MONTREAL PROTOCOL
ON SUBSTANCES THAT DEPLETE
THE OZONE LAYER

UNEP

2010 REPORT OF THE HALONS TECHNICAL OPTIONS COMMITTEE

2010 ASSESSMENT

Montreal Protocol
On Substances that Deplete the Ozone Layer

United Nations Environment Programme (UNEP)

2010 Assessment Report of the
Halons Technical Options Committee

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The following persons were instrumental in developing this report:

Committee Co-chairs

David Catchpole
PRA
United Kingdom

Dr. Sergey Kopylov
All Russian Research Institute for Fire Protection
Russian Federation

Dr. Daniel Verdonik
Hughes Associates, Inc.
USA

Committee Members

Tareq K. Al-Awad
King Abdullah II Design & Development Bureau
Jordan

Jamal Alfuzaie
Kuwait Fire Department
Kuwait

Seunghwan (Charles) Choi
Hanju Chemical Co., Ltd.
South Korea

Dr. Michelle Collins
EECO, Inc.
USA

Salomon Gomez
Tecnofuego
Venezuela
Andrew Greig
Protection Projects, Inc.
South Africa

Zhou Kaixuan
CAAC-AAD
China

H.S. Kaprwan
Consultant–Retired
India

Dr. Nikolai Kopylov
All Russian Research Institute for Fire Protection
Russia

Dr. David Liddy
UK Government/European Commission
United Kingdom

Bella Maranion
United States EPA
USA

John O'Sullivan, M.B.E.
Bureau Veritas
United Kingdom

Emma Palumbo
Safety Hi-tech srl
Italy

Erik Pedersen
Consultant–World Bank
Denmark

Donald Thomson
Manitoba Hydro & MOPIA
Canada

Caroline Vuillin
European Aviation Safety Agency
France

Robert Wickham
Consultant-Wickham Associates
USA

Mitsuru Yagi
Nohmi Bosai Ltd. & Fire and Environment Protection Network
Japan

Consulting Experts

Tom Cortina
Halon Alternatives Research Corporation
USA

Matsuo Ishiyama
Nohmi Bosai Ltd. & Fire and Environment Protection Network
Japan

Steve McCormick
United States Army
USA

John G. Owens
3M Company
USA

Dr. Mark Robin
DuPont, Inc.
USA

Dr. Joseph Senecal
Kidde-Fenwal, Inc.
USA

Dr. Ronald Sheinson
Naval Research Laboratory - Retired
USA

Ronald Sibley
Consultant–Defence Supply Center
USA

Peer Reviewers

The Halons Technical Options Committee also acknowledges with thanks the following peer reviewers who took time from their busy schedules to review the draft of this report and provided constructive comments. At the sole discretion of the Halons Technical Options Committee, these comments may or may not have been accepted and incorporated into the report. Therefore, listing of the Peer Reviewers should not be taken as an indication that any reviewer endorses the content of the report, which remains solely the opinion of the members of the Committee.

John Allen – Tyco International, UK

Bradford Colton – American Pacific Corporation, USA

John Demeter – Wesco, USA

Anton Janssen – NL Ministry of Defence, The Netherlands

Dave Koehler – Prospective Technology, Inc., USA

Richard Marcus – RemTech International, USA

Steve Montzka – NOAA, USA

Pete Mullenhard – SAIC, USA

Yuko Saso – National Research Institute of Fire and Disaster, Japan

Dawn Turner – Manitoba Hydro, Canada

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E.1 Introduction

The following sector summaries show that despite the introduction of new halon alternatives and the remarkable progress in switching to them, there is still an on-going need for halons. As such, halon recycling is becoming even more important to ensure that adequate stocks of halons are available to meet the future needs of the Parties.

E.2 Global Production and Consumption Phase-out of Halons

As of January 1, 2010, halon production and consumption, as defined by the Montreal Protocol, for fire protection ceased. Additionally, there has been no essential use halon production since 2000 (as authorised by Decision VIII/9). However, halon 1301 (CF_3Br) continues to be produced in China and France for use as a feedstock in the manufacture of the pesticide Fipronil. The current total halon feedstock production quantities in these countries are not known to the HTOC, but have been increasing annually in China since 2005.

Since 2006, nine Parties have reported a negative production of halons for fire protection, indicating that they have been destroying halons. In addition, the last two producers of halons for fire protection, China and South Korea, reported no exports in 2008 or 2009. However, some halons may have been exported as fire extinguishers and or fire extinguishing systems. Only eight Parties operating under Article 5 reported importing newly produced halons in 2008, down from sixteen in 2006. The global trade in recycled halons is robust, but as would be expected, the trade in recycled halons by Article 5 Parties has been limited, since they were allowed to import newly produced halons through 2009.

Now that there is no global production of halons for fire protection uses, management of the remaining stock becomes crucial for ensuring sufficient halons for applications that need them

E.3 Fire Protection Alternatives to Halon

Since the 2006 Assessment, there have been some changes made to national and international fire protection standards that affect some of the measures of performance and guidelines for use of the alternative agents. Some harmonisation has taken place, new minimum concentrations recommended for certain re-ignition risks, and new procedures developed for determining safe personnel exposure to the alternatives.

Alternatives based on hydrofluorocarbons (HFCs) continue to dominate the in-kind gaseous alternatives market for flooding applications, whereas alternatives based on hydrochlorofluorocarbon (HCFC)-123 are dominant for the much smaller in-kind streaming market. As yet, an alternative with all of the beneficial characteristics of the halon it is attempting to replace has not yet been developed. Nevertheless, new agents and technologies continue to appear on the market for specific applications. Most recent are pyrotechnic products that generate nitrogen or mixtures of nitrogen and water vapour, and unsaturated hydrobromofluorocarbons (HBFCs).

The selection of the best fire protection method in the absence of halons is often a complex process. Either alternative gaseous fire extinguishing agents, so called in-kind alternatives, or not-in-kind alternatives may replace halon but the decision is driven by the details of the hazard being protected, the characteristics of the gaseous agent or alternative method, and the risk management philosophy of the user.

E.4 Climate Considerations for Halons and Alternatives

HFCs, HCFCs, and to a much lesser extent perfluorocarbons (PFCs) have been commercialised as replacements for halons. The development of these chemicals for use in fire and explosion suppression applications was instrumental in achieving the halon production phase-out mandated by the Montreal Protocol. In some applications, HFC based agents are the only alternatives for halons.

The Technology and Economic Assessment Panel (TEAP) update of the Intergovernmental Panel on Climate Change (IPCC) / TEAP Special Report on Ozone and Climate concludes that the greenhouse gas (GHG) reduction potential from fire protection is small due in part to the relatively low emission level and the significant shift to not-in-kind alternatives. Nevertheless, in 2009 and again in 2010 amendments have been proposed that would add HFCs to the Montreal Protocol and slowly phase down their production. The Parties may wish to consider that any future HFC amendments or adjustments include provisions for fire protection uses that have no alternatives other than ozone depleting substances (ODSs) or the high global warming potential (GWP) HFCs.

There are a few important fire protection applications such as crew bays of armoured vehicles where the only current options are to use recycled halon or a high GWP HFC. From a total environmental impact perspective, is it better to reuse an already produced, recycled halon or produce a high GWP HFC for the application? This is a challenge that the Parties may wish to consider.

E.5 Global Halon 1211 and 1301 Banking

Halon banking is a critical part of the management of halons. Halon Bank Programmes must be accessible to all halon users or the risk of accelerated atmospheric emissions will escalate as users find themselves with redundant stock.

