psi (kPa)	Maximum Temperature Time Area °F-min (°C-min)	Comments
Bulk Load	730 (387.8)	a	11,900 (6593)	Temperature limit starting 30 seconds after suppression system activation. Temp.-Time area for 30 minutes starting with suppression system activation.
Containerised Load	670 (354.4)	a	15,400 (8538)	Temperature limit starting 30 seconds after suppression system activation. Temp-time area for 30 minutes starting with suppression system activation.
Surface Fire	1250 (676.7)	a	3,270 (1799)	Temperature limit starting 30 seconds after suppression system activation. Temp.Time area for 5 minutes starting with suppression system activation.
Aerosol Can	a	0	a	There shall be no explosion.

Further research is taking place in this field, it is being performed by the USA-FAA and European-JAA. However, there is no indication that there is a ready made replacement for halons, but research and testing will continue.

3.8 Lavatory Trash Receptacle

Lavatories are located in the pressurised aircraft cabin with environmental conditions similar to the conditions in other occupied areas. The likely fire threat in the lavatory trash receptacle would involve Class A materials (paper and paper products), with the typical ignition source being burning materials discarded into the container, such as a lit cigarette. The trash containers are designed to contain the likely fire. No fire detection system is provided in the container. Rulemaking was implemented on April 29, 1987, that required each lavatory trash container be equipped with a built-in automatic fire extinguisher that discharges automatically into the container upon the occurrence of a fire. In order to accomplish this, the extinguisher bottle incorporates a eutectic device at the end of a tube directed into the container. In the event of a fire the heat generated will melt the eutectic tip, releasing the agent directly into the receptacle. Currently, all aircraft lavatory disposal receptacle fire extinguishers use halon 1301 as the fire extinguishing agent.

A relatively small amount of agent (100 grams of 1301) is effective in extinguishing this type of fire. For this reason, suitable gaseous replacement agents such as HFC 227ea and HFC-125 can be used in this application, as the additional amount of agent required to extinguish the fire is negligible.

The agent for trash containers must meet the following requirements in addition to the essential requirements identified in the Minimum Performance Standard.

a. The agent must extinguish a Class A (paper towel) fire as defined in the Minimum Performance Standard (MPS).

b. The agent must have a toxicity such that, if the same quantity of agent used for the trash container is released into the entire lavatory, the NOAEL is not exceeded.

This is one of the areas where research and testing has proved that there is a suitable alternative suppression system available for this application, which meets the criteria for space and weight, toxicological factors, and costs identical to that of halon systems. The small negative is that replacement agents have a global warming potential, but with such small amount of agents stored and used it would not be a significant environmental factor. This is an area where commercial aviation could now develop a technical business case for change without a financial penalty and not reduce the fire safety of the aircraft.

3.9 Hand-Held Extinguishers

Portable extinguishers are required to be carried on board all commercial air transports above a certain passenger capacity. The vast majority of the incidents in which they are used are readily addressable by a suitably rated standard hand held extinguisher. There are documented instances of “hidden” fires in areas which are inaccessible in flight and have been extinguished successfully using halon 1211 and it is likely that other agents would have failed. Rare though these occurrences are, they could have led to loss of the aircraft and its occupants, and for this reason halon 1211 “or equivalent” is mandated in Airworthiness Regulations. A programme of work, sponsored by the UK Civil Aviation Authority, and performed by Kidde International Research and USA-FAA had led to the development of a defined test method which allows portable extinguishers already having a suitable conventional rating to be assessed for their effectiveness against representative “hidden” fires.

The FAA has defined a representative and reproduceable test on petrol-soaked aircraft seat to deal with the terrorist or hijack threat.

For effectiveness, ease of use, weight and space, dealing with hidden fires, little toxicological problems and ease of training of flight and cabin crew has established halon 1211 as an excellent fire extinguishing agent and does not create a condition within the passenger cabin that would concern the passengers.

Since 1992 the use of halon 1211 for training has stopped, with simulation using water as the training measure. This has proved most effective over the past 10 years. This has the effect of halon 1211 becoming almost none emissive.

A hand-held fire extinguisher for aviation use must meet the following requirements. These requirements are specified in detail in the Minimum Performances Standards.

a. Any hand-held fire extinguisher adopted for final use shall be listed by a listing organisation such as UL or equivalent, be of a specific rating, and be of a size and weight that a typical flight attendant can use. The smallest recommended hand held extinguisher has a UL 5-B:C rating in accordance with the UL 711 Standard or a BS 3A:34B rating in accordance with British Standards. This corresponds to 2.5 pounds for a halon 1211 extinguisher. It is expected that this UL 5-B:C or BS 3A:34B fire-extinguishing ability along with a demonstrated ability to extinguish a hidden fire will be required for agents used in this application.

b. The extinguisher must be able to extinguish fires in indirectly accessible spaces (hidden fires) as effectively as halon 1211. It is desirable that the agent be sufficiently volatile to allow expansion and penetration into such spaces. Hand held extinguishers are by nature streaming agents; however halon 1211 has the ability to also function as a flooding agent. To insure no loss of safety, replacement agents must maintain this ability. A hidden fire test has been developed to assess the firefighting performance of the hand held extinguisher/agent combination in a flooding scenario.

c. The extinguisher must have an acceptable toxicity for use where people are present and must not cause unacceptable visual obscuration or passengers discomfort. The combined toxicity of the agent and fire products must not be unacceptable for use in an aircraft fire under in-flight conditions.

A Minimum Performance Standard has been published. USA Underwriters Laboratories is performing tests on hand held extinguishers using an alternative agent for equivalency of halon 1211 extinguishers. Two hand held extinguishers have been approved for aircraft cabin use. One is a HCFC and the other is a HFC substance. Both of these units do not fit into the same space and weight criteria and also have a significantly higher global warming potential. One of the important aspects that needs to be taken into consideration with this change is that training costs will increase significantly. Because fire suppression performance of these substances is different to halon 1211, it is most likely that crew will need to be trained with the real material as a substitute is not likely to provide the level of competency that would be required for certification. The replacement cost for change over may appear on first impression to be reasonable, but when full training costs are added it will make it 4 times more expensive than halon 1211 and will have regulatory problems in certain parts of the world due to global warming.

3.10 Fuel Tank Inerting

This application used to be unique to military aircraft, however, there have been a few major aircraft accidents where the cause may have been due to technical problems within the aircraft fuel tanks. This has resulted in the USA FAA acquiring a B747 SP aircraft to carry out this research and testing programme. The FAA issued an Advisory Circular some time back, and this is due to be updated as a result of new information made available as a result of the current test programme. It is unlikely that a halocarbon will be used for this risk, it is more likely to be a nitrogen system if adopted at some future date.

3.11 Flightline

Protection of aircraft and their occupants while on the ground, for instance during preparation for flight, was traditionally covered by the provision of halon 1211 wheeled appliances in the ramp area. Most operators have already replaced these with foam, dry chemical or carbon dioxide extinguishers, depending on the particular needs and circumstances. This is an area where halon 1211 can be removed because the alternatives are approved and listed.

3.12 Crash Rescue Vehicles

There is a licensing requirement for complementary fire suppression and extinguishing media to be carried on Emergency Responding vehicles. Halon 1211 because of its excellent fire control performance has been the agent used for many years . Some countries and regulators continue to use this agent.

Extensive testing has taken place on replacement agent and some regulatory bodies now accept alternatives such as Dry Chemical, CO2, Halongenated agent, and this is included in the ICAO Annex 14 standard. There is an opportunity subject to regulatory approval to replace halon 1211 with alternative materials.

Some Military establishments consider that there are still outstanding technical issues to be resolved, before they consider such a change.

3.13 Halon Banks

It is clear from the foregoing that halon will continue to be needed for several aviation applications, probably for a considerable period of time. Even if new designs adopt new agents and approaches, retrofit of existing aircraft and those now being built to current designs is unlikely. The life expectation of these aircraft is thirty years or more.

At present, the halon demands of aviation are readily met by recycling agent being withdrawn from applications in other industries. This source of supply will be dramatically reduced, perhaps to the point of non-existence, long before the aircraft now being built and fitted with halon systems are retired. Those airlines, air forces and other users who have not already done so are strongly advised to consider whether the installed stocks of halon they own in non-flying applications are sufficient to meet their long term needs; to ascertain that these installed stocks are being properly managed to ensure they are redirected to be available for Critical needs when they are in due course decommissioned; and to determine whether it is necessary to procure and store additional agent now, while it is relatively easy to do so, to meet long term critical demands.

To be consistent with this policy, and to maintain their status as suitable purchasers and responsible users of recycled halon, airlines, airframe manufacturers and system maintenance suppliers need to continue to implement policies which eliminate or minimise discharge in testing, training and maintenance.

3.14 New Generation Aircraft

With the world production of halon now close to an end, it is important that for new aircraft design not yet in service, that the manufacturers of the airframes and engines give serious consideration to using alternative fire suppression agents that have been approved and tested by regulatory authorities.

This will become more acute as each decade goes by as the halon bank decreases in size. If the industry does not take steps to control its own destiny now it will be very difficult if not impossible to get a new production essential use agreed by the Parties. Planning should now commence to prevent such a request being made, and prevent a more serious political issue having to be managed in the future.

3.15 Mandatory Halon Decommissioning

Many industries that have been users of halons have for a number of years been decommissioning systems. The halon being removed has been recycled, banked, and in some situations marketed on to another industry with a critical use need. However, in general there are two different approaches to deal with halon decommissioning. Within the European Union lawmakers have chosen the mandatory approach by introducing regulation 2037/2000, which requires the decommissioning of all halon systems by December 2003, except for those on the critical use list as outlined in Annex VII of the regulation. The creation of a critical use criteria has been an experience that has not been done without pain to many industries. Despite the problems and for better or worse the list exists. This list will be reviewed frequently by an expert panel from the section affected. This will be a very technical and challenging process.

For many countries outside of the EU a different method of control measures exists. There is no mandatory decommissioning and no critical list. They have chosen the option to retain halon in a system, and when the protected facility comes to the end of its serviceable life to decommission the system and move the halon on to an essential use. Due to the enhanced maintenance controls, they have made halon systems in ground facilities virtually non-emissive. However, we now find that even by using this criteria we are now getting to the stage where the key industries with a critical need are being identified.

The key factor is to ensure that the aviation industry has a business plan in place that can manage stocks of halons for the future, this may need to be: operators, service providers, airframe and engine manufacturers, to prevent having to make an essential use nomination.

3.16 Conclusions

The aviation industry remains highly active in the search for replacements for halon, and in the meantime has eliminated or dramatically reduced emissions in testing, training and maintenance. Significant progress has already been achieved and, in some applications, technically acceptable replacements are available and have been, or are in the process of being, implemented. However several of the areas where halon is used in aviation present unique and demanding technical challenges. An active programme of work to find suitable approaches for these remaining areas continues, co-ordinated for the commercial aviation industry by an International Aircraft Systems Fire Protection Working Group open to all interested parties. Until these projects reach successful conclusions, aircraft will be reliant on halon for their fire protection and Airworthiness Certification. Support for these and existing aircraft will continue to necessitate recycling, conservation and banking of halon, probably for their expected life of some thirty years; airlines, other users are strongly recommended to review their policies on discharge minimisation and on banking and their preparedness for this long term need.

Where changes are likely to be made it is important that holistic approach is made to that decision process to ensure that level of safety offered to the aircraft crew and passengers is not negated in any way by changes that may be politically moved forward, without the necessary technical substations and significant financial implications for an industry that is the most regulated and competitive in the world.

Although the number of areas where changes can now be made are small, nevertheless where it is technically and economically possible to change these should be a move to do now.

As this is a very sensitive area in terms of safety for the commercial aviation industry it is time that the matter was referred to ICAO for discussion to enable an agreed technical, environmental and commercial business plan be agreed.

4. Merchant Shipping

4.1 Introduction

The status of halons in merchant shipping must be viewed in two different contexts: existing ships already equipped with halons and new ships that are not permitted to employ halons.[3]

At the center of this halon subject is the International Maritime Organization (IMO) which has been the cohesive force to address the halon status in both contexts. In that regard, IMO has …..

- enacted an international ban on the use of halons aboard new ships on international voyages, nearly 2 years before the halt of production of halons in non-Article 5 countries.
- developed and published the approval guidelines and test methods for the systems using halon alternatives on shipboard applications.
- developed recommended procedures for ships with discharged / depleted halon systems to safely move from one port to another where system replenishment is possible.
- established, distributed and has maintained an international listing of halon agent replenishment sources for ships needing a system recharged.