There has been an unanticipated lag in the establishment of halon banking and management programmes in Article 5 Parties globally. Halon banking operations can play a significant role in ensuring the quality and availability of recycled halon, in managing the halon use down to zero, and in assisting with emission data by providing regional estimates that should be more accurate than global estimates. National or regional banking schemes that maintain good records offer the opportunity to minimise the uncertainty in stored inventory and stock availability. Parties may wish to encourage such national halon banking schemes in order to ensure that needs considered critical by a Party are met.

Numerous Parties have not implemented halon bank management programmes or are experiencing significant challenges with their programmes. Some of the impediments include lack of a focal point for halon management, insufficient infrastructure, segmentation of halon users such as the military and industry with no sharing of information or resources, users' lack of awareness regarding environmental concerns, and lack of supportive policies. There are companies available globally that will purchase and "clean" cross-contaminated halons; however, in some Parties, because of a prohibition on halon exports, cross-contaminated halons are a financial liability and are reported to be vented to the atmosphere.

E.6 Global Halon 2402 Banking

Halon 2402 had been produced nearly exclusively in the former USSR, and at the time of production phase-out the bank of halon 2402 was very small and insufficient to support existing applications. As a consequence, the Parties allowed the Russian Federation to continue to produce limited quantities of halon 2402 from 1996 until the end of 2000 under the essential use process.

The applications of halon 2402 are a special case because the equipment that uses it was almost exclusively manufactured in the former USSR until its dissolution and in the Russia Federation and the Ukraine afterwards. This equipment mainly comprises military equipment and civil aircraft that was sold within the former USSR, Eastern Europe, and South-East and East Asia.

The Russian Federation and Ukraine, traditionally recognised as potential sources of halon 2402 for other Parties, still own a large installed capacity of halon 2402, but their markets are estimated as currently well balanced with no surplus available for outside customers. This is a problem for Parties whose installed base is very small and consequently bank of halon 2402 limited. Some of these Parties have managed to establish recycling and banking facilities with assistance from the GEF. It is also a problem for larger users, e.g., India, who traditionally relied on supplies from the Russian Federation and never established their own bank. Where possible such Parties are switching to other halons or alternatives.

Emissions, transformation and consumption of halon 2402 by the Russian chemical industry as a process agent has substantially reduced the total bank of halon 2402, and new uses in non-traditional applications are a cause for concern to the HTOC. While there is no apparent shortage of recycled halon 2402 on a global basis, there are regional shortages today that Parties may wish to address.

E.7 Global/Regional Supply and Demand Balance

Based on a review of the situation in a large number of the Parties, with the exception of aviation, it has been concluded that generally halons have been replaced by substitutes for all new applications where halons were traditionally used. However, the demand for recycled halons remains high for existing applications in some Parties. Nevertheless, to date the Parties have not indicated to the Ozone Secretariat that they are unable to obtain halons to satisfy their needs, although some Parties have expressed cost concerns to HTOC members. The HTOC therefore concludes that current demand is being satisfied by the available supply, although the extent of continued needs indicates there may be global or regional problems in the future.

E.8 Continued Reliance on Halons

Halon production for fire protection purposes ceased at the end of 1993 in non-Article 5 Parties and at the end of 2009 in all Parties. However, many Parties have allowed recycled halons to be used to maintain and service existing equipment. This has permitted users to retain their initial equipment investment and allowed halons to continue to be used in applications where alternatives are not yet technically and/or economically viable. In particular, these include civil aviation, military uses, and legacy systems in oil and gas production in cold climates, aerosol fill rooms, grain silos, paper production and milk powder processing plants.

Aviation applications of halon are among the most demanding uses of all three halons, and require every one of their beneficial characteristics, including dispersion and suppression at low temperatures, minimal toxic hazards to passengers and flight crew, and ground maintenance staff, and low weight and space requirements for the hardware. While alternative methods of fire suppression for ground-based situations have been implemented, the status of halon in the civil aircraft sector must be viewed in three different contexts: existing aircraft, newly produced aircraft of existing models, and new models of aircraft. All of them continue to depend on halon for the majority of their fire protection applications. Given the anticipated 25–30 year lifespan of civil aircraft, this dependency is likely to continue well beyond the time when recycled halon is readily available, and the time available for making the transition to halon alternatives may be much less than many in the civil aviation industry realise.

Another critical development since the last assessment report is the finding of contaminated halons making their way into the civil aviation industry as reported by the UK Civil Aviation Authority (CAA) to the European Aviation Safety Agency (EASA) in 2009, raising concerns about the acceptability of the remaining banks of halons.

The halon alternatives available for mainline civil aviation are essentially the same as those reported in the 2006 HTOC Assessment, with the exception that a “low GWP” unsaturated HBFC, known as 3,3,3-trifluoro-2-bromo-prop-1-ene or 2-BTP is currently undergoing tests for suitability in hand-held extinguishers.

As a follow on from the HTOC’s work with the International Civil Aviation Organisation (ICAO) – reference Decision XXI/7 – the HTOC has continued its cooperation with ICAO in the development of a revised resolution, containing amended halon replacement dates agreed to by industry that was adopted at the ICAO 37th Assembly in September 2010 as Resolution A37/9. In addition to the ICAO halon replacement dates, the European Union introduced legislation in 2010 that has “cut-off dates” and “end dates” when all halon systems or extinguishers in a particular application – including civil aviation - must be decommissioned.

Halons continue to be used worldwide by military organisations in many frontline applications where alternatives are not technically or economically feasible at this time. These include existing systems in crew and engine compartments of armoured fighting vehicles; engine nacelles, auxiliary power units, portable extinguishers, cargo bays, dry bays, and the fuel tank vapour space of certain military aircraft; and machinery spaces, fuel pump rooms, flammable liquid storage rooms, operational rooms, command centres and on flight decks of certain naval vessels. Nevertheless, the militaries of many Parties have devoted considerable effort and resources to reduce and eventually eliminate the use of halons wherever technically and economically feasible. Extensive research, development and testing have all but eliminated the need for halons in new equipment designs in armoured fighting vehicles, military aircraft, and naval vessels. For applications where an acceptable alternative has not yet been implemented, operational and maintenance procedures and training can and have been improved to minimise emissions and conserve the limited supplies of recyclable materials that are available. Supplies of halons from converted and decommissioned systems and extinguishers, both from within military organisations and from the open market, have been banked by many Parties to support their on-going military needs.

Existing oil and gas pipelines and production facilities in inhospitable climates continue to use halons for fire suppression and explosion prevention. For new facilities, companies are now adopting an inherently safe design approach to avoid or minimise hazards such as the release of hydrocarbons. Where an inerting agent is still required in occupied spaces, halon has been replaced by HFC-23 or Fluoroketone (FK)-5-1-12, if temperatures permit, as part of the facility protection design. As HFC-23 is the only alternative where very low temperatures are encountered, the question mentioned in E.4 is relevant, i.e., should such a high GWP agent be diverted from destruction to replace an existing, recycled halon?

For other commercial/industrial applications, halons are no longer necessary and systems are gradually being decommissioned and replaced by systems agents using alternative agents. However, the cost to re-engineer systems to replace some legacy systems can be expensive and, in many cases, unless industry is mandated to do so, they rely on recycled halon from the halon bank to maintain the system.

In its 2006 Assessment, the HTOC detailed the status of the use of halon and their alternatives on board Merchant ships. Essentially the situation now is unchanged other than less ships are dependent upon halon owing to decommissioning of ships in the intervening period. For those remaining ships that still require halons, the industry appears to have concluded that this problem, if not solved, is certainly manageable for the near future.