4.2 New Ships

In general, since the 1992 IMO ban on the use of halons on new ships, the industry has found ways to incorporate systems using halon alternatives, both new and old, into the design and construction of new ships. While there have been some difficulties integrating those systems using halon alternatives, as – when compared to halon systems - they take up more space and add more weight to the vessel, the marine industry has found ways to work around these differences.

In addition to other well established agents that had been found acceptable for the protection of shipboard machinery spaces, namely carbon dioxide, high expansion foam or water spray, IMO has developed approval guidelines and test methods for three new types of systems for machinery space protection: water mist,[4] other gaseous agents[5] and aerosol systems.[6] With the development of these guidelines and methods, there have

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[3] Regulation 10, Paragraph 4.1.3 of Chapter II-2 of the International Convention for the Safety of Life at Sea, 2000 Amendment requires "Fire extinguishing systems using Halon 1211, 1301 and 2402 and perfluorocarbons shall be prohibited."

[4] "Amendments to the Test Method for Equivalent Water-Based Fire-Extinguishing Systems for Machinery Spaces of Category A and Cargo Pumprooms Contained in MSC Circular 668, Annex, Appendix B," MSC/Circ.728 International Maritime Organization, 4 Albert Embankment, London SE1 7SR, England: June 1996.

[5] "Revised Guidelines for the Approval of Equivalent Fixed Gas Fire-Extinguishing Systems, as Referred to in SOLAS 74, for Machinery Spaces and Cargo Pump Rooms," Annex to IMO Maritime Safety Committee Circular 848, International Maritime Organization, 4 Albert Embankment, London SE1 7SR, England: June 1998.

[6] "Guidelines for the Approval of Fixed Aerosol Fire-Extinguishing Systems Equivalent to Fixed Gas Fire-Extinguishing Systems, as Referred to in SOLAS 74, for Machinery Spaces;" MSC/Circ.1007, International Maritime Organization, 4 Albert Embankment, London SE1 7SR, England: June 2001.

been many halocarbon, inert gas, water mist and aerosol extinguishing systems installed on both new ships and existing ships.

But a recent survey[7] has illustrated that 9 out of 10 new ships use carbon dioxide systems for the protection of the machinery space. While systems using the new halon alternatives are safer than carbon dioxide in terms of personnel exposure to the agents, they are all more expensive than carbon dioxide systems, thus accounting for the new popularity of carbon dioxide. Irrespective of the safety devices and measures employed with total flooding carbon dioxide systems, the history of deaths and injuries caused by these systems is ample evidence that their wholesale employment will likely produce higher rates of deaths and injuries than we are currently experiencing. This regression to carbon dioxide systems has alarmed many health and safety officials. On the basis of the growing life safety concerns, it is likely there will be efforts to effect a ban on the use of carbon dioxide total flooding systems in normally occupied spaces – including shipboard machinery spaces.

4.3 Mandatory Halon Decommissioning Regulations

The most visible mandatory decommissioning program at this time is the European Union Regulation 2037/2000 which requires the removal of all halon systems by December 31, 2003. This has turned out to be a complex matter for the merchant shipping industry for ships that sail under the flags of the member states of the EU. While there is an exemption for critical uses of halon 1301 ….

> "- for the making inert of occupied spaces where flammable liquid and/or gas release could occur in the military and in the oil, gas and petrochemical sector, and in existing cargo ships;"

The language of the exception is problematical for two reasons: first, the expression "cargo ships" is not defined in the regulation and second, the expression "making inert" is also undefined. How one interprets either one of those expressions will make the difference between shipowners having to remove the halon 1301 systems or not. Further, it is believed the interpretation of this exception is likely to vary from state to state, thus resulting in different enforcement actions across the European Union.

4.4 Existing Ships Equipped With Halon Systems

The existing ships presently equipped with halon systems can be further defined either as those subject to the requirements of a flag state that has a mandatory halon decommissioning program or those not subject to a decommissioning program.
For ships that are subject to the decommissioning regulations, it would seem that few options exist other than removing the halon systems and installing an acceptable alternate type fire extinguishing system. See items 3 and 4 below.
For ships not subject to mandatory decommissioning regulations, the options are broader but still somewhat problematical as they all involve risks, costs or both. These include:

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[7] Wickham, Robert. T, "Status Of Industry Efforts To Replace Halon Fire Extinguishing Agents," Wickham Associates, Stratham, NH: March 2002 http://www.epa.gov/ozone/snap/fire/status.pdf .

1. Continue operating with the halon systems, hoping they will not discharge and - if they do - it will happen somewhere where halon replenishment agent is available.
2. Develop a program within the framework of the maritime industry to establish inventories of recharge halon agent in key locations around the world, the cost and management of which would be shared by a coalition of shipowners and other parties with a financial stake in the fire protection of the ships involved.
3. Make a significant investment by removing the halon systems and replacing them with a new halocarbon or inert gas alternative or a water mist system, any of which will certainly be challenging from an engineering standpoint due to space and weight considerations.
4. Incur a slightly lower cost by removing the halon systems and replacing them with carbon dioxide systems, facing the same engineering challenges (weight and space) as with the other systems with the addition of incurring the life safety risks inherent with carbon dioxide.

It appears that most owners are taking a wait and see position (1 above) on this matter. Not necessarily in the order of importance, there are several reasons for making this choice:

- History has shown us that the discharge of a shipboard fire extinguishing system is indeed a rare occurrence, thus making this option in the eyes of many shipowners a risk worth taking.
- Any of the other three alternatives (2, 3 or 4 above) represents a certain, pre-planned but immediate cost outlay whereas the first option (1 above) represents a low probability but high consequences (cost) scenario.
- While this may change, replenishment halon is readily available worldwide and today at costs in some regions at levels much lower than ever seen before. IMO has published a circular[8] identifying international sources for replenishment halon with the following note on Australia where the world saw its first problems with recharging a marine halon system some years ago:

  > "In view of the stock of recycled halon 1301 now held by the Australian National Halon Bank, the supply of halon to a foreign flag ship in an Australian port can be guaranteed on request. Nevertheless, such a supply will be limited to a "one off" provision essential for the safe operation of the ship.
  >
  > The supply of halon from the Australian National Halon Bank will be subject to approvals from Environmental Australia and the Australian maritime Safety Authority. The Australian national Halon Bank will acquire these approvals on behalf of the foreign flag ship prior to supply.
  >
  > The Australian National Halon Bank is committed to ensuring that a supply of recycled halon 1301 over and above that required for Australia's domestic needs will be retained for the purpose of meeting the emergency needs of foreign flag ships."

[8] "Halon Banking And Reception Facilities," FP/Circ.23, International Maritime Organization, 4 January 2002; available at http://www.imo.org/includes/blastDataOnly.asp/data_id%3D4405/23.pdf

- IMO has developed and published[9] recommended procedures for marine authorities to employ to facilitate the movement of a ship with discharged halon systems to another port where replenishment halon is available. Thus the likelihood of having one's ship tied up for an extended period due to the unavailability of replenishment halon is remote. The complete text of that circular instructs:

1. The Maritime Safety Committee, at its sixty-sixth session (21 May to 5 June 1996), agreed that any ship with a shortage of halon quantities required for the satisfactory operation of its fixed fire-extinguishing system, in ports where halon is not available, should be dealt with under the current established procedures for ships with any major defect or deficiency.
2. The Committee, at its sixty-seventh session (2 to 6 December 1996), having been advised by the Sub-Committee on Fire Protection at its forty-first session, recommended that flag Administrations should, in consultation with the ship's master and owners, and in co-operation with the port State and the authorities of any specified ports of call and the port for rectification of the defect or deficiency, establish a procedure to enable the ship to safely depart the port, call at specified ports for discharge or loading of cargo, and arrive at the port for rectification of the deficiency.
3. Such a procedure should specify the "port and date of departure", the "port of rectification of the deficiency", the "maximum duration of the voyage" and the "ports of call and operations approved en route".
4. Member Governments are advised to consider establishing a procedure along the lines prescribed in paragraphs 2 and 3, when considering invoking flag State equivalent provisions when a ship is found to have a less than fully charged fixed halon fire-extinguishing system for machinery spaces or cargo pump-rooms.

- In light of this, there is a temptation for the industry to conclude this problem is solved and many may have been lulled into believing that is the case.

4.5 Prognosis for Existing Ships Equipped With Halon Systems

It is clear that the world's supply of replenishment (recharge) halon is destined to shrink to a point that the agent becomes prohibitively expensive or not available at all. This is due both to normal consumption and to the extraordinary efforts of some governments to accelerate the process by mandatory decommissioning of halon systems and the destruction of existing agent supplies.

It is also clear that the industry has had many years of experience of equipping both new and – to a lesser degree - existing ships with the systems using various alternatives to halons. The rule making process for accepting new alternatives has been very open, at

[9] "Ships With Reduced Halon Quantities," MSC/Circ.775, International Maritime Organization: 12 December 1996.

least to the 162 member Administrations of IMO, as have been the discussions and decisions about dealing with halon shortages when they occur.

For owners who are subject to the decommissioning regulations, the decision has been made for them. They will likely be removing their halon systems and replacing them with acceptable alternatives.

For those owners not bound by decommissioning regulations, some have or will take actions to assure access to a continuing supply of agent to replenish any halon systems that are discharged. Others will pre-plan the conversion of their halon fire extinguishing systems to an alternate type system. Still others will actually make the conversions. All of the owners who take one or more of these actions will be well prepared for the inevitable halon shortage.

However, once the shortage occurs, many less well prepared owners are going to find that the costly conversions they could have planned and made earlier have become much more costly when done in an emergency manner. In essence, the longer one waits to take action, the more it will cost to solve the problem.

4.6 Conclusion

It is important that the marine industry closely monitor the change in availability of replenishment halon around the world. This is a dynamic situation and it will only be through pre-planning that owners and authorities are going to be well prepared for the inevitable halon shortage. It would be the recommendation of the HTOC that all Parties to the Montreal Protocol and all Members of the International Maritime Organization continually remind the marine industry of the importance of preparing for this problem.

5. Inertion / Explosion Suppression

5.1 Pipelines/Oil and Gas Industry

The use of halon 1301 systems in this industry for explosion prevention (inertion) has been focused on inhospitable locations such as the Alaskan North Slope in the United States and the North Sea in Europe where facilities have had to be enclosed due to the harsh climatic conditions. The process areas in the production modules and the pumping stations live under constant threat of methane gas and crude oil leaks that can lead to potential explosive atmospheres. Halon 1301 has been the agent of choice for mitigating this threat. When reviewing protection measures brought about by the phase out of halon, there are two distinct cases to consider, existing facilities and new facilities. Halon supplies are only a consideration for existing facilities, as new facilities are not being designed to use halon.

5.1.1 Existing Facilities

In most cases, existing facilities were designed and constructed with halon 1301 fixed systems as an integral part of the safety system design as well as the physical layout of the facility. After extensive research, it has been determined that the replacement of such systems with currently available alternatives is economically impossible, and that current research is unlikely to lead to an economic solution. Thus the approach to the phase out of halon has been one of reducing emissions through either of two methodologies, which can be summarized as follows:

i) Reassess the hazards and evaluate whether an inerting system is still required.

   In some aging offshore platforms, process pressures have declined such that an accidental gas or crude oil release could not result in an explosive cloud. The result may be a fire hazard but not an explosion hazard and so the original fixed halon system can often be replaced with an alternative fire suppression system. Although each company has adopted its own philosophy – in some cases driven by national regulations or company directive – a preference for environmentally friendly agents such as fine water mist, inert gases, and CO_2 (for non occupied areas) prevails over halocarbon alternatives in the approach to halon free facilities. The halocarbon agents are perceived to be ‘last resort’ due to other potential environmental impacts, e.g. global warming, which may curtail their availability before the useful life of the protected facility is over.

ii) Contain the halon and avoid spurious releases.

   Typically, if an inerting system has been required then it is also used for fire suppression in the same facility. Thus, in looking at methods to avoid spurious emissions, focus has been on upgrading both fire and gas detection systems. For fire detection, Triple Infrared detectors or, more recently, Close Circuit Television (CCTV) flame detectors, have been employed because of their reliability in response to fire and also their ability to tune out non-fire conditions. In particular, CCTV flame detectors can be programmed with a range of algorithms to determine whether the changes with in its field of view are a fire or not. Such systems are immune to common false alarms such as hot CO_2 emissions; reflections from flare radiation, black body radiation, and hot work such as welding. An added benefit is that an operator can see the hazard in real time and can intervene and prevent a halon discharge if the situation warrants it.

For flammable gas detection, open path gas detectors use the latest infrared laser beam technology. These devices produce an infrared beam that is directed across the area to be monitored. The received light is analysed at two or more frequencies, some of which is absorbed by the target gas or gases; the reference frequency is not. Given the initial and final intensities, the average concentration of gas in the path is calculated and transmitted to the control panel. Different path length options are available, from short-range (about 2 feet) versions for monitoring ventilation ducts, up to instruments capable of traversing 300 feet or more. Such devices are simple to maintain and are immune to the common problems that affect catalytic bead detectors.

5.1.2 New Facilities

For new facilities, companies are now adopting an inherently safe design approach to facility protection. The basis behind this is the identification of the hazards associated with the process and the elimination (if possible) or reduction of the risk associated with them to a level which is as low as practicable.

The primary tool of inherent safe design is the avoidance of hazards to the extent possible. This means preventing the release of hydrocarbons (loss of containment), eliminating the availability of flammable or explosive materials, and minimising electrical and instrument cables. Only when all such measures have been considered, and a residual risk of the hazard still remains, are other risk reducing measures considered. These include those which control incidents, e.g. limit the extent and duration of a hazardous event, and those that mitigate the effects, e.g. active explosion prevention (inerting). In most cases, the new technology detection systems described above are employed to shutdown and blow-down processes, and turn on high rate ventilation systems rather than closing up the space and trying to inert it with an extinguishing agent. Advantage is also being taken of new materials that can withstand the affects of harsh climatic conditions and allow the construction of open facilities to avoid the accumulation of potentially explosive gases. Where an inerting agent is still required in occupied spaces, halon 1301 has been replaced by HFC-23 as part of the facility protection design.

5.1.3 Halon Supplies

As a general statement, it is probably safe to say that in countries where regulatory authorities have not documented the amount of halon within their boarders, no company knows what is available locally to meet its future needs.

In regions/countries where regulatory actions have forced the decommissioning of halon 1301 systems, companies are either stockpiling the resulting surplus (if permitted) or are relying on government/private halon ‘banks’ to supply their ongoing needs. In some cases, regulations require a company to submit their halon requirements to a ‘critical use’ review board to determine whether or not they can obtain necessary supplies.

In regions/countries without regulatory controls on halon use, there appear to be no compelling reasons to stockpile halon as demand is being met from recycled supplies. Companies are making opportune buys as halon comes to market at reasonable cost, and larger corporations are generally maintaining stocks at the 3 to 5 year level. However, clearly they are continuing to rely on market forces to support their needs, and without regulatory direction are unlikely to change this practice.

5.2 Commercial/Industrial Explosion Protection

Outside of the oil and gas industry, halon has been used to suppress explosions in industries such as aerosol fill rooms, grain silos, paper production and milk powder processing plants. In some of these applications, as well as halon 1301 and halon 1211, the agent of choice has been halon 1011.

5.2.1 Aerosol Fill Rooms

In the past, halon 1301 was the standard suppression agent used in North America, whereas aqueous systems were employed in Europe. Since approximately 1996, the standard agent for new systems in North America has been water. Retrofit activity from halon 1301 to water in North America has occurred but only to a limited extent, and significant conversion is not likely absent a regulatory mandate.

5.2.2 Industrial Sector

In North America, although halon 1011 systems were used in the past, dry chemical is now used for 95% of explosion suppression applications. The balance of applications is served with water or an aqueous salt solution. A significant fraction of older halon 1011 systems have been changed over to dry chemical. In the United States, decommissioning is not required, but halon 1011 systems cannot be recharged.

In Europe the default suppressant for industrial explosion protection has been dry powder since the mid eighties, prior to the ozone depleting substances issue, and therefore halon systems were the exception. Most European customers that had old halon 1011 and halon 1211 systems have been contacted and advised that these systems are no longer supported - in most cases this has resulted in system replacement with powder or water. There remain a few residual systems that now need to be decommissioned to comply with the European Union regulations - these are old and unsupported systems. It is believed that within the European Union, no supplier supports or sustains any installed halon-based industrial explosion protection system.

For several years in Europe, a novel suppression device has been available to address dust (or powder) explosions in the food processing industry. The technology employed is called Pressure Hot Water and it is capable of producing very fine water mist in the 10-micron droplet range. The extent of the acceptance of this device is unknown.

5.2.3 Agricultural Sector

One manufacturer supplied halon 1301 systems designed specifically for protection of bucket elevators in grain silo applications until about 1997. The product was subsequently redesigned to employ HFC-125. The use of a gaseous agent having a low boiling point is important owing to the fact that the application requires agent penetration into obstructed spaces often at very low ambient temperatures. However, there has not been a significant move by owners of existing halon 1301 systems to retrofit.

6. Halon Phase-out in Countries with Economies in Transition

6.1 Introduction

Among the 180 countries that are Parties to the Montreal Protocol, 26 are so called Countries with Economies in Transition (CEIT). They comprise the states of the former Soviet Union and those of Central and Eastern Europe that had been members of the Eastern bloc prior to the 1990s, including: Armenia, Azerbaijan, Bosnia and Herzegovina, Belarus, Bulgaria, Croatia, the Czech Republic, Estonia, Georgia, Hungary, Kazakhstan Kyrgyzstan, Latvia, Lithuania, Macedonia, Moldavia, Poland, Romania, Russian Federation, Slovakia, Slovenia, Taijkistan, Turkmenistan, Ukraine, Uzbekistan and Yugoslavia. All these countries have been undergoing a process of major structural, economic and social change, which has resulted in severe financial and administrative difficulties for the governments, industries and communities. These changes have also affected implementation of international agreements such as the phase-out of ozone depleting substances (ODS) in accordance with the Montreal Protocol.

CEITs are not granted any special status under the Montreal Protocol. 20 CEITs operate under Article 2 and, like other developed countries, they were required to implement halon production and consumption phase-out before January 1994, and are obliged to pay contributions to the Multilateral Fund. Romania, Georgia, Moldova and the countries of the former Yugoslavia have Article 5 (1) status, which does not require complete halon production/consumption phase-out until the end of 2009[10]. Armenia is still considering applying for reclassification as an Aritcle 5 Party[11]. These countries, like other Art. 5(1) Parties, are eligible for financial support from the Multilateral Fund for implementation of Montreal Protocol activities. Other CEITs, classified as non-Art. 5(1) Parties, could be supported from the Global Environmental Facility (GEF) fund, via different implementing agencies such as UNEP, UNDP, UNIDO or the World Bank. (*Two of former Soviet Union countries are still Non-Parties, as they have not yet ratified the Protocol.)*

CEITs differ significantly from each other, both with respect to the level of economic and technical development, and the level of organisational infrastructure. These differences are reflected in the progress made in implementing Decisions of the Parties to the Montreal Protocol. In general, countries that are in an advanced state of integration with the European Union have implemented all control measures required by the Protocol. Some Commonwealth of Independent States (CIS) - known more recently as the Newly Independent States (NIS) - however, still have problems in meeting their commitments regarding:

- Regulatory and administrative steps (ratification of the Montreal Protocol and its Amendments);
- Financial contributions (to the Multilateral Fund);
- Reporting data and approaches towards ODS phase-out implementation (e.g. halon management programme);

[10] Status of ratification/accession/acceptance/approval of the agreements on the protection of the stratospheric ozone layer; UNEP/OzL./Rat. 59; 30 June 1998 (znale__ pó_niejsze)
[11] Report of the Implementation Committee under the non-compliance procedure for the MP UNEP/OzL.Pro/ImpCom/28/4, August 2002

- Consumption phase-out.

Some CIS applied for reclassification under Article 5 (1), but only Georgia and Moldova were successful. Other countries have applied, unsuccessfully, for special status[12]. However, the Parties have recognised the special situation of the CEITs and the possible non-compliance in some of the new countries created when the USSR was dissolved. An Ad-Hoc Working Group/Task Force was established by the TEAP to assess the basic problems confronting the CEITs in complying with the Montreal Protocol.[13] Also, the Implementation Committee paid special attention to the CEIT problems at its 27th meeting, encouraging the implementing agencies and the GEF to pay special attention to phase-out projects in those countries[14].

6.2 Halon production and consumption in CEIT

With respect to halon production and consumption, the CEITs can be grouped into the following three categories:

(A) Countries that produced halons and manufactured halon based fire protection equipment;

(B) Countries that imported halons and manufactured halon based fire protection equipment;

(C) Countries that imported halons by importing halon based fire equipment.

The Russian Federation (USSR before 1991) is the only category (A) country amongst the CEITs. Halon production in the Russian Federation is given in Table 8-1. In 1990 halon production in the Russian Federation peaked at 4,250 tonnes (31,700 ODP tonnes in total). During the next decade, the Russian Federation reduced halon production gradually and finally stopped it totally the 20th December 2000 under the international framework of “the Special Initiative for Production Closure of the ODS in the Russian Federation”. From 1994 until 2000, halon 2402 production in the Russian Federation was granted by the Parties to the Montreal Protocol under the essential use procedure, following a recommendation by the HTOC and the TEAP, who supported the Russian Federation government’s requests.

[12] Handbook for the International Treaties for the Protection of the Ozone Layer, Ozone Secretariat, UNEP; Fourth Edition 1996, p.246

[13] Final Report of the TEAP Task Force on CEIT Aspects, TEAP, November 1996

[14] Report of the Implementation Committee under the non-compliance procedure for the MP UNEP/OzL.Pro/ImpCom/27/4, October 2001

Table 6-1. Halon production in the Russian Federation (tonnes)[15]

Halon type	1990	1994	1998	2000
1301	1100			
1211	700			
2402	2450	400	255	90

Central European countries, such as the Czech Republic, Hungary, Poland, Slovakia and Slovenia, can generally be classified as category (B). Their imports included halon 1211 and halon 1301 from CEFIC (Conseie Europeen Federation d'e Industrie Chimique-European Chemical Industry Council) countries, and halon 2402 which came with military equipment from the USSR. Also, the former Yugoslavia can be classified as category (B), with the main imports of halons 1301 and 1211 coming from CEFIC countries. The largest consumers of halons 1301 and 1211 among the CEITs were Hungary and Poland, but even there the level of consumption was lower than that of Western countries. All halon imports ceased in 1994.

The CIS and the Baltic countries fall into categories (B) and (C). They have imported mostly halon 2402 and halon based equipment from the USSR and the Russian Federation. In Decisions VII/18 the Parties to the Protocol allowed the Russian Federation to export controlled substances to Parties that are members of the CIS, including Belarus and Ukraine, but banned export to Non-Parties and re-export to any country. At the same time, that decision together with decisions VII/17 and VII/19 required the Russian Federation and CIS countries to report yearly on the progress in phasing out ODS.[16]

With respect to halon consumption amongst the 26 CEITs, two are currently in non-compliance with their Montreal Protocol obligations – Kazakhstan and Tajikistan. These countries are importing small amounts of halon (5 ODP tonnes in 2002) and have agreed to phase-out consumption in the year 2004. The Implementation Committee and the Parties have requested them to submit annual reports demonstrating decreasing imports. Also, in 2001, Uzbekistan requested an essential use exemption for halon consumption. However, on the advice of the HTOC, the Ozone Secretariat recommended that the country use existing, recovered halon from international sources/banks for supporting its remaining critical needs.

It is virtually impossible to establish data for the baseline year, or data on halon 2402 consumption in CIS and Baltic countries before 1990. Production of halons was reported by the USSR for the whole country, and the transfer amongst the republics was not recorded. It is still difficult to determine consumption data in some CIS, as the accounting systems and customs services are still being developed. Therefore, it is impossible to estimate a halon inventory based on import data. Some countries did estimate their inventories based on information provided by halon equipment suppliers, and verified

[15] Essential Use nomination document

[16] Handbook for the International Treaties for the Protection of the Ozone Layer, Ozone Secretariat, UNEP; Fifth Edition 2000, pp.160-172

them by information received from the main users. According to project documentation requirements, such estimates were done for those countries that have sort financial support either from the GEF or the MLF. Based on project documents such data is currently available for the Russian Federation, Ukraine, Estonia, Latvia, Lithuania, Kazakhstan, Azerbaijan and Yugoslavia. While developing its halon use phase-out strategy, Poland estimated its halon inventory. Hungary reported the size of its inventory based on estimates in its Halon Management Program document, as provided to the Ozone Secretariat in answer to Decision X/7.