E.9 Estimated Global Inventories of Halons 1211, 1301 and 2402

The HTOC 2010 Assessment indicates that at the end of 2010 the global bank of halon 1301 is estimated at approximately 42,500 MT, halon 1211 at approximately 65,000 MT and halon 2402 at approximately 2,300 MT. From this assessment, the HTOC remains of the opinion that adequate global stocks of halon 1211 and halon 1301 currently exist to meet the future needs of all existing halon fire equipment until the end of their useful life. However, there remains concern about the availability of halon 2402 outside of the Russian Federation and the Ukraine to support existing uses in aircraft, military vehicles, and ships. Much of the bank of halon 2402, which was intended to service fire protection needs for existing applications, was consumed within the Russian Federation as a process agent several years ago. In addition, a new product that encapsulates halon 2402 in a paint matrix is being commercialised in the Russian Federation that would further deplete supplies of halon 2402 to support existing uses. The HTOC is concerned that long-term, important users of halon 2402 will not have enough halon 2402 to support their needs if the bank continues to get depleted through use in non-fire protection uses and/or in new products.

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 programmes that require the recovery and destruction of halons will obviously eliminate future availability of halons as a source of supply for many needs. As adequate global 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 particularly important application for halons 1211, 1301 or halon 2402.

E.10 Practices to Ensure Recycled Halon Purity

The recent experience within Europe, where it was found that contaminated halons were making their way into the civil aviation industry, has highlighted the need for end users to be aware of the purity of any reclaimed or recycled halon that they purchase. With an impure halon the performance can range from poor or no fire extinguishing effectiveness to one where the impure agent may actually intensify the fire in the case where the impurity is a flammable material. Generally speaking, end users have to rely on the aftermarket supply chain to collect, process, test and certify that the halon agent is of acceptable purity, and it is this last step, relying on a supplier's certification alone that can introduce risk with respect to agent purity. Thus it is important that a written purity certification is obtained from an internationally or nationally recognised testing laboratory that has tested the halon to internationally recognised standards, such as ISO, ASTM or GOST.

E.11 Halon Emission Reduction Strategies

Releasing halon into the atmosphere is fundamental to the process of flame extinction and enclosed space inertion. However, these necessary emissions only use a small proportion of the available supply of halon in any year. Most countries have discontinued system discharge testing and discharge of extinguishers for training purposes resulting in emission reductions in some cases of up to 90%. Additional and significant reductions of halon emissions can be realised by improving maintenance procedures, detection and control devices, etc., and through non-technical steps such as the development of Codes of Conduct, implementing Awareness Campaigns, workshops, and training, policies, and legislating regulations and ensuring enforcement. Halon emissions reduction strategies are a combination of "responsible use" and political regulatory action.

Good engineering practice dictates that, where possible, hazards should be designed out of facilities rather than simply providing protection against them. A combination of prevention, inherently safe design, minimisation of personnel exposure, passive protection, equipment duplication, detection, and manual intervention should be considered as well. Also, attention to maintenance programs and personnel training can add years to a halon bank by reduced emissions.

Emission reductions can be achieved by implementing a comprehensive Awareness Campaign. This should address a description of halons and their uses, environmental concerns related to the ozone layer, key goals and deadlines in the Montreal Protocol, country-specific policy and regulations on ODS, recycling requirements, alternatives and options, points of contact in government and fire protection community, and answers to Frequently Asked Questions such as "what do I do with my halon 1211 extinguisher?"

Avoidable halon releases account for greater halon emissions than those needed for fire protection and explosion prevention. Clearly such releases can be minimised.

E.12 Destruction

Since the 2006 Assessment, considerable interest has focused on the potential ozone and climate benefits from the avoided emissions of ODS still remaining in equipment, products, and stockpiles. The recent introduction of carbon credits for ODS destruction creates a limited window of opportunity to increase ODS recovery at equipment end of life and to avoid potential emissions altogether by destroying unwanted material. Halons, more than some of the other ODS, are readily accessible for collection, storage, and disposal, making them very attractive for potential ODS destruction projects under a carbon credit protocol. However, owing to the continued global demand for halons in applications such as aviation, the HTOC has recommended that destruction as a final disposition option should be considered only if the halons are cross-contaminated and cannot be reclaimed to an acceptable purity. The global phase-out of halons has been planned based upon halons being reclaimed and reused until the end of the useful life of the systems they are employed in and until there are no longer any important uses. Early destruction of halons undermines the long-range plan set by the Parties, imposes significant financial burdens on users who invested in their halon systems, and puts at risk uses that generally have the potential for preventing significant loss of life in a fire scenario.

There are also concerns that the availability of carbon credits for halon destruction may inadvertently lead to the wrong incentives – to actions that actually lead to more environmental harm and, worse, to potentially illegal activities, e.g., production simply for destruction credits since newly produced halon is technically indistinguishable from recycled halon. The Parties may wish to consider asking TEAP/HTOC to investigate the issues related to halon destruction further in order to better understand the full implications to the halon phase out under the Protocol, and the impacts to ozone layer recovery and climate protection.

1.0 Global Production and Consumption Phase-out of Halons

As of January 1, 2010, halon production and consumption, as defined by the Montreal Protocol, for fire protection ceased. Additionally, there has been no essential use halon production since 2000 (as authorised by Decision VIII/9).

Based on the 2009 Article 7 data reported to the Ozone Secretariat as of September 2010, halons were produced for fire protection uses by two countries, and only three countries reported positive consumption of halons in 2009. Two of these were the remaining producers of halons and the other one was a net importer of halons. Eight Parties, who reported consumption in 2008, have not yet reported their 2009 Article 7 data. The European Union (EU) and the United States of America (USA) reported negative production and consumption data, which indicates the net destruction of halons.

Halon 1301 (CF_3Br) continues to be produced in China and France for use as a feedstock in the manufacture of the pesticide Fipronil (CAS 120068-37-3). The current total halon feedstock production quantities in these countries are not known to the HTOC, but have been increasing annually in China since 2005. As production for feedstock uses is not controlled by the Montreal Protocol (MP), it can be assumed that the production will continue for as long as there is a demand for Fipronil.

1.1 Halon Production

Table 1-1 below shows the countries that have reported production for the period from 2005 to 2009. As seen from the table, only China and South Korea are reporting positive production figures, while the reports from other countries show negative production figures. Owing to the MP definition of production (see Annex B), positive production shows actual production for uses controlled by the MP, i.e., fire protection, while negative figures represent a net destruction of halons. NR indicates not yet reported in all tables.

Table 1-1: Reported production of halons by Parties as of September 2010 (ODP tons)

Party	2005	2006	2007	2008	2009
Belgium	-198.1	-123.0	-49.8	0.0	NR
China	5,475.8	995.0	988.3	977.3	985.6
Czech Republic	0.0	-2.0	0.0	0.0	NR
Finland	-100.0	-28.0	-46.0	-50.7	NR
France	0.0	-764.3	-392.7	-297.2	NR
Hungary	-30.9	0.0	-18.1	-27.4	NR
Netherlands	-7.2	-24.0	-2.0	-207.3	NR
South Korea	855.0	1,470.0	1,104.0	737.0	1,122.0
Sweden	-69.0	-175	-69.4	-12.4	NR
United Kingdom (UK)	145.4	-202.0	-510.0	0.0	NR
USA	0.0	0.0	-1.3	-224.4	NR

China produced both halon 1211 and halon 1301 in 2005. The halon 1211 production stopped by end of 2005, and from 2006 until end of 2009 China only produced halon 1301. South Korea produced both halon 1211 and halon 1301 in the period from 2005 to end of 2009.

1.2 Reported Halon Consumption

As shown in Table 1-2, the reported halon production and consumption data were the same from 2008–2009 for China and from 2005-2009 for South Korea, which, owing to the MP definition of consumption (see Annex B), indicates that no halons were exported. However, as exports of halon contained in products, i.e., halon fire extinguishers and halon fire extinguishing systems, are not controlled by the MP, some halons may have been exported as fire extinguishers and or fire extinguishing systems.