Only 2 CEIT could be classified as high volume installed capacity countries – the Russian Federation and the Ukraine. Approximately 10,000 tonnes of halon (more then 60,000 ODP tonnes) is stockpiled in the Russian Federation (installed, as backup and in storage), including a significant amount of halon installed in the Moscow Region (approx. 600 tonnes) owing to its dense industrial infrastructure and the presence of other critical users such as aviation. Of the 10,000 tonnes estimated to be the Russian Federation inventory, about 8,000 tonnes is thought to be in the civilian sector, the remaining 2,000 tonnes being used by the military. The World Bank mission study on the Russian inventory of halon 2402 indicated about 1,850 tonnes located in 3 regions (Siberia, Rostov on Don, Moscow) as well as the civil aviation sector. This data does not cover the military sector or other regions of the Russian Federation.

A preliminary study on the installed capacity, together with estimates made during preparation of the Ukrainian Halon Management Program, indicated that up to 720-780 tonnes of halon (4600-5100 ODP tonnes) is stockpiled in the Ukraine (installed, as backup and in storage). A significant amount of halon is installed in the Lugansk Region due to its dense industrial infrastructure and the presence of other critical users. Of the 690 tonnes estimated to be stored in fire protection systems throughout the Ukraine, about 70% is thought to be in the civilian sector, the remaining 30% being used by the military[17].

Hungary and Poland could be classified as medium installed capacity countries, and Estonia, Latvia and Lithuania as small installed capacity countries. There are no adequate data available for Armenia, Belarus, Kazakhstan, Kyrgyzstan, Macedonia, Taijkistan, Turkmenistan and Uzbekistan. In answer to Decision X/7, Moldova reported to the Ozone Secretariat that there is no use of halon in the country.

6.3 Halon Management Programmes – Implementation of the Halon Use Phase-out in CEIT

In general, each of the CEITs developed their National Halon Management Programmes (NHMP). Their focus and degree of implementation, however, differs depending on country conditions, economy and infrastructure (technical and organisational), as well as geopolitical.

[17] Ukraina sub-project doc, 2001

1. Countries accessing the EU[18]

The Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia – countries that are accessing the European Union in the year 2004 - are well advanced in the process of implementing into national law the Regulation No 2037/2000/EC of the European Parliament and of the Council[19]. Consumption of newly produced halon in those countries stopped in 1994, and the importation of recycled halon is restricted by regulation. The use of recovered halon for new installations is limited to critical applications only. In most of these countries, no new halon equipment has been installed over last 5-6 years.

According to EU Regulation 2037/2000/EC, after 31st December 2002, the use of recovered and recycled halon for re-filling of existing halon equipment will only be allowed for critical applications, as determined in Annex VII of the Regulation . All non-critical systems must be decommissioned by 31st December 2003. In most of the EU accessing CEIT, the deadline for implementation of the above will be the same as the date of full membership to the EU (mid 2004). In general, in these countries the early decommissioning of non-critical, halon-based equipment, and the change to alternative fire protection is already enforced. However, there remain areas that are still protected by halon that are not identified under 2037/2000/EC as critical. Current efforts are directed at changes in fire protection for theses applications.

A broad spectrum of alternative solutions have already been approved and introduced into markets in these countries. They include gaseous systems based on halocarbons - mainly HFCs, and to a much lower extent HCFCs (Czech Republic) and PFCs (Poland). In the Baltic States, a mixture of HFCs (Halotron II) is also in use. Other gaseous alternatives, such as different mixtures of inert gases and carbon dioxide systems, are also broadly used in these countries.. There has also been a significant increase in the use of not-in-kind replacements based on dry powder, water and foam. Medium term action plans are focused on halon recovery and recycling for critical applications, safe storage, and the preparation for destruction. Advanced awareness campaigns to prepare the fire protection community and main users for the incoming changes have been organised in these countries.

2. Russian Federation and Ukraine

The Russian Federation and Ukraine, which were the biggest halon producers and consumers among CEITs, and have the biggest inventories of halon, are a focus of attention of the Parties, the GEF and the implementing agencies.

Production of halons of all types ceased in the Russian Federation in the year 2000, as part of an international agreement between 10 donor countries- Parties to the Montreal Protocol and the GEF. However, new halon is still available from producers' stocks. The price has risen from US$7.5 per kg at the end of 2000, to US$9.5 per kg in 2001, and it is expected to rise quickly to a level of US$10-12 per kg. For the Russian Federation, the most important problem is to create an adequate supply of recovered/recycled halon 2402.

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[18] Reports on Halon Management Programmes

[19] Regulation No 2037/2000/EC of the European Parliament and of the Council on substances that deplete the ozone layer, October 2000

Recovery and recycling of halon 2402 started in 2000. There are three halon recycling units operating in the Russian Federation (one in St. Petersburg and two in Moscow), with a total capacity of up to 600 tonnes per year. Currently the level of recycling is approximately 200 tonnes per annum. The existing recycling capacity was expected to be increased significantly by the addition of four halon recovery, reclaim and storage facilities. Four halon-banking sub-projects were prepared for support by the GEF, and were approved by the Executive Committee. However, due to the elongated and several times postponed bidding process, about US$2,000,000 remained unallocated, and the subprojects were withdrawn. This may result in an insufficient supply of recovered/recycled halon 2402 in the Russian Federation..

Many use areas are still dependent upon halon 2402, especially for fire protection in the military sector, oil and gas industry and nuclear power plants. From the estimated halon 2402 inventory in the Russian Federation, it is evident that there is a sufficient amount of halon 2402 that can be recovered from non-critical applications and reallocated to support the country's critical needs. The Russian Federation will concentrate its efforts on recovery and recycling issues in order to overcome possible difficulties with a shortage of supply for critical country needs. Critical needs for halons 1211 and 1301 are not currently a problem, as those halons are presently available world-wide in banks in other countries. However, there is no certainty that this availability will continue, especially in light of the EU regulation banning the export of recycled halon for non-critical uses. Therefore the Russian Federation's focus on recovery and recycling should include these halons as well.

A wide selection of alternative technologies has been introduced into the Russian Federation. Among gaseous, in-kind alternatives, the following halocarbons are currently available and used: HFC-23, HFC-125, HFC-227ea, FC-3-1-10 and FC-3-1-8. HFC –227ea and HFC-23 are still imported, but their production in Russia has already started. HFC-125 is produced in Russia in sufficient quantities to cover market needs. CEA 410 (FC-3-1-10) was imported in small quantities, and CEA 418 (FC-3-1-8 was produced in Russia in small quantities. However, according to Russian experts, there is now little interest in these products and they will not be used in the future. Specific for Russia is the use of SF6 as an extinguishing agent, however its consumption has decreased significantly. Non-halocarbon gases such as nitrogen, carbon dioxide and mixtures of inert gases (Ar, N2 and sometime CO2) are also in use. The Russian Federation has a new alternative technology of its own, based on solid particulate aerosols. A range of generators is in use in different applications, depending on the area to be protected.

The Ukraine is implementing a National Halon Management Program (NHMP) utilizing technical assistance and support from the GEF. The NHMP is under the supervision of the Ukrainian Scientific Research Fire Safety Institute (USRFSI) of the Ministry of Internal Affairs of Ukraine. The USRFSI has established a "Halon Office" within its organizational structure as a permanent facility to oversee halon management in accordance with the country's obligations and needs. They are currently initiating several GEF funded technical assistance activities. These include the development of a data management system to support a planned national halon data-base that will serve as a "clearing house" on halon availability and needs. It also includes the implementation of training programs to improve inspection and equipment maintenance activities, as well as initiate adequate regulatory approaches. An investment sub-project to be supported by the GEF was proposed to provide basic national operational capability to support the

NHMP. However, the preparatory stage was too long and the implementation schedule too compact. It is believed that the sub-project was withdrawn.

The Russian Federation and the Ukraine have allowed market forces to control the change out of halon systems to alternatives. However, in the current difficult economic situation of the Russian Federation and the Ukraine, "market forces" tends to promote the cheapest solutions – using halon 2402 protection. Therefore, the need for halon for use in new systems and for re-filling of existing halon equipment is much higher than in Western countries or the CEIT that wish to join the EU. No deadline to change "non-critical halon systems" to alternative protection has been set as yet.

3. CIS countries – non Art. 5 Parties

Almost all halon equipment installed in these countries came from the USSR, and after 1991 from the Russian Federation. In most cases the systems are based on halon 2402. These countries have never produced halon. It is important to note that currently, critical needs of these countries can only be supported by recovered halon from the Russian Federation. To facilitate this, the Parties to the Montreal Protocol, in Decision VII/18, allowed the Russian Federation to export controlled substances to Parties that are members of the CIS, including Belarus and Ukraine. However, at this time the Russian Federation has not supported any request for export of halon 2402 to the CIS countries, e.g. Uzbekistan was denied permission by the Russian Federation to import small quantities of halon 2402 to continue their Tupoliev aircraft production (2 aircraft per year).

It has been observed that products, which did not find a market in Western countries due to their poor performances (either toxic or environmental), are aggressively marketed in these countries. It has also been noted that there is a lack of knowledge among involved parties about the necessary sector changes required during the halon phase-out process.

In countries such as Uzbekistan, Kazakhstan, Armenia, Tajikistan and other CIS, there is an urgent need for training that can be provided to all stakeholders in their national language. This training should cover technical issues related to halon use phase-out, including a halon management programme, alternative fire protection technologies, halon systems decommissioning etc. This would assist in the phase-out process and would facilitate long-term, sustainable alternative fire protection choices in these countries.

4. Former Yugoslavia, Romania, Georgia and Moldova

The former Yugoslavia, Romania, Georgia and Moldova, like other Art. 5 (1) Parties are concentrating their efforts on reducing consumption levels to meet 2005 targets. The implementation of the MLF "halon banking" project in the former Yugoslavia should allow this country to reduce halon consumption and achieve its 2005 goals.

There is still a lack of knowledge about the available new alternative fire protection technologies that are in broad use in Western countries. For example, the geopolitical and economic situation in the former Yugoslavia during the past decade has resulted in a limited transfer of knowledge and technical information on changes in the fire protection sector as a consequence of the Montreal Protocol agreement. This was observed during the UNIDO fact-finding mission, and confirmed during the discussions with the fire protection community at the subsequent Halon Management Seminar[20]. The war, and later the UN embargo, resulted in limited activity by Western fire protection manufacturers, who would normally have offered their successful alternative fire protection products to distributors within the country. At the same time, other companies promoted products that have not found wide application in Western countries due to their poor performance (e.g. environmental impact, toxicity). As a consequence, since September 2001, inert gas and HFC based extinguishing technologies that are widely used in Western countries for the protection of occupied areas are not available in the Federal Republic of Yugoslavia. At the present time, only two "clean gas" alternatives have been introduced into Yugoslavia, NAF S-III and Halotron I. Both belong to the group of HCFC blends with non-zero ODPs, and are thus classified as transitional substances. NAF-SIII also contains a PFC and thus its atmospheric lifetime is relatively long. These products are therefore not a long-term sustainable choice for alternative fire protection. The increase in use of traditional extinguishing technologies based on carbon dioxide, powders and foams has also been observed in the country.

Several technical halon sector projects have been implemented in the CEIT. An overview of those projects is given in Table 8-2.

Table 6-2. Technical projects in the halon sector in the CEIT, supported by the MLF and the GEF funds

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Country	Type of the project	Status of implementation	Fund/ Implementing Agency
Azerbaijan	Halon banking	In implementation	GEF/UNDP
Baltic States	Regional Halon Banking	Finalised in 2002	GEF/UNDP
Croatia	Halon Banking	In preparation	GEF/UNIDO
Hungary	Halon Banking	Finalised in 1997	GEF/WB
Kazakhstan	Halon Banking	In implementation	GEF/UNDP
Poland	Training on Alternative Tech.	Finalised in 1994	GEF/WB
Russian Federation	Halon Banking	withdrawn	GEF/WB
Ukraine	Halon Banking	withdrawn	GEF/WB
Yugoslavia	Halon Banking	In implementation	MLF/UNIDO

[20] UNIDO Seminar on Alternative to Halon Fire Protection Technologies & Halon Management Strategy, July 2001

6.4 Conclusions

1. From a technical perspective, the same unresolved issues and current status of selected uses of halon identified in Chapter 1 for Article 5(1) and non-Article 5(1) countries applies to all CEIT. The main difference is the higher economic cost to the communities of the change from halon based fire protection systems to alternatives, in particular in the CIS.

2. The installed capacity of halon 2402 in the Russian Federation is sufficient to guarantee that enough recovered/recycled halon 2402 will be available to meet the critical needs of the Russian Federation and those of the CIS for the foreseeable future. Parties may wish encouraged the Russian Federation to support the critical needs for halon 2402 in the CIS.

3. There should not be any need for an "Essential Use" nomination for any halon in the CIS. However, all CEIT governments should make their "critical users/sectors" aware of the requirement to make appropriate plans to support their future needs. The Russian Federation should focus its attention on the recovery and recycling of halon 1211, 1301 and 2402.

4. In order to facilitate the transfer from halon based fire protection towards long-term, sustainable fire protection alternatives in the CIS, HTOC strongly recommends to the implementing agencies that technical training and assistance be provided to the CIS.

7. Halon phase-out in countries operating under Article 5(1) of the Montreal Protocol

7.1 Introduction

Halons are controlled substances under the Montreal Protocol. Both production and consumption[21] are required to be phased out in accordance with the time schedule as agreed by the Parties to the Montreal Protocol. Article 5, paragraph 1 has given developing countries with a consumption of less than 0.3 tons ODP per capita a 10 year grace period compared to the originally agreed schedule for halon phase-out for developed countries. Accordingly, the Montreal Protocol requirements for developing countries are the freeze of production and consumption at the countries baseline level by 2002, 50% reduction in 2005 and no production and consumption after year 2009. More than than 120 countries are operating under Article 5 of the Montreal Protocol and are eligible for financial and technical support for fulfilling their phase-out obligations under the Protocol.

7.2 Halon Production

The total halon production as reported to the Ozone Secretariat in 1999 by Article 5 countries totaled 24,928 tons ODP and consumption by the same countries was reported as 26,162.9 tons ODP. Unfortunately, no breakdown between 1211 and 1301 are provided by the reports of Ozone Secretariat. The only two halon-producing countries remaining globally are China and South Korea. China has entered into an agreement with the Multilateral Fund for annual reductions of halon production and consumption and final closure of halon production by 2005 for halon 1211 and 2009 for halon 1309. Details on the China production phase-out is provided in the table below.

Table 7-1: Halon production in China as per the Halon Sector Plan.

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Halon 1211	11,644	7,842	5,965	3,978	3118	*2,654*	*1,990*	*1,990*	*1,990*
Halon 1301	618	450	484	428	213	*600*	*500*	*500*	*500*

The production shown in the table above are actual production for the period 1997 to 2002, while the figures from 2002 to 2005 are allowable production under the agreement between China and the Executive Committee of the Multilateral Fund of the Montreal Protocol. Production of halon 1211 will stop by December 2005 while only up to 150 tons per year of halon 1301 will be produced until December 2009. As there are also agreed limits on domestic consumption, the production quota can only be utilized if the export quotas are fully used utilized. Due to very low export in 2000 and 2001, the actual halon production of halon 1301 is much lower than allowed under the agreement. Halon 1301 has not even been produced in 2002 due to limited demand and existing stocks. As

[21] Consumption as defined by the Montreal Protocol meaning production plus import minus export minus destruction.

a result, the halon 1301 produced has agreed to reduce the limit from 600 tons down to 500 tons halon 1301.

South Korea does not have a phase-out agreement with the Multilateral Fund but will follow the phase-out schedule for article 5 countries. Based on information available, and the general MP phase-out schedule for developing countries is followed, the production will be limited to the baseline level of 3,678 tons ODP in 2002, reduction to a maximum of 1,839 tons ODP by 2005 and a complete end to production by 2009. No breakdown on Halon 1211 and 1301 production is available for South Korea, but assuming only Halon 1301 is produced, the maximum production would be 367.8 tons halon 1301.

7.3 Halon Consumption

The phase-out of halon in Article 5 countries has been very successful. The reported consumption of halons in Article 5 countries in 1999 was 26,163 tons ODP of which China and South Korea used 20,798 tons for their own consumption, leaving around 5,365 tons ODP for the rest of the Article 5 countries. Table 2 provides information on regional halon consumption. (The reported consumption by Article 5 countries are around 8000 tons ODP) Again, unfortunately, the report from the Ozone Office of the Montreal Protocol does not provide a breakdown between halon 1211, halon 1301 and halon 2402. Nor does it provide information on how much is used for manufacturing of new halon fire-fighting equipment and how much for servicing.

Based on the information available from a number of Article 5 countries, it can be estimated that the 8000 tons ODP consisted of around 500 tons halon 1301 and 850 tons halon 1211. The consumption figures does not mach the annual production figures due to stocks from previous years in various countries. Based on studies carried under projects prepared for various countries, it is estimated that all halon 1301 and 80% to 90% of halon 1211 are used for servicing of existing halon fire equipment. It should be noted that national records of imports of halons has not always been able to be captured in the actual import. In many cases in past, halon has been imported as fire extinguishing agent and not as an ODS substance. In other cases, halon has been considered as fire equipment and the halon contained in the cylinders has not been reported as ‘fire extinguishing agent” only.

Table 7-1. Regional Consumption

Regional consumption	Production (tons ODP)	2000 Consumption (tons ODP)
Africa	0	1,155.3
South East Asia (minus China and South Korea)	0	500
West Asia (Iran plus the Arab countries)	0	2,247.7
South Asia (India, Pakistan, Bangladesh, Sri Lanka etc.)	0	217
Latin America and the Caribbean	0	236.6
Non Article 5 countries	553.0*	380*
Total	**553.0**	**4736.6**

* 1999 production.

The switch to substitute has, for a major part, been driven by the fire protection industry in the developed countries. With the early stop of production and promotion of substitutes, the fire equipment industry in USA, Canada, Europe and Japan took a central role in developing the fire engineering concept and commercializing substitute fire extinguishing agents and fire protection technologies. Through international, regional and national workshops and seminars, the information on the Montreal Protocol and halon phase-out has been disseminated and the availability of halon substitute fire protection technologies has been promoted and are well now known to the fire protection industry and larger companies and organizations. Especially companies and organizations with hazardous and/or critical operations/installations/applications has been active in identifying alternatives for their applications and developing long-term halon management and phase-out plans.

For the portable fire extinguisher market, ABC powder, foam and CO2 has been the main choice. HCFC have been marketed in some developing countries as an "in-kind halon replacement" and taken over part of the market, especially in South East Asia.

The Multilateral Fund has provided financial support to a large number of fire equipment manufacturers to facilitate their change of business from halon to traditional substitutes. The projects normally include minor modifications of fire extinguisher cylinder production, filling equipment for ABC powder and CO2 extinguishers, testing and certification of new extinguishers and retraining of staff.

Substitutes for halon 1301 for fixed systems has been more diversified. The main substitutes are HFC-227ea (FM-200) and inert gases (Inergen, Argon etc.), while CO_2 fixed fire extinguishing systems, sprinkler systems have regained some market shares. Financial support has been provided to companies to assist them in changing their halon 1301 substitutes. Due to the low costs and availability as general chemicals, HCFC blends has been promoted by many fire equipment companies. The main objectives for the financial assistance has been to ensure that a company would maintain its capacity to sell, install and maintain substitute fire extinguishing systems in a safe manner and without violating existing patents etc. Hence, financial support is provided for licensing fees, development of capacity to design, installation and maintain e.g., HFC-227ea or Inert gas fire extinguishing systems, design standards and software for system design etc. Financial support has also been provided for training of staff in maintaining substitute fire extinguishing systems, storage tanks, filling equipment and recycling equipment for servicing purposes as relevant.

Funding has in most cases been given on a national level as part of an overall commitment from the fire protection industry to stop the use of halons for new fire extinguishers and fire extinguishing systems. In some countries, a ban on sale of new halon fire equipment has been supported by national regulations and the MLF has financially supported national programs in countries like China, Jordan, Philippines, India, Malaysia, Thailand.

7.4 Halon Management and Banking

Financial support for setting up halon management and halon banking operations has been given to a total of 15 projects covering 32 countries provided under the Multilateral Fund. The funding of halon banks has been based on the guidance provided by the HTOC and the two Canadian bilateral halon management and halon banking projects for Brazil and Venezuela.

Table 7-2. National Halon Management and Banking Projects Financed by the MLF

Name of country	Expected completion	Import of halons to be banned	Implementing Agency
Argentina	Dec. 2000	June 2001	World Bank
Algeria	Jan, 2005	July 2006	Germany
Brazil	[1996]	[1998]	Canada
Egypt	Jan, 2004	July 2004	UNDP
India	Jan 2004	July 2004	Canada/Australia
Indonesia	April 2003	October 2003	World Bank
Iran	Aug 2003	Jan 2004	France
Jordan	Dec 2003	June 2004	World Bank
Malaysia	July 1992	Jan 1997	World Bank
Mexico	Jan 2005	July 2005	UNDP
Nigeria	Aug 2005	Jan 2006	Germany
Syria	Aug 2004	Jan 2005	France/Germany
Thailand	Dec 2003	June 2004	World Bank
Turkey	Dec 2004	July 2005	World Bank
Yugoslavia	Jan 2004	July 2004	UNIDO
Venezuela	1996	Jan 1998	Canada
Vietnam	NA	NA	UNIDO

Table 7-3. Regional Halon Management and Halon Banking Projects Funded by MLF

Regional Bank Operations	Expected completion	Import of halons to be banned	Working with
African Region I HMP (Ethiopia, Botswana, Kenya, Lesotho, Namibia, Tanzania, Zimbabwe)	Jan, 2005	July 2005	Germany
African Region II, (Benin, Burkina Faso, Cameroon, Congo, Congo DR, Guinea)	Aug 2005	Jan 2006	UNDP
West Asia (Bahrain, Qatar, Yemen, Lebanon)	Oct 2001?	April 2002?	France, Germany UNEP

With the involvement of UNEP-ROWA, GTZ-PROKLIMA and AFD the Governments of Bahrain, Lebanon, Qatar, Yemen, Syria and Jordan (in the case of Jordan as a Worldbank project) realized in the last two years the management of halon:

- Legislation on halon management had been established through policy advice.
- Installed fire protection system had been identified through surveys.
- Involvement of stakeholders guaranteed through workshops.
- Recovery and recycling equipment provided through technology transfer
- Training for Government officials organized through international experts
- Training of fire protection engineers organized in using environmental friendly alternatives
- Substitution of halons realized through environmental friendly fire protection systems.

Saudi Arabia, Kuwait, the Emirates and Oman had benefited from the avant-garde role of their neighbor countries so far that they are following on the regional approach for the management of halons.

As a result, the region will stop the imports of halons. All this was achieved in a very cost efficient way using bilateral and multilateral funds with a strong contribution of the respective Governments. Around one million US$ had been provided through this means. Only 0,02 US$ had been spent per kg phased out ODS.

The results confirmed that a regional approach is effective and stimulates even environmental sound projects in non-financial benefiting countries (Saudi Arabia, UAE). It could be demonstrated that the cooperation with the armies in Arabian countries on environmental issues are possible and that HBMP are drying out the demand for halon.

An interesting approach has been developed by GTZ PROKLIMA addressing the halon banking and recycling in a number of low halon consuming countries. GTZ PROKLIMA has now bought on behalf of the West Asia halon steering committee a mobile halon reclamation center. The mobile unit will be used to recover halons from fire extinguishing cylinders, clean halon from impurities and separate halon from nitrogen. The unit is shipped with two storage tanks. The unit will be used in Bahrain, Qatar, Yemen and Lebanon on request by each ozone office. The respective ozone office will be responsible for customs clearance, transport in the country., The ozone office will identify a operator of the mobile unit. The operator will have to cover all operational costs for liquid nitrogen, filters and spare parts. GTZ PROKLIMA will bare all costs involved for transport of the mobile unit from one country to the next and a first training for the operators of the equipment. The halon users requesting halon recovery should pay 0.5US$ for each kg halon recovered to the halon steering committee, if not otherwise decided by the steering committee. The halon users should also finance storage tanks for their recovered and recycled halon.

The same approach will be followed for the regional projects for the Anglophone and francophone African countries.

7.5 Path to Halon Management and Banking Plan

The halon management and banking project normally comprise of the following components;

- Survey on installed capacities. Database of halon users
- Establishing of National Halon steering committee
- Involvement of stakeholders
- Discussion and approval of code of conduct/strategy
- Development of halon regulations (analogue EU2037).
- Provision with halon recovery and recycling equipment
- Decommissioning of halon systems
- Promotion of alternatives
- Engineering support

Funds provided has been consistent with the general guidance provided by HTOC and demonstration projects approved in 1996/97.

7.6 Challenges

- Halon Reclamation centers in A5 countries are either operated on a private commercial or on a public funded basis. Each implementation has its advantages and disadvantages. Commercial aspects of trade of recycled halon have to be discussed and technical problems during operation of halon reclamation centres solved.