Table 1-2: Production and consumption of halon 1211 and 1301 by halon producing Parties (ODP tons)

Party	2005		2006		2007		2008		2009	
	Prodn.	Cons.	Prodn.	Cons.	Prodn.	Cons.	Prodn.	Cons.	Prodn.	Cons.
China	5,475.8	4,516.5	995.0	161.0	988.3	594.5	977.3	977.3	985.9	985.9
S. Korea	885.0	885.0	1,470.0	1,470.0	1,104.0	1,104.0	737.0	737.0	1,122.0	1,122.0

Table 1-3 shows consumption data reported by the Parties. As noted above, neither China nor the South Korea exported any halons in 2008 and 2009, which indicates that stockpiles of new halons might still exist in various places.

1.3 Recycled Halons

The trade in recycled halons is also reported under Article 7. The records for 2006 to 2009 are presented in Table 1-4 in ODP tons, (not all 2009 figures have yet been reported to the Ozone Secretariat). As Article 5 countries were allowed to import newly produced halons, it should be expected that the amount of recycled halons traded by them would be limited. Now that halon production has ceased globally, the data reported for recycled halons will become very important in determining regional imbalances and demand. HTOC will continue to monitor these data.

1.4 Halon Demand and Replacement

The demand for new halons has been eliminated through the availability of substitute fire extinguishing agents and alternatives, and through halon recycling programs. Based on a review of the situation in a large number of the Parties, with the exception of aviation, it has been concluded that generally halons have been replaced by substitutes for all new applications where halons were traditionally used. However, the demand for recycled halons remains high for existing applications.

Table 1-3: Consumption of halons by non-producing Parties (ODP tons)

Party	2005	2006	2007	2008	2009
Algeria	80.0	80.0	67.0	67.0	0.0
Argentina	3.0	0.0	0.3	0	NR
Botswana	0.3	0.3	0.6	0.6	NR
Brazil	3.0	2.0	1.6	0.0	NR
Cameroon	1.2	1.2	1.0	1.0	NR
Chile	1.2	0.0	0.0	0.0	NR
Democratic Republic of the Congo	22.8	6.8	2.6	0.0	NR
Egypt	145.0	44.0	0.0	0.0	0.0
Eritrea	0.3	0.0	0.0	0.0	NR
Ethiopia	0.4	0.0	0.0	0.0	NR
Equatorial Guinea	0.0	1.0	1.0	0.0	NR
European Union	-2,339.8	-254.9	-211.0	0.0	-41.2
Georgia	16.5	0.0	0.0	0.0	0.0
Iraq	NA	56.6	29.0	39.1	NR
Jordan	47.0	36.0	0.0	0.0	NR
Libyan Arab Jamahiriya	714.5	304.5	291.5	0.0	0.0
Mexico	52.8	51.6	0.0	0.0	0.0
Saudi Arabia	0.0	0.0	0.0	50.0	50.0
Serbia	0.9	0.0	0.0	1.8	0.0
Somalia	20.1	18.8	13.2	0.0	0.0
Syrian Arab Republic	79.0	56.0	0.0	0.0	NR
Thailand	10.9	0.0	0.0	0.0	NR
Tunisia	39.0	0.0	0.0	0.0	NR
Turkey	30.0	30.0	14.3	0.0	NR
United Arab Emirates	25.0	12.3	7.4	4.9	NR
United States of America	0.0	0.0	-1.3	-224.4	NR
Yemen	0.3	1.2	0.7	0.6	NR

Table 1-4: Trade in recycled halons (ODP tons)

Party	2005		2006		2007		2008		2009	
	Imp	Exp	Imp.	Exp.	Imp	Exp.	Imp.	Exp.	Imp.	Exp.
Non-Article 5										
Andorra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Australia	3.3	0.6	1.7	36.1	0.0	0.2	1.8	0.0	NR	NR
Canada	0.0	32.3	0.0	8.1	0.0	72.0	0.0	42.0	0.0	48.3
EU	20.9	0.0	41.2	79.8	21.0	243.2	0.0	102.3	0.0	77.8
Israel	70.5	0.0	96.0	0.0	66.5	0.0	67.8	0.0	NR	NR
Norway	0.0	44.1	0.0	0.8	0.0	747.0	0.0	0.0	NR	NR
Russian Federation	31.4	1.7	0,0	0.0	16.7	0.0	15.0	0.9	NR	NR
Switzerland	0.0	0.0	0.0	4.0	0.0	3.2	0.0	3.2	NR	NR
USA	132.0	0.0	136.3	0.0	263.7	0.0	27.0	0.0	NR	NR
Uzbekistan	0.0	0.0	0.0	0.0	1.7	0.0	0.9	0.0	NR	NR
Total Non-A5	**258.1**	**77.7**	**275.2**	**128.8**	**369.6**	**1,065.6**	**112.5**	**148.4**		
Article 5										
Bahrain	0.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	NR	NR
China	0.0	0.0	0.5	0.0	0.9	0.0	0.0	5.0	NR	NR
Colombia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7
India	27.0	0.0	0.0	0.0	124.6	0.0	0.0	0.0	NR	NR
Jordan	0.0	0.0	0.0	0.0	7.0	0.0	9.2	0.0	NR	NR
Serbia	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NR	NR
Singapore	0.0	0.0	0.0	15.1	1.4	0.0	0.0	0.0	NR	NR
Thailand	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	NR	NR
Total A5	**27.3**	**13.0**	**0.5**	**23.1**	**126.9**	**0.0**	**0.0**	**5.0**		
Global Total	**285.3**	**90.7**	**275.7**	**151.9**	**496.5**	**1,065.6**	**112.5**	**153.4**		

1.5 Challenges

Now that there is no global production of halons for fire protection uses, management of the remaining stock becomes crucial for ensuring sufficient halons for applications that need them.

2.0 Fire Protection Alternatives to Halon

The following information can also be found in the Halon Technical Options Committee's Technical Note 1.

2.1 Introduction

Halons, as defined in Group II of Annex A and Group III of Annex C of the Montreal Protocol (MP), form a class of halogenated chemicals containing bromine that have been and continue to be used as gaseous extinguishing agents in a wide range of fire and explosion protection applications. Halons are very potent stratospheric ozone depleting chemicals when released to the atmosphere. Halons have been phased out of production under the M P. The phase-out of halon production has had a dramatic impact on the fire and explosion protection industry. Halons are clean, non-conductive, and highly effective. Halon 1301, in particular, is safe for people when used at concentrations typically employed for "total flooding" fire extinguishing systems and explosion prevention (inerting) applications. Halon 1211 was widely employed in portable fire extinguishing units for use in what are called "streaming agent" applications. Halon 2402 has been used in both total flooding and streaming agent applications. Fire extinguishing agent alternatives to halons, in the form of non-ozone depleting gases, gas-powder blends, powders and other not-in-kind technologies (i.e., non-gaseous agents) are now available for virtually every fire and explosion protection application once served by halons.

Selection of the best fire protection method in the absence of halons is often a complex process. Either alternative gaseous fire extinguishing agents, so called in-kind alternatives, or not-in-kind alternatives may replace halon but the decision is driven by the details of the hazard being protected, the characteristics of the gaseous agent or alternative method, and the risk management philosophy of the user.

Gaseous extinguishing agents that are electrically non-conductive and which leave no residue are referred to as "clean" agents. Several clean agents and new "not-in-kind" alternative technologies have been introduced to the market. The purpose of this chapter is to provide a brief review of the types of alternatives to halons that are available, including information on physical and chemical characteristics (Table 2-3), fire protection capabilities and toxicity (Table 2-4), and key environmental parameters (Table 2-5).

Since the 2006 Assessment, there have been some changes made to national and international fire protection standards that affect some of the measures of performance and guidelines for use of the agents described herein.

- International standards recognise Class A fire hazards involving specific arrangements of electrified equipment may pose additional extinguishing challenges and re-ignition risks. In such cases higher minimum agent design concentrations are recommended.
- New procedures have been developed for determining safe personnel exposure guidelines where halocarbon agents are employed in occupied spaces. These procedures are based on what is referred to as the Physiologically-Based PharmacoKinetic (PBPK) model where exposure time is considered in addition to the

No Observed Adverse Effect Level (NOAEL) and Lowest Observed Adverse Effect Level (LOAEL) values of an agent.

- Both national and international standards are now in harmony with respect to requiring a 30% minimum safety factor where the fire hazard is due to Class B flammable and combustible liquids. The minimum safety factor for Class A surface fire hazards is 20% in some standards and 30% in others. This means that the minimum design concentration (MDC) of a gaseous fire extinguishing agent must be at least 1.2 or 1.3 times the minimum extinguishing concentration (MEC), as determined by test, for a particular fire hazard and depending on which standard governs the application.

Total Flooding Applications: A number of fire extinguishing agent technologies have been commercialised as alternatives to halon 1301 for use in total flooding applications. These are summarised in Table 2-1.

Several agents listed in Table 2-1 have been approved for use in normally occupied spaces. These agents include the named inert gas agents, HFC agents, FK-5-1-12 agent, gaseous agents containing particulate solids and HCFC Blend A. These agents may be used for total flooding fire protection in normally occupied spaces provided that the design concentration is below the safe exposure threshold limits presented in Table 2-4 for gaseous halocarbon agents without powder additives or Table 2-9 for inert gas agents. The United States Environmental Protection Agency (EPA), under the Significant New Alternatives Policy (SNAP) program, has reviewed a number of materials as substitutes for halons as fire extinguishing agents. The approval status of a number of such alternatives for use in total flooding systems and as streaming agents may be found at the EPA website:

http://www.epa.gov/spdpublc/snap/fire/lists/index.html

Agents listed in Table 2-1 that are not suitable for use in occupied spaces include carbon dioxide, FIC-13I1, FIC-217I1, HCFC-124, and the aerosol powders.

In addition to gaseous agents, powders, and mixtures of these, a number of other technologies have been evaluated for fire extinguishing applications where halon 1301 might have formerly been used. These include water-foam technologies and several types of water mist systems.

Water mist system technologies strive to generate and distribute within a protected space very small mist droplets which serve to extinguish flames by the combined effects of cooling and oxygen dilution by steam generated upon water evaporation. Technologies used to generate fine water mists include:

- Low pressure single fluid atomisation
- High pressure single fluid atomisation
- Dual-fluid atomisation
- Hot water steam generation

Table 2-1: Fire Extinguishing Agent Alternatives to Halons for Use in Total Flooding Applications

Agent	Constituents
Inert gases, pressurised	
IG-01	Argon, Ar
IG-100	Nitrogen, N_2
IG-541	Nitrogen, 52 vol. %; Argon, 40 vol. %; Carbon dioxide, 8 vol.%
IG-55	Nitrogen, 50 vol. %; Argon, 50 vol. %
Carbon dioxide	Carbon dioxide, CO_2
Inert gases, pyrotechnically generated	
Nitrogen	Nitrogen
Nitrogen-water vapour mixture	Nitrogen and water
Water mist	Water
Hydrofluorocarbons	
HFC-125	C_2HF_5 – Pentafluoroethane
HFC-23	CHF_3 - Trifluoromethane
HFC-227ea	CF_3CHFCF_3 - 1,1,1,2,3,3,3-heptafluoropropane
HFC-236fa	$CF_3CH_2CF_3$ - 1,1,1,3,3,3-hexafluoropropane
HFC Blend B	HFC-134a, CH_2FCF_3, 1,1,1,2-tetrafluoroethane, 86 wt.%; HFC-125, C_2HF_5, Pentafluoroethane, 9 wt.%; Carbon dioxide, CO_2, 5 wt.%
Fluoroketone	
FK-5-1-12	$CF_3CF_2(O)CF(CF_3)_2$ – Dodecafluoro-2-methylpentan-3-one
Iodofluorocarbons	
FIC-13I1	CF_3I – Iodotrifluoromethane
FIC-217I1	C_3F_7I – Iodoheptafluoropropane
Hydrochlorofluorocarbons	
HCFC-124	CHFClCF3, 1-Chloro-1,2,2,2-tetrafluoroethane
HCFC Blend A	HCFC-22, $CHClF_2$ - Chlorodifluoromethane, 82 wt. % HCFC-124, CHClF-CF_3,1-Chloro-tetrafluoroethane, 9.5 wt.% HCFC-123, $CHCl_2$-CF_3, 1,1-dichloro-trifluoroethane, 4.75 wt.% isopropenyl-1-methylcyclohexane, 3.75 wt.%
Gaseous Agents Containing Particulate Solids	
HFC227BC	HFC-227ea with 5 to 10 wt.% added sodium bicarbonate
Gelled mixture of HFC plus dry chemical additive.	HFC-125 plus ammonium polyphosphate or sodium bicarbonate HFC-227ea plus ammonium polyphosphate or sodium bicarbonate HFC-236fa plus ammonium polyphosphate or sodium bicarbonate
Aerosol Powders	
Powdered Aerosol A	Proprietary formulation
Powdered Aerosol C	Proprietary formulation
Powdered Aerosol D	Proprietary formulation
Powdered Aerosol E	Proprietary formulation

New or emerging technologies in total flooding applications

1. Water mist technologies continue to evolve. Recently commercialised innovations include:
    a. New atomisation technology using two-fluid system (air and water) to create ultrafine mist with spray features that are adjustable by changing the flow ratio of water to air;
    b. Water mist combined with nitrogen to gain extinguishing benefits of both inert gas and water mist.
2. Pyrotechnic products. Development continues on the use of pyrotechnic products to generate nitrogen or mixtures of nitrogen and water vapour, with little particulate content, for use in total flooding fire extinguishing applications.
3. Low GWP HFCs. One chemical manufacturer is developing unsaturated HFC compounds for various uses including as total flooding fire extinguishing agents. The molecules of these chemicals contain a double carbon-carbon bond which causes them to have short atmospheric lifetimes and, therefore, low values of GWP.
4. Unsaturated hydrobromofluorocarbon (HBFC). 3,3,3-trifluoro-2-bromo-prop-1-ene (2-BTP), CAS 1514-82-5

Each approach to generating fine water mists has its own advantages and drawbacks. Additional comments on water mist systems are given in Section 2.2.4.

<u>Local Application:</u> Extinguishing agents suitable for use as alternatives for halon 1211 are listed in Table 2-2.

New or emerging technologies in local application systems

1. Phosphorous tribromide, PBr_3. PBr_3 is a clear liquid with a boiling point of 173°C. It reacts vigorously with water liberating HBr and phosphoric acid and is, therefore, a toxic substance at ambient conditions. Though the agent contains bromine, it poses little risk to stratospheric ozone. The agent decomposes rapidly in the atmosphere and the HBr formed is quickly eliminated by precipitation. PBr_3 is an effective fire extinguishant in part due to its bromine content. Given its high boiling point, and low volatility, this agent must be delivered as a spray or mist into the fire zone in order to be effective. It has been commercialised for use as a fire extinguishant in one small aircraft engine application.
2. Water with additives. One manufacturer has introduced a novel non-corrosive and low toxicity water-based agent by employing multiple salts to achieve a very low freezing point (-70°C) without the use of glycols (spills are non-reportable) and excellent fire extinguishing effectiveness that includes film-forming capability. Initial commercial applications are as fixed local application systems in industrial vehicles such as mining and forestry.