- Training aspects for fire protection experts from A5 countries. Training must be provided for fire protection engineers in the design and calculation of gaseous fire protection systems. Giving them the capacity to use the alternatives available in a safe manner. Fire experts from halon users have to be trained in general fire protection and how to make a good choice when they are going to replace their existing halon system with substitutes in a cost effective manner and ensure halons are available for essential applications.

- As halon becomes more scares, management of the remaining stock will become critical for ensuring sufficient halons for essential applications.

8. Estimated inventories of halon 1211 and halon 1301

The HTOC is of the opinion that adequate stocks of halon 1211, halon 1301, and halon 2402 currently exist to meet the future service needs and replenishment needs of all existing critical or essential halon fire equipment until the end of their useful life. Owners of existing halon fire equipment that would be considered as meeting the needs of one or more of the preceding categories would be prudent to ensure that their future needs will be met from their own secure stocks. Current and proposed regulatory programs that require the recovery and destruction of unnecessary halons will obviously eliminate future availability of halons as a source of supply for critical or essential needs. As adequate supplies presently exist it would be unlikely that inadequate planning would serve as a reasonable basis for a future essential use nomination by a Party on behalf of an owner of a particular essential or critical application for halon 1211, halon 1301, or halon 2402.

The following spreadsheets provide the most current estimates of inventories for halon 1211 and halon 1301. These estimates have been coordinated with the Science Panel.

Halon 1211 Summary

(All quantities are metric tonnes)

YEAR	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
ANNUAL PRODUCTION																							
North America, Western Europe and Japan	50	100	200	300	500	700	900	1260	1700	2200	2750	3300	3800	4356	5000	5650	6280	6910	6689	7485	8259	10408	12491
CEIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	30
Article 5(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	210	266	336	425	538	680	1061	1342
TOTAL ANNUAL PRODUCTION	50	100	200	300	500	700	900	1260	1700	2200	2750	3300	3800	4356	5000	5860	6546	7246	7114	8023	8939	11499	13863
ANNUAL PRODUCTION ALLOCATION																							
North America	15	30	60	90	150	210	270	378	510	660	825	990	1140	1307	1500	1695	1884	2073	2007	2246	2478	3122	3747
Western Europe and Australia	18	35	70	105	175	245	315	441	595	770	963	1155	1330	1525	1750	1978	2198	2419	2341	2620	2891	3643	4372
Japan	3	5	10	15	25	35	45	63	85	110	138	165	190	218	250	283	314	346	334	374	413	520	625
CEIT	3	5	10	15	25	35	45	63	85	110	138	165	190	218	250	283	314	346	334	374	413	550	655
Article 5(1)	13	25	50	75	125	175	225	315	425	550	688	825	950	1089	1250	1623	1836	2064	2097	2409	2745	3663	4465
TOTAL ANNUAL PRODUCTION ALLOCATION	50	100	200	300	500	700	900	1260	1700	2200	2750	3300	3800	4356	5000	5860	6546	7246	7114	8023	8939	11499	13863
ANNUAL EMISSIONS																							
North America	2	4	9	15	26	40	57	82	114	155	205	264	329	424	489	585	690	807	909	1038	1181	1378	1608
Western Europe and Australia	2	5	10	17	30	47	66	95	133	181	239	307	384	495	570	683	805	941	1060	1211	1378	1608	1877
Japan	0	0	0	1	1	2	4	5	7	10	14	19	25	36	40	50	62	75	89	105	123	144	169
CEIT	0	0	1	2	3	5	8	11	15	21	28	37	46	57	69	83	97	113	127	143	160	183	212
Article 5(1)	1	3	6	13	22	37	55	79	112	154	207	272	345	451	518	633	773	928	1088	1255	1447	1690	2007
TOTAL ANNUAL EMISSIONS	4	12	26	48	83	130	189	272	382	521	694	899	1130	1464	1686	2034	2427	2863	3273	3751	4287	5002	5874
CUMMULATIVE PRODUCTION																							
North America, Western Europe and Japan	50	150	350	650	1150	1850	2750	4010	5710	7910	10660	13960	17760	22116	27116	32766	39046	45956	52645	60130	68389	78797	91288
CEIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	60
Article 5(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	210	476	812	1237	1775	2456	3516	4858
TOTAL CUMMULATIVE PRODUCTION	50	150	350	650	1150	1850	2750	4010	5710	7910	10660	13960	17760	22116	27116	32976	39522	46768	53882	61905	70845	82343	96206
CUMMULATIVE PRODUCTION ALLOCATIONS																							
North America	15	45	105	195	345	555	825	1203	1713	2373	3198	4188	5328	6635	8135	9830	11714	13787	15794	18039	20517	23639	27386
Western Europe and Australia	18	53	123	228	403	648	963	1404	1999	2769	3731	4886	6216	7741	9491	11468	13666	16085	18426	21046	23936	27579	31951
Japan	3	8	18	33	58	93	138	201	286	396	533	698	888	1106	1356	1638	1952	2298	2632	3007	3419	3940	4564
CEIT	3	8	18	33	58	93	138	201	286	396	533	698	888	1106	1356	1638	1952	2298	2632	3007	3419	3970	4624
Article 5(1)	13	38	88	163	288	463	688	1003	1428	1978	2665	3490	4440	5529	6779	8402	10237	12301	14398	16808	19553	23216	27680
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	50	150	350	650	1150	1850	2750	4010	5710	7910	10660	13960	17760	22116	27116	32976	39522	46768	53882	61905	70845	82343	96206
CUMMULATIVE EMISSIONS																							
North America	2	5	14	29	55	95	151	233	347	502	707	970	1300	1724	2213	2798	3488	4295	5203	6241	7422	8800	10408
Western Europe and Australia	2	6	16	34	64	110	177	272	405	586	825	1132	1516	2011	2581	3264	4069	5010	6071	7281	8659	10267	12143
Japan	0	0	1	1	3	5	8	14	21	31	46	65	90	126	166	217	278	353	442	547	669	813	982
CEIT	0	1	1	3	6	11	19	30	45	66	95	131	178	235	304	386	483	596	724	866	1026	1209	1421
Article 5(1)	1	3	10	22	45	81	136	216	327	481	689	960	1306	1757	2275	2908	3681	4609	5697	6952	8398	10088	12095
TOTAL CUMMULATIVE EMISSIONS	4	16	42	89	172	303	492	764	1146	1666	2361	3259	4389	5853	7539	9573	12000	14863	18136	21887	26174	31177	37050
INVENTORY																							
North America	14	40	91	166	290	460	674	970	1366	1871	2491	3218	4028	4911	5922	7032	8226	9492	10590	11798	13095	14839	16978
Western Europe and Australia	16	46	106	194	339	537	786	1132	1594	2183	2906	3754	4700	5729	6909	8204	9597	11074	12355	13764	15277	17312	19808
Japan	2	7	17	31	55	88	129	187	265	364	487	633	798	980	1189	1422	1674	1945	2190	2460	2750	3127	3582
CEIT	2	7	16	29	51	81	118	171	240	329	438	567	710	871	1052	1252	1469	1702	1909	2140	2393	2761	3203
Article 5(1)	12	34	78	140	243	381	551	787	1100	1496	1976	2530	3134	3772	4504	5493	6556	7692	8702	9856	11154	13128	15585
TOTAL INVENTORY	46	134	308	561	978	1547	2258	3246	4564	6244	8299	10701	13371	16263	19577	23403	27522	31905	35746	40018	44670	51167	59156

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Halon 1211 Summary
(All quantities are metric tonnes)

YEAR	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
ANNUAL PRODUCTION																			
North America, Western Europe and Japan	13731	17058	20181	16182	14852	11882	7921	3960	0	0	0	0	0	0	0	0	0	0	0
CEIT	30	35	35	80	700	50	50	0	0	0	0	0	0	0	0	0	0	0	0
Article 5(1)	1658	19142	22761	19336	19268	16578	14973	12673	10448	11250	14180	12124	8175	6265	4278	2599	2954	2290	2290
TOTAL ANNUAL PRODUCTION	15419	36235	42977	35598	34820	28510	22944	16633	10448	11250	14180	12124	8175	6265	4278	2599	2954	2290	2290
ANNUAL PRODUCTION ALLOCATION																			
North America	4119	5117	6054	4855	4456	3565	2376	1188	0	0	0	0	0	0	0	0	0	0	0
Western Europe and Australia	4806	5970	7063	5664	5198	4159	2772	1386	0	0	0	0	0	0	0	0	0	0	0
Japan	687	853	1009	809	743	594	396	198	0	0	0	0	0	0	0	0	0	0	0
CEIT	717	888	1044	889	1443	644	446	198	0	0	0	0	0	0	0	0	0	0	0
Article 5(1)	5091	23407	27806	23382	22981	19549	16953	13663	10448	11250	14180	12124	8175	6265	4278	2599	2954	2290	2290
TOTAL ANNUAL PRODUCTION ALLOCATION	15419	36235	42977	35598	34820	28510	22944	16633	10448	11250	14180	12124	8175	6265	4278	2599	2954	2290	2290
ANNUAL EMISSIONS																			
North America	1846	2162	2523	2458	2378	2222	2015	1773	1635	1443	1417	1404	1398	1372	1342	1302	1248	1182	1102
Western Europe and Australia	2153	2522	2943	2868	2775	2592	2351	2068	1907	1683	1654	1638	1631	1600	1566	1520	1456	1379	1285
Japan	198	231	270	293	307	313	313	314	312	325	339	358	382	394	403	403	394	376	349
CEIT	244	283	330	397	467	503	539	586	639	657	637	601	547	470	396	325	247	165	104
Article 5(1)	2376	3663	6233	7926	8874	9262	9259	8944	8289	8606	8997	10864	12570	13437	14021	14151	13973	13577	12922
TOTAL ANNUAL EMISSIONS	6817	8861	12299	13943	14801	14891	14477	13684	12781	12713	13043	14864	16528	17272	17728	17701	17319	16678	15763
CUMMULATIVE PRODUCTION																			
North America, Western Europe and Japan	105019	122077	142258	158440	173292	185174	193095	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055
CEIT	90	125	160	240	940	990	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040
Article 5(1)	6516	25658	48419	67755	87023	103601	118574	131247	141695	152945	167125	179249	187424	193689	197967	200566	203520	205810	208100
TOTAL CUMMULATIVE PRODUCTION	111625	147860	190837	226435	261255	289765	312709	329342	339790	351040	365220	377344	385519	391784	396062	398661	401615	403905	406195
CUMMULATIVE PRODUCTION ALLOCATIONS																			
North America	31506	36623	42677	47532	51988	55552	57929	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117
Western Europe and Australia	36757	42727	49790	55454	60652	64811	67583	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969
Japan	5251	6104	7113	7922	8665	9259	9655	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853
CEIT	5341	6229	7273	8162	9605	10249	10695	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893
Article 5(1)	32771	56178	83984	107365	130346	149895	166848	180511	190959	202209	216389	228513	236688	242953	247231	249830	252784	255074	257364
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	111625	147860	190837	226435	261255	289765	312709	329342	339790	351040	365220	377344	385519	391784	396062	398661	401615	403905	406195
CUMMULATIVE EMISSIONS																			
North America	12254	14416	16939	19397	21776	23998	26013	27785	29420	30862	32280	33683	35082	36453	37796	39098	40346	41528	42630
Western Europe and Australia	14296	16819	19762	22630	25405	27997	30348	32416	34323	36006	37660	39297	40929	42529	44095	45615	47071	48449	49735
Japan	1180	1411	1681	1974	2281	2594	2906	3220	3532	3856	4195	4553	4935	5329	5731	6134	6529	6904	7253
CEIT	1665	1949	2279	2676	3143	3646	4185	4771	5410	6067	6704	7305	7852	8322	8717	9042	9289	9454	9558
Article 5(1)	14471	18134	24367	32293	41166	50429	59687	68631	76920	85526	94523	105386	117956	131393	145414	159565	173538	187115	200037
TOTAL CUMMULATIVE EMISSIONS	43867	52729	65028	78971	93771	108663	123139	136823	149604	162317	175360	190225	206753	224025	241753	259454	276773	293450	309213
INVENTORY																			
North America	19252	22207	25738	28135	30212	31555	31916	31331	29697	28254	26837	25433	24035	22663	21321	20018	18770	17588	16487
Western Europe and Australia	22460	25908	30028	32824	35247	36814	37235	36553	34646	32963	31310	29672	28040	26440	24874	23355	21898	20520	19234
Japan	4071	4693	5432	5948	6384	6665	6748	6633	6321	5996	5658	5300	4918	4524	4121	3718	3324	2948	2600
CEIT	3676	4280	4994	5486	6462	6603	6510	6122	5483	4826	4189	3588	3041	2571	2176	1851	1604	1439	1335
Article 5(1)	18300	38044	59617	75073	89180	99466	107161	111880	114040	116684	121867	123127	118732	111561	101818	90265	79246	67959	57327
TOTAL INVENTORY	67758	95132	125809	147465	167484	181103	189570	192519	190186	188723	189860	187120	178767	167759	154309	139207	124843	110455	96983