Table 2-2: Fire Extinguishing Agent Alternatives to Halon 1211 for Use in Local Application Fire Protection[1]

Substitute	Constituents	Approved for Residential Use?
HCFC-123	CF_3CHCl_2	NO
HCFC-124	CF_3CHFCl	NO
HCFC Blend B	HCFC-123, 95 mol% min, Argon, 0.2 mol% min, CF_4, 0.4 mol% min	NO
Gelled Halocarbon/Dry Chemical Suspension	Halocarbon plus dry chemical plus gelling agent	YES
Surfactant Blend A	Mixture of organic surfactants and water	YES
Carbon dioxide	CO_2	YES
Water	H_2O	YES
Water Mist Systems	H_2O	YES
Foam	-	YES
Dry Chemical	-	YES
HFC-227ea	CF_3CHFCF_3	NO
HFC-236fa	$CF_3CH_2CF_3$	NO
FIC-13I1 *	CF_3I	NO
FK-5-1-12	$CF_3CF_2C(O)CF(CF_3)_2$	NO
Hydrofluoro-polyethers*	Hydrofluoro-polyethers	NO

* Added to table in 2010 Edition

3. Fluoroketone. FK-5-1-12, used in total flooding applications, is being further evaluated as a local application or streaming agent. The agent has a boiling point of 49°C but a vapour pressure of about 0.3 bar at 20°C so it can readily vaporize.
4. Trifluoromethyliodide. CF_3I is offered by one manufacturer and is available for research in fire extinguishing applications.

2.2 Alternatives to Halon 1301 for Total Flooding Fire Protection using Fixed Systems

2.2.1 Halocarbon Agents (without powder additives)

Halocarbon agents share several common characteristics, with the details varying among products. Common characteristics include the following:

1. All are electrically non-conductive;
2. All are clean agents, meaning that they vaporize readily and leave no residue;
3. All are stored as liquids or as liquefied compressed gases either as single component agents or as multi-component mixtures;
4. All can be stored and discharged from fire protection system hardware that is similar to that used for halon 1301;

[1] See Mark Robin http://www.haifire.com/magazine/halon_1211_streaming.htm

5. All (except HFC-23) use nitrogen super-pressurisation for discharge purposes;
6. All (except CF_3I) are less efficient fire extinguishants than halon 1301;
7. All, upon discharge, vaporize when mixed with air (except HCFC Blend A which contains 3.75% of a non-volatile liquid). Many require additional care relative to nozzle design; and
8. All (except CF_3I) produce more decomposition products, primarily hydrogen fluoride (HF), than halon 1301 given similar fire type, size, and discharge time.

These agents differ widely in areas of toxicity, environmental impact, storage weight and volume requirements, cost, and availability of approved system hardware. Each of these categories will be discussed for each agent in the following sections.

2.2.1.1 Agent Toxicity

In general, personnel should not be exposed unnecessarily to atmospheres into which gaseous fire extinguishing agents have been discharged. Mixtures of air and halon 1301 have low toxicity at fire extinguishing concentrations and there is little risk posed to personnel that might be exposed in the event of an unexpected discharge of agent into an occupied space. The acceptance of new agents for use in total flooding fire protection in normally occupied spaces has been based on criteria which have evolved over the period of introduction of new technologies into the marketplace. In the case of inert gas agents the usual concern is the residual oxygen concentration in the protected space after discharge. For chemical agents the primary health issue is cardiac effects as a consequence of absorption of the agent into the blood stream. The highest agent concentration for which no adverse effect is observed is designated the “NOAEL” for “no observed adverse effect level”. The lowest agent concentration for which an adverse effect is observed is designated the “LOAEL” for “lowest observed adverse effect level”. This means of assessing chemical agents has been further enhanced by application of physiologically based pharmacokinetic modelling, or “PBPK” modelling, which accounts for exposure times. Some agents have their use concentration limits based on PBPK analysis. The approach is described in more detail in ISO 14520-1, Annex G, 2nd Edition (2006).

Table 2-4 summarises the toxicity information[2] available for each chemical.

2.2.1.2 Environmental Factors

The primary environmental factors to be considered for halocarbon agents are ozone-depletion potential (ODP), global-warming potential (GWP), and atmospheric lifetime. These factors are summarised in Table 2-5. It is important to select the fire protection choice with the lowest environmental impact that will provide the necessary fire protection performance for the specific application. The use of any synthetic compound that accumulates in the atmosphere carries some potential risk with regard to atmospheric equilibrium changes. Perfluorocarbons (PFCs), in particular, represent an unusually severe potential environmental impact due to the combination of extremely long atmospheric lifetime and high GWP.

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[2] The principal basis for assessing the safety of gaseous halocarbon agents is cardiac sensitivity. A more complete discussion on the PBPK model may found at http://www.harc.org/pbpkharc.pdf.

International agreements and individual actions by national governments may affect future availability of these compounds and subsequent support for installed fire protection systems that utilise them. Some examples are presented below:

- HCFCs are scheduled for a production and consumption phase out for fire protection uses under the Montreal Protocol in 2020 in non-Article 5 Parties and 2030 in Article 5 Parties.
- The United Nations Framework Convention on Climate Change (UNFCCC) has identified carbon dioxide, methane, nitrous oxide and the fluorochemicals HFCs, PFCs and SF_6 as the basket of long-lived (>1 year) gases primarily responsible for anthropogenic changes to the greenhouse effect and potentially subject to emission controls. All uses of fluorochemicals represent 4–5% of current worldwide greenhouse gas emissions from long-lived gases on a carbon equivalent basis and fire protection uses represent less than 1% of those fluorochemical emissions.
- In the EU, Regulation (EC) No 842/2006 (known as the F Gas Regulation), introduces requirements to reduce emissions of specific fluorinated greenhouse gases. The regulation also requires that no new fire protection products using PFCs are placed on the market.

Table 2-3: Physical Properties of Gaseous Fire Extinguishing Agent Alternatives to Halons Used in Total Flooding Applications

Generic Name	Vapour Pressure @ 20ºC, bar	k1 m^3/kg (1)	k2 $m^3/kg/^oC$ (1)	Vapour Density @ 20ºC & 1 atm, kg/m^3	Liquid Density @ 20ºC, kg/m^3
Halon 1301 (a)	14.3	0.14781	0.000567	6.255	1,574
HCFC Blend A	8.25	0.2413	0.00088	3.861	1,200
HCFC-124 (b)	3.30	0.1585	0.0006	5.858	1,373
HFC-23	41.80	0.3164	0.0012	2.933	807
HFC-125	12.05	0.1825	0.0007	5.074	1,218
HFC-227ea (c)	3.89	0.1269	0.0005	7.282	1,408
HFC-236fa	2.30	0.1413	0.0006	6.544	1,377
FIC-13I1	4.65	0.1138	0.0005	8.077	2,096
FK-5-1-12	0.33	0.0664	0.000274	13.908	1,616
HFC Blend B (b)	12.57	0.2172	0.0009	4.252	1,190

Note 1: (1) Agent vapour specific volume $s = k1 + k2 \bullet t$, m^3/kg at an atmospheric pressure of 1.03 bar where t is the vapour temp. in ºC. Vapour density = 1/s.

Note 2: All values from ISO 14520 except where noted: (a) NFPA 12A (2009) and Thermodynamic Properties of Freon 13B1 (DuPont T-13B1); (b) NFPA 2001 (2008); (c) DuPont.