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Halon 1211 Summary

(All quantities are metric tonnes)

YEAR	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
ANNUAL PRODUCTION																			
North America, Western Europe and Japan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CEIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Article 5(1)	2290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL ANNUAL PRODUCTION	2290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANNUAL PRODUCTION ALLOCATION																			
North America	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Europe and Australia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Japan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CEIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Article 5(1)	2290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL ANNUAL PRODUCTION ALLOCATION	2290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANNUAL EMISSIONS																			
North America	1033	971	912	856	798	738	680	614	542	492	446	411	391	385	392	390	385	376	363
Western Europe and Australia	1205	1133	1064	999	931	861	793	716	632	574	520	479	456	449	458	455	449	439	423
Japan	323	299	275	252	225	197	167	132	93	65	40	22	13	13	21	27	32	36	38
CEIT	1335	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Article 5(1)	12327	11943	9903	7577	5798	4134	2819	1891	1267	938	628	392	0	0	0	0	0	0	0
TOTAL ANNUAL EMISSIONS	16222	14347	12154	9683	7752	5930	4460	3354	2533	2069	1633	1304	861	847	871	872	866	851	824
CUMMULATIVE PRODUCTION																			
North America, Western Europe and Japan	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055	197055
CEIT	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040	1040
Article 5(1)	210390	210390	210390	210390	210390	210390	210390	210390	210390	210390	210390	210390	210390	210390	210390	210390	210390	210390	210390
TOTAL CUMMULATIVE PRODUCTION	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485
CUMMULATIVE PRODUCTION ALLOCATIONS																			
North America	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117	59117
Western Europe and Australia	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969	68969
Japan	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853	9853
CEIT	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893
Article 5(1)	259654	259654	259654	259654	259654	259654	259654	259654	259654	259654	259654	259654	259654	259654	259654	259654	259654	259654	259654
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485	408485
CUMMULATIVE EMISSIONS																			
North America	43663	44634	45546	46402	47200	47938	48618	49232	49773	50265	50711	51122	51513	51898	52290	52680	53065	53441	53803
Western Europe and Australia	50940	52073	53137	54136	55066	55927	56721	57437	58069	58643	59163	59642	60099	60547	61005	61460	61909	62347	62771
Japan	7576	7874	8150	8401	8627	8823	8991	9123	9216	9281	9320	9343	9356	9369	9390	9417	9449	9486	9524
CEIT	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893	10893
Article 5(1)	212364	224307	234210	241787	247584	251719	254538	256429	257696	258634	259262	259654	259654	259654	259654	259654	259654	259654	259654
TOTAL CUMMULATIVE EMISSIONS	325435	339782	351935	361619	369370	375300	379760	383114	385647	387716	389349	390653	391514	392361	393232	394104	394970	395820	396645
INVENTORY																			
North America	15454	14482	13571	12715	11917	11179	10499	9885	9343	8851	8406	7995	7603	7219	6826	6436	6052	5676	5313
Western Europe and Australia	18029	16896	15832	14834	13903	13042	12249	11532	10901	10326	9807	9327	8871	8422	7964	7509	7060	6622	6199
Japan	2277	1978	1703	1451	1226	1029	862	730	637	572	532	510	497	484	463	436	403	367	329
CEIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Article 5(1)	47290	35347	25444	17867	12070	7935	5116	3225	1958	1020	392	0	0	0	0	0	0	0	0
TOTAL INVENTORY	83050	68704	56550	46867	39115	33185	28726	25372	22839	20770	19137	17832	16971	16124	15253	14381	13516	12665	11841

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Halon 1211 Summary
(All quantities are metric tonnes)

YEAR	2024	2025	2026	2027	2028	2029	2030
ANNUAL PRODUCTION							
North America, Western Europe and Japan	0	0	0	0	0	0	0
CEIT	0	0	0	0	0	0	0
Article 5(1)	0	0	0	0	0	0	0
TOTAL ANNUAL PRODUCTION	0	0	0	0	0	0	0
ANNUAL PRODUCTION ALLOCATION							
North America	0	0	0	0	0	0	0
Western Europe and Australia	0	0	0	0	0	0	0
Japan	0	0	0	0	0	0	0
CEIT	0	0	0	0	0	0	0
Article 5(1)	0	0	0	0	0	0	0
TOTAL ANNUAL PRODUCTION ALLOCATION	0	0	0	0	0	0	0
ANNUAL EMISSIONS							
North America	345	324	300	276	252	230	211
Western Europe and Australia	402	378	351	322	294	268	246
Japan	39	38	35	32	29	25	21
CEIT	0	0	0	0	0	0	0
Article 5(1)	0	0	0	0	0	0	0
TOTAL ANNUAL EMISSIONS	786	739	686	630	574	522	477
CUMMULATIVE PRODUCTION							
North America, Western Europe and Japan	197055	197055	197055	197055	197055	197055	197055
CEIT	1040	1040	1040	1040	1040	1040	1040
Article 5(1)	210390	210390	210390	210390	210390	210390	210390
TOTAL CUMMULATIVE PRODUCTION	408485	408485	408485	408485	408485	408485	408485
CUMMULATIVE PRODUCTION ALLOCATIONS							
North America	59117	59117	59117	59117	59117	59117	59117
Western Europe and Australia	68969	68969	68969	68969	68969	68969	68969
Japan	9853	9853	9853	9853	9853	9853	9853
CEIT	10893	10893	10893	10893	10893	10893	10893
Article 5(1)	259654	259654	259654	259654	259654	259654	259654
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	408485	408485	408485	408485	408485	408485	408485
CUMMULATIVE EMISSIONS							
North America	54148	54472	54772	55048	55300	55530	55740
Western Europe and Australia	63173	63551	63901	64223	64517	64785	65030
Japan	9562	9600	9636	9668	9696	9721	9742
CEIT	10893	10893	10893	10893	10893	10893	10893
Article 5(1)	259654	259654	259654	259654	259654	259654	259654
TOTAL CUMMULATIVE EMISSIONS	397430	398170	398856	399486	400060	400582	401060
INVENTORY							
North America	4968	4645	4344	4068	3816	3587	3376
Western Europe and Australia	5796	5419	5068	4746	4452	4185	3939
Japan	290	253	217	185	156	132	111
CEIT	0	0	0	0	0	0	0
Article 5(1)	0	0	0	0	0	0	0
TOTAL INVENTORY	11055	10316	9629	8999	8425	7903	7426

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Halon 1301 Summary
(All quantities are metric tonnes)

YEAR	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
ANNUAL PRODUCTION																							
North America, Western Europe and Japan	10	20	30	40	50	60	100	200	550	839	1292	1461	2019	3172	3550	4015	4718	4877	5694	7565	7386	8692	9781
CEIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	30
Article 5(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	94
TOTAL ANNUAL PRODUCTION	10	20	30	40	50	60	100	200	550	839	1292	1461	2019	3172	3550	4015	4718	4877	5694	7565	7386	8792	9905
ANNUAL PRODUCTION ALLOCATION																							
North America	4	8	11	15	19	23	38	75	206	315	485	548	757	1190	1331	1506	1769	1829	2135	2837	2770	3260	3668
Western Europe and Australia	2	5	7	9	11	14	23	45	124	189	291	329	454	714	799	903	1062	1097	1281	1702	1662	1956	2201
Japan	2	3	5	6	8	9	15	30	83	126	194	219	303	476	533	602	708	732	854	1135	1108	1304	1467
CEIT	1	1	2	2	3	3	5	10	28	42	65	73	101	159	178	201	236	244	285	378	369	465	519
Article 5(1)	2	4	6	8	10	12	20	40	110	168	258	292	404	634	710	803	944	975	1139	1513	1477	1808	2051
TOTAL ANNUAL PRODUCTION ALLOCATION	10	20	30	40	50	60	100	200	550	839	1292	1461	2019	3172	3550	4015	4718	4877	5694	7565	7386	8792	9905
ANNUAL EMISSIONS																							
North America	1	2	3	5	7	9	13	23	55	92	149	197	276	414	526	650	801	925	1093	1355	1507	1754	2009
Western Europe and Australia	0	1	2	3	4	5	7	13	31	53	85	111	156	235	297	366	449	517	612	763	850	994	1143
Japan	0	0	1	1	1	2	3	5	10	18	30	42	59	88	117	149	186	223	266	326	378	442	512
CEIT	0	0	0	1	1	1	2	3	8	13	21	27	38	58	71	86	104	117	139	175	190	230	264
Article 5(1)	0	1	2	3	5	6	9	16	37	63	103	140	195	288	372	460	564	651	758	925	1032	1204	1382
TOTAL ANNUAL EMISSIONS	2	5	8	12	17	23	34	60	141	239	388	516	724	1083	1382	1711	2104	2433	2868	3544	3957	4623	5309
CUMMULATIVE PRODUCTION																							
North America, Western Europe and Japan	10	30	60	100	150	210	310	510	1060	1899	3191	4652	6671	9843	13393	17408	22126	27003	32697	40262	47648	56340	66121
CEIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	60
Article 5(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	164
TOTAL CUMMULATIVE PRODUCTION	10	30	60	100	150	210	310	510	1060	1899	3191	4652	6671	9843	13393	17408	22126	27003	32697	40262	47648	56440	66345
CUMMULATIVE PRODUCTION ALLOCATIONS																							
North America	4	11	23	38	56	79	116	191	398	712	1197	1745	2502	3691	5022	6528	8297	10126	12261	15098	17868	21128	24795
Western Europe and Australia	2	7	14	23	34	47	70	115	239	427	718	1047	1501	2215	3013	3917	4978	6076	7357	9059	10721	12677	14877
Japan	2	5	9	15	23	32	47	77	159	285	479	698	1001	1476	2009	2611	3319	4050	4905	6039	7147	8451	9918
CEIT	1	2	3	5	8	11	16	26	53	95	160	233	334	492	670	870	1106	1350	1635	2013	2382	2847	3366
Article 5(1)	2	6	12	20	30	42	62	102	212	380	638	930	1334	1969	2679	3482	4425	5401	6539	8052	9530	11338	13389
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	10	30	60	100	150	210	310	510	1060	1899	3191	4652	6671	9843	13393	17408	22126	27003	32697	40262	47648	56440	66345
CUMMULATIVE EMISSIONS																							
North America	1	3	6	10	17	25	39	62	117	209	358	554	830	1245	1771	2421	3221	4146	5239	6594	8101	9854	11863
Western Europe and Australia	0	1	3	6	10	15	22	35	67	119	204	316	472	707	1004	1370	1819	2336	2949	3712	4562	5556	6699
Japan	0	0	1	2	3	5	8	13	23	41	70	112	171	259	376	524	711	934	1200	1526	1904	2345	2857
CEIT	0	0	1	2	2	4	5	9	17	31	52	79	117	175	245	331	435	553	691	866	1056	1286	1550
Article 5(1)	0	2	4	7	12	18	27	43	80	143	246	386	580	869	1240	1701	2264	2915	3673	4598	5631	6835	8217
TOTAL CUMMULATIVE EMISSIONS	2	6	15	27	44	67	101	161	303	542	930	1446	2171	3254	4636	6347	8451	10884	13752	17296	21254	25876	31186
INVENTORY																							
North America	3	9	17	27	39	53	78	129	281	503	839	1190	1671	2446	3252	4107	5076	5980	7022	8504	9767	11273	12932
Western Europe and Australia	2	5	10	17	24	33	48	80	172	308	514	731	1029	1507	2009	2547	3159	3739	4408	5347	6158	7120	8178
Japan	1	4	8	13	19	26	39	64	136	244	408	586	829	1217	1633	2087	2608	3117	3705	4513	5244	6106	7061
CEIT	0	1	2	3	5	7	10	17	36	64	108	153	217	317	424	539	671	798	944	1147	1326	1561	1817
Article 5(1)	2	4	8	13	18	24	35	59	132	237	392	545	754	1100	1438	1781	2161	2486	2866	3454	3899	4503	5171
TOTAL INVENTORY	8	24	45	73	106	143	209	349	757	1357	2261	3206	4500	6589	8757	11061	13675	16119	18945	22966	26394	30564	35160