Table 2-4: Gaseous Fire Extinguishing Agent Alternatives to Halons Used in Total Flooding Applications – Minimum Extinguishing Concentrations and Agent Exposure Limits

Generic Name ISO standard reference	Minimum Design Conc., Class A Fire Vol. % (1)	Minimum Design Conc., Class B Fire Vol. % (1)	Inerting Conc. Methane/Air, Vol. %	NOAEL Vol. % (2)	LOAEL Vol. % (2)
Halon 1301	5.0 (3)	5.0 (3)	4.9	5	7.5
HCFC Blend A ISO 14520-6	7.8	13.0	20.5	10	>10
HCFC-124 (5,6)	-	8.7 (4)	-	1	2.5
HFC-23 ISO 14520-10	16.3	16.4	22.2	30	>50
HFC-125 ISO 14520-8	11.2	12.1	-	7.5	10
HFC-227ea ISO 14520-9	7.9	9.0	8.8	9	10.5
HFC-236fa ISO 14520-11	8.8	9.8	-	10	15
FIC-13I1 (5) ISO 14520-2	4.6 (7)	4.6	7.2 propane	0.2	0.4
FK-5-1-12 ISO 14520-5	5.3	5.9	8.8	10	>10
HFC Blend B (5)	14.7 (7)	14.7	-	5	7.5

Note 1: Design concentration = Extinguishing concentration x 1.3, the minimum permitted by ISO 14520.

Note 2: A halocarbon agent may be used at a concentration up to its NOAEL value in normally occupied enclosures provided the maximum expected exposure time of personnel is not more than five minutes. A halocarbon agent may be used at a concentration up to the LOAEL value in normally occupied and normally unoccupied enclosures provided certain criteria are met that depend on agent toxicity and egress time. The reader is referred to NFPA 2001-1.5 (2008) and ISO 14520-G.4.3 (2006) for details of the recommended safe exposure guidelines for halocarbon agents.

Note 3: Exceptions, halon 1301 design concentration is taken as the historical employed value of 5%.

Note 4: HCFC-124 data from 1999 revision of this report.

Note 5: Not approved for use in occupied spaces.

Note 6: These agents are not generally supplied in new suppression systems but may be found in legacy systems.

Note 7: Agent manufacturer did not provide Class A extinguishing concentration data. Class A design concentration in this case was taken as Class B design concentration.

Table 2-5: Gaseous Fire Extinguishing Agent Alternatives to Halons Used in Total Flooding Applications – Environmental Factors

Generic Name	Ozone Depletion Potential	Global Warming Potential, 100 yr. (1)	Atmospheric Life Time, yr. (1)
Halon 1301	10	7,140	65
HCFC Blend A: HCFC-22	0.055	1,790	11.9
HCFC Blend A: HCFC-124	0.022	619	5.9
HCFC Blend A: HCFC-123	0.02	77	1.3
HCFC-124	0.022	619	5.9
HFC-23	0	14,200	222
HFC-125	0	3,420	28.2
HFC-227ea	0	3,580	38.9
HFC-236fa	0	9,820	242
FIC-13I1	0.0001	1**	7 Days*
FK-5-1-12	0	1**	7–14 Days*
HFC Blend B: HFC-134a	0	1,370	13.4
HFC Blend B: HFC-125	0	3,420	28.2

Note 1: Source: 2010 Scientific Assessment of Ozone Depletion

* These are approximate lifetimes for short-lived gases, though actual lifetimes for an emission will depend on the location and season of that emission

** Data were supplied by the manufacturer.

Table 2-6: Gaseous Fire Extinguishing Agent Alternatives to Halons Used in Total Flooding Applications – Halocarbon Agent Quantity Requirements for Class A Combustible Hazard Applications (1, 2)

Generic Name	Agent Mass, kg/m^3 of Protected Volume	Mass Relative to Halon 1301	Agent Liquid Volume litre/m^3 of Protected Volume	Maximum Cylinder Fill Density, kg/m^3 (3)	Cylinder Storage Volume Relative to Halon 1301 (4)	Cylinder Pressure @ 20°C, bar
Halon 1301	0.331	1.000	0.210	1,121	1.00	25 or 42
HCFC Blend A (6)	0.577	1.74	0.481	900	2.17	25 or 42
HCFC-124 (6,7)	0.549	1.66	0.400	1,185	1.57	25
HFC-23	0.571	1.73	0.708	860	2.25	43
HFC-125	0.640	1.93	0.525	929	2.33	25
HFC-227ea	0.625	1.89	0.444	1,150	1.84	25 or 42
HFC-236fa	0.631	1.91	0.459	1,200	1.78	25 or 42
FIC-13I1 (6)	0.389	1.18	0.186	1,680	0.79	25
FK-5-1-12	0.778	2.35	0.482	1,480	1.78	25, 34.5, 42 or 50
HFC Blend B (6,7)	0.733	2.22	0.616	929	2.67	25 or 42

Note 1: Halon alternative agent quantities based on 1.3 safety factor.
Note 2: Mass and volume ratios based on "Minimum Class A Fire Design Concentrations" from Table 2-4.
Note 3: Fill density based on 25 bar pressurisation except for HFC-23.
Note 4: Agent cylinder volume per m^3 protected volume = (Agent Mass, kg/m^3 protected volume)/ (Maximum Fill Density, kg/m^3 cylinder) = ($V_{CYL}/V_{ProtVol}$). For halon 1301 cylinder volume per m^3 hazard = (0.331 kg/m^3 hazard)/ (1,121 kg/m^3 cylinder) = 0.0002953 m^3 cylinder /m^3 protected volume.
Note 5: NFPA 12A; ASTM D5632.
Note 6: Agent manufacturer did not supply complete Class A extinguishing data, hence no Class A MDC established; the heptane MDC was employed in this table.
Note 7: NFPA 2001 (2008).

Table 2-7: Gaseous Fire Extinguishing Agent Alternatives to Halons Used in Total Flooding Applications - Halocarbon Agent Requirements for Class B Fuel Applications (1,2)

Generic Name	Agent Mass, kg/m³ of Protected Volume	Mass Relative to Halon 1301	Agent Liquid Volume litre/m³ of Protected Volume	Maximum Cylinder Fill Density, kg/m³ (3)	Cylinder Storage Volume Relative to Halon 1301 (4)	Cylinder Pressure @ 20°C, bar
Halon 1301	0.331	1.00	0.210	1,121	1.00	25 or 42
HCFC Blend A	0.577	1.74	0.481	900	2.17	25 or 42
HCFC-124	0.549	1.66	0.400	1,185	1.57	25
HFC-23	0.575	1.74	0.713	860	2.27	43
HFC-125	0.698	2.11	0.573	929	2.55	25
HFC-227ea	0.720	2.18	0.512	1,150	2.12	25 or 42
HFC-236fa	0.711	2.15	0.516	1,200	2.01	25 or 42
FIC-13I1	0.389	1.18	0.186	1,680	0.79	25
FK-5-1-12	0.872	2.63	0.540	1,480	2.00	25, 34.5, 42 or 50
HFC Blend B	0.733	2.22	0.616	929	2.67	25 or 42

Note 1: Nominal maximum discharge time is 10 seconds in all cases.
Note 2: Mass and volume ratios based on "Minimum Class B Fire Design Concentrations" from Table 2-4.
Note 3: Fill density based on 25 bar pressurisation except for HFC-23.
Note 4: Agent cylinder volume per m^3 of protected volume = (Agent Mass, kg/m^3 of protected volume)/(Maximum Fill Density, kg/m^3 cylinder) = ($V_{CYL}/V_{ProtVol}$). For halon 1301 cylinder volume per m^3 of protected volume = (0.331 kg/m^3 hazard)/ (1,121 kg/m^3 cylinder) = 0.0002953 m^3 cylinder/m^3 of protected volume.

2.2.2 Carbon Dioxide

Carbon dioxide, used widely for fire protection prior to the introduction of halons, has seen a resurgence in use subsequent to the halon production phase out, particularly in new commercial ship construction where halon 1301 once had a significant role. Minimum design concentrations for carbon dioxide are specified in national and international standards such as NFPA 12 and ISO 6183. The minimum design concentration for carbon dioxide systems is, typically, 35 vol. % for Class B fuels and 34 vol. % for Class A applications.

2.2.2.1 Agent Toxicity

Carbon dioxide is essentially chemically inert as a fire extinguishing gas. Carbon dioxide does, however, have significant adverse physiologically effects when inhaled at concentrations above 4 vol. %. The severity of physiological effects increases as the concentration of carbon dioxide in air increases. Exposure to carbon dioxide at concentrations exceeding 10 vol. % poses severe health risks including risk of death. As such, atmospheres containing carbon dioxide at fire extinguishing concentrations are always lethal to humans. Precautions must always be taken to ensure that occupied spaces are not put at risk by ingress of carbon dioxide from a space into which the agent has been discharged.

NFPA 12 (2008) includes new restrictions on the use of carbon dioxide in normally occupied spaces.

2.2.2.2 Environmental Factors

The carbon dioxide used in fire protection applications is not produced for this use. Instead, it is captured from an otherwise emissive use temporarily sequestering it until it is released. Thus, carbon dioxide from fire protection uses has no net effect on the climate.

2.2.3 Inert Gas Agents

There have been at least four inert gases or gas mixtures commercialised as clean total flooding fire suppression agents. Inert gas agents are typically used at design concentrations of 35-50 vol. % which reduces the ambient oxygen concentration to between 14% to 10% vol. %, respectively. Reduced oxygen concentration (hypoxia) is the principal human safety risk for inert gases except for carbon dioxide which has serious human health effects at progressive severity as its concentration increases above 4 vol. %. Inert gas agents mixed with air lead to flame extinguishment by physical mechanisms only. The inert gas agents commercialised since 1990 consist of nitrogen, argon, blends of nitrogen and argon. One blend contains 8% carbon dioxide. The features of the commercialised inert gas agents are summarised in Tables 2-8 and 2-9.

These agents are electrically non-conductive, clean fire suppressants. The inert gas agents containing nitrogen or argon differ from halocarbon agents in the following ways:

- Inert gases can be supplied from high pressure cylinders, from low pressure cryogenic cylinders, or from pyrotechnic solids. High pressure systems use pressure reducing devices at or near the discharge manifold. This reduces the pipe thickness requirements and alleviates concerns regarding high pressure discharges.
- High pressure system discharge times are on the order of one to two minutes. This may limit some applications involving very rapidly developing fires.
- Inert gas agents are not subject to thermal decomposition and hence form no hazardous by-products.

Table 2-8: Inert Gas Agents for Fixed Systems Agent Properties

Generic name	IG-541 ISO 14520-15	IG-55 ISO 14520-14	IG-01 ISO 14520-12	IG-100 ISO 14520-13
Agent composition				
Nitrogen	52%	50%		100%
Argon	40%	50%	100%	
Carbon Dioxide	8%			
Environmental factors				
Ozone depletion potential	0	0	0	0
Global warming potential, 100 yr.	0	0	0	0
Properties				
k1, m^3/kg (1)	0.65799	0.6598	0.5612	0.7998
k2, m^3/kg/deg C (1)	0.00239	0.00242	0.00205	0.00293
Specific Volume, m^3/kg	0.697	0.708	0.602	0.858
Gas Density @ 20°C, 1 atm, kg/m^3	1.434	1.412	1.661	1.165
Extinguishing (2)				
Min. Class A fire design conc., vol. %	39.9	40.3	41.9	40.3
Oxygen conc. at min. Class A design conc., vol. %	12.6	12.5	12.2	12.5
Min. Class B fire design conc., vol. %	41.2	47.5	51	43.7
Oxygen conc. at min. Class B design conc., vol. %	12.3	11.0	10.3	11.8
Inerting design conc., Methane/Air, vol. %	47.3	-	61.4	-
Oxygen conc. at min. inerting design conc., vol. %	11.0	-	8.1	-

Note 1: Agent vapour specific volumes = k1 + k2 x t, m3/kg at an atmospheric pressure of 1.03 bar where t is the vapour temperature in deg C. Vapour density = 1/s.
Note 2: Extinguishing and design concentration values from ISO 14520 2nd Edition (2006).

2.2.3.1 Physiological Effects

The primary health concern relative to the use of the inert gas agents containing nitrogen or argon is the effect of reduced oxygen concentration on the occupants of a space. The use of reduced oxygen environments has been extensively researched and studied. Many countries have granted health and safety approval for use of inert gases in occupied areas in the workplace. One product contains 8 vol. % carbon dioxide[3], which is intended to increase blood oxygenation and cerebral blood flow in low oxygen atmospheres.

[3] Inert gas agent IG-541 contains 8% carbon dioxide and is approved by the U.S. EPA SNAP rules as a safe alternative to halon 1301 in total flooding fire protection systems. At elevated concentrations, however, carbon dioxide is not safe for human exposure and is lethal at fire extinguishing concentrations.

2.2.3.2 Environmental Factors

Inert gas agents are neither ODSs nor GHGs and, as such, pose no risk to the environment.

Table 2-9: Inert Gas Agents Fixed System Features

Generic name	IG-541	IG-55	IG-01	IG-100
Agent exposure limits				
Max unrestricted agent conc., vol. % (1)	43	43	43	43
Max restricted agent conc., vol. % (2)	52	52	52	52
System requirements per m3 of protected volume				
Class A hazard				
Agent gas volume, m^3	0.457	0.529	0.509	0.494
Cylinder storage volume, litre (3)	3.04	3.53	2.83	2.75
Cylinder volume relative to halon 1301 (4)	10.0	11.5	9.3	9.0
Class B hazard				
Agent gas volume, m^3	0.531	0.643	0.715	0.574
Cylinder storage volume, litre (3)	3.54	4.29	3.97	3.19
Cylinder volume relative to halon 1301 (4)	11.6	14.0	13.0	10.4
System Features				
Available cylinder sizes (typical), litre	16;67;80	16;67;80	16;67;80	16;67;80
Available cylinder pressures, bar	150 to 300	150 to 300	150 to 300	150 to 300
Nominal Discharge Time, seconds	60	60	60	60

Note 1: Corresponds to a residual oxygen concentration of 12 Vol. %.
Note 2: Corresponds to a residual oxygen concentration of 10 Vol. %.
Note 3: Approximate, for the minimum indicated cylinder pressure.
Note 4: Halon 1301 cylinder volume per m3 hazard. See Note 4 of Table 2-6.

2.2.4 Water Mist Technology

One of the non-traditional halon replacements which has been developed and commercialised is fine water mist technology. Water mist fire suppression technologies are described in national and international standards such as NFPA 750 *Standard on Water Mist Fire Protection Systems* and the FM Approvals Standard No. 5560 *Water Mist Systems*. The latter 296 page document is available at no charge from the following website:

http://www.fmglobal.com/assets/pdf/fmapprovals/5560.pdf

Briefly, fine water mist relies on sprays of relatively small diameter droplets (less than 200 μm) to extinguish fires. The mechanisms of extinguishment include the following:

- Gas phase cooling
- Oxygen dilution by steam formation
- Wetting and cooling of surfaces, and
- Turbulence effects

Water mist systems have attracted