Halon 1301 Summary
(All quantities are metric tonnes)

YEAR	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
ANNUAL PRODUCTION																			
North America, Western Europe and Japan	11076	11604	12551	11152	9115	7326	4884	2442	0	0	0	0	0	0	0	0	0	0	0
CEIT	30	35	30	30	1100	50	50	0	0	0	0	0	0	0	0	0	0	0	0
Article 5(1)	127	193	214	227	360	572	511	650	700	750	800	750	535	475	475	590	650	650	650
TOTAL ANNUAL PRODUCTION	11233	11832	12795	11409	10575	7948	5445	3092	700	750	800	750	535	475	475	590	650	650	650
ANNUAL PRODUCTION ALLOCATION																			
North America	4154	4352	4707	4182	3418	2747	1832	916	0	0	0	0	0	0	0	0	0	0	0
Western Europe and Australia	2492	2611	2824	2509	2051	1648	1099	549	0	0	0	0	0	0	0	0	0	0	0
Japan	1661	1741	1883	1673	1367	1099	733	366	0	0	0	0	0	0	0	0	0	0	0
CEIT	584	615	658	588	1556	416	294	122	0	0	0	0	0	0	0	0	0	0	0
Article 5(1)	2343	2514	2724	2457	2183	2037	1488	1138	700	750	800	750	535	475	475	590	650	650	650
TOTAL ANNUAL PRODUCTION ALLOCATION	11233	11832	12795	11409	10575	7948	5445	3092	700	750	800	750	535	475	475	590	650	650	650
ANNUAL EMISSIONS																			
North America	2289	2534	2810	2611	2343	2048	1711	1385	1182	1011	939	873	806	751	705	665	633	606	581
Western Europe and Australia	1311	1457	1621	1513	1365	1201	1018	836	728	631	599	567	538	509	479	450	422	394	370
Japan	590	668	751	729	681	617	537	448	391	338	328	318	308	299	291	283	276	269	262
CEIT	302	335	370	338	476	314	266	219	197	176	168	161	154	147	140	134	128	123	117
Article 5(1)	1577	1764	1961	1883	1767	1630	1428	1225	1098	974	902	835	765	701	651	610	594	590	591
TOTAL ANNUAL EMISSIONS	6068	6758	7513	7073	6632	5809	4959	4112	3596	3130	2935	2754	2571	2407	2266	2143	2052	1981	1921
CUMMULATIVE PRODUCTION																			
North America, Western Europe and Japan	77197	88801	101352	112504	121619	128945	133829	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271
CEIT	90	125	155	185	1285	1335	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385
Article 5(1)	292	485	699	926	1286	1857	2368	3018	3718	4468	5268	6018	6553	7028	7503	8093	8743	9393	10043
TOTAL CUMMULATIVE PRODUCTION	77579	89411	102206	113615	124190	132137	137582	140674	141374	142124	142924	143674	144209	144684	145159	145749	146399	147049	147699
CUMMULATIVE PRODUCTION ALLOCATIONS																			
North America	28949	33300	38007	42189	45607	48354	50186	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102
Western Europe and Australia	17369	19980	22804	25313	27364	29013	30112	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661
Japan	11580	13320	15203	16876	18243	19342	20074	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441
CEIT	3950	4565	5223	5810	7366	7782	8076	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199
Article 5(1)	15731	18245	20969	23427	25609	27646	29134	30273	30973	31723	32523	33273	33808	34283	34758	35348	35998	36648	37298
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	77579	89411	102206	113615	124190	132137	137582	140674	141374	142124	142924	143674	144209	144684	145159	145749	146399	147049	147699
CUMMULATIVE EMISSIONS																			
North America	14152	16686	19497	22107	24450	26498	28209	29594	30776	31787	32726	33599	34405	35156	35861	36526	37159	37764	38345
Western Europe and Australia	8009	9467	11088	12601	13966	15167	16184	17020	17747	18379	18977	19544	20083	20591	21071	21521	21943	22336	22707
Japan	3447	4114	4865	5594	6276	6893	7429	7877	8269	8607	8935	9253	9561	9861	10152	10435	10711	10980	11241
CEIT	1852	2186	2557	2895	3370	3684	3950	4169	4366	4542	4710	4871	5025	5172	5312	5446	5574	5697	5814
Article 5(1)	9794	11558	13518	15401	17167	18797	20225	21450	22548	23522	24423	25259	26023	26725	27375	27985	28579	29169	29760
TOTAL CUMMULATIVE EMISSIONS	37254	44011	51525	58598	65229	71038	75997	80110	83706	86836	89771	92526	95096	97504	99770	101913	103965	105946	107867
INVENTORY																			
North America	14797	16614	18510	20082	21157	21857	21977	21508	20325	19315	18376	17503	16697	15946	15241	14576	13943	13337	12757
Western Europe and Australia	9360	10513	11716	12712	13398	13846	13927	13641	12914	12282	11684	11117	10578	10070	9590	9140	8718	8325	7954
Japan	8133	9206	10337	11281	11967	12449	12645	12563	12172	11834	11506	11188	10879	10580	10289	10006	9730	9461	9199
CEIT	2098	2379	2666	2916	3995	4098	4126	4030	3833	3657	3488	3328	3174	3027	2887	2753	2624	2502	2385
Article 5(1)	5937	6687	7451	8026	8442	8849	8909	8823	8425	8201	8099	8014	7784	7558	7382	7362	7418	7478	7537
TOTAL INVENTORY	40325	45399	50681	55017	58960	61099	61585	60565	57668	55288	53153	51149	49113	47181	45389	43836	42434	41103	39832

Halon 1301 Summary

(All quantities are metric tonnes)

YEAR	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
ANNUAL PRODUCTION																			
North America, Western Europe and Japan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CEIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Article 5(1)	650	200	200	200	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL ANNUAL PRODUCTION	650	200	200	200	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANNUAL PRODUCTION ALLOCATION																			
North America	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Europe and Australia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Japan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CEIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Article 5(1)	650	200	200	200	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL ANNUAL PRODUCTION ALLOCATION	650	200	200	200	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANNUAL EMISSIONS																			
North America	557	536	514	494	475	456	437	419	406	397	390	382	373	358	347	336	324	310	290
Western Europe and Australia	350	333	317	304	292	280	268	258	249	243	237	231	224	214	206	199	193	186	177
Japan	255	248	240	232	224	216	207	198	189	181	174	168	162	156	152	149	147	145	144
CEIT	112	107	101	97	92	87	82	77	73	76	69	68	65	62	60	57	55	53	50
Article 5(1)	593	597	570	548	525	504	471	439	416	402	397	386	378	359	349	343	336	316	287
TOTAL ANNUAL EMISSIONS	1867	1819	1743	1675	1608	1542	1464	1391	1334	1299	1268	1235	1202	1149	1114	1084	1054	1010	948
CUMMULATIVE PRODUCTION																			
North America, Western Europe and Japan	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271	136271
CEIT	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385	1385
Article 5(1)	10693	10893	11093	11293	11493	11493	11493	11493	11493	11493	11493	11493	11493	11493	11493	11493	11493	11493	11493
TOTAL CUMMULATIVE PRODUCTION	148349	148549	148749	148949	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149
CUMMULATIVE PRODUCTION ALLOCATIONS																			
North America	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102	51102
Western Europe and Australia	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661	30661
Japan	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441	20441
CEIT	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199	8199
Article 5(1)	37948	38148	38348	38548	38748	38748	38748	38748	38748	38748	38748	38748	38748	38748	38748	38748	38748	38748	38748
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	148349	148549	148749	148949	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149	149149
CUMMULATIVE EMISSIONS																			
North America	38902	39438	39952	40446	40921	41376	41813	42232	42639	43036	43426	43808	44181	44540	44887	45223	45547	45857	46147
Western Europe and Australia	23057	23389	23706	24011	24303	24583	24851	25109	25358	25601	25838	26069	26293	26507	26713	26913	27105	27291	27468
Japan	11496	11744	11983	12215	12439	12655	12861	13059	13248	13429	13604	13771	13933	14089	14241	14390	14537	14682	14825
CEIT	5926	6032	6134	6230	6322	6409	6490	6567	6641	6716	6786	6854	6919	6981	7041	7099	7154	7207	7257
Article 5(1)	30353	30950	31520	32068	32593	33098	33568	34007	34424	34826	35223	35609	35987	36346	36694	37037	37373	37689	37976
TOTAL CUMMULATIVE EMISSIONS	109734	111553	113296	114970	116578	118120	119584	120975	122309	123608	124876	126111	127314	128463	129577	130661	131715	132725	133673
INVENTORY																			
North America	12199	11664	11150	10655	10181	9725	9288	8869	8463	8066	7676	7293	6920	6562	6215	5879	5555	5245	4955
Western Europe and Australia	7604	7272	6955	6650	6358	6078	5810	5552	5303	5060	4823	4592	4368	4154	3948	3748	3556	3370	3193
Japan	8945	8697	8458	8226	8001	7786	7579	7381	7193	7011	6837	6669	6507	6352	6200	6051	5904	5759	5615
CEIT	2273	2166	2065	1968	1877	1790	1708	1631	1558	1482	1413	1345	1279	1217	1157	1100	1045	992	942
Article 5(1)	7594	7197	6827	6479	6154	5650	5179	4740	4324	3922	3525	3139	2761	2402	2053	1710	1374	1058	771
TOTAL INVENTORY	38616	36996	35454	33979	32571	31029	29565	28174	26840	25541	24273	23038	21836	20686	19572	18488	17434	16424	15476

Halon 1301 Summary
(All quantities are metric tonnes)

YEAR	2024	2025	2026	2027	2028	2029	2030
ANNUAL PRODUCTION							
North America, Western Europe and Japan	0	0	0	0	0	0	0
CEIT	0	0	0	0	0	0	0
Article 5(1)	0	0	0	0	0	0	0
TOTAL ANNUAL PRODUCTION	0	0	0	0	0	0	0
ANNUAL PRODUCTION ALLOCATION							
North America	0	0	0	0	0	0	0
Western Europe and Australia	0	0	0	0	0	0	0
Japan	0	0	0	0	0	0	0
CEIT	0	0	0	0	0	0	0
Article 5(1)	0	0	0	0	0	0	0
TOTAL ANNUAL PRODUCTION ALLOCATION	0	0	0	0	0	0	0
ANNUAL EMISSIONS							
North America	267	241	216	195	181	165	150
Western Europe and Australia	167	156	145	136	129	121	112
Japan	142	141	139	139	139	138	136
CEIT	42	40	37	36	35	34	33
Article 5(1)	253	219	299	0	0	0	0
TOTAL ANNUAL EMISSIONS	871	797	837	505	484	457	430
CUMMULATIVE PRODUCTION							
North America, Western Europe and Japan	136271	136271	136271	136271	136271	136271	136271
CEIT	1385	1385	1385	1385	1385	1385	1385
Article 5(1)	11493	11493	11493	11493	11493	11493	11493
TOTAL CUMMULATIVE PRODUCTION	149149	149149	149149	149149	149149	149149	149149
CUMMULATIVE PRODUCTION ALLOCATIONS							
North America	51102	51102	51102	51102	51102	51102	51102
Western Europe and Australia	30661	30661	30661	30661	30661	30661	30661
Japan	20441	20441	20441	20441	20441	20441	20441
CEIT	8199	8199	8199	8199	8199	8199	8199
Article 5(1)	38748	38748	38748	38748	38748	38748	38748
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	149149	149149	149149	149149	149149	149149	149149
CUMMULATIVE EMISSIONS							
North America	46413	46654	46870	47066	47246	47411	47561
Western Europe and Australia	27635	27791	27936	28071	28201	28322	28433
Japan	14967	15108	15247	15386	15525	15662	15798
CEIT	7299	7339	7376	7412	7447	7481	7513
Article 5(1)	38229	38449	38748	38748	38748	38748	38748
TOTAL CUMMULATIVE EMISSIONS	134544	135340	136177	136682	137166	137623	138053
INVENTORY							
North America	4689	4448	4231	4036	3855	3690	3541
Western Europe and Australia	3026	2870	2725	2590	2460	2339	2228
Japan	5473	5333	5193	5055	4916	4778	4642
CEIT	900	860	822	787	752	718	685
Article 5(1)	518	299	0	0	0	0	0
TOTAL INVENTORY	14606	13809	12972	12467	11983	11526	11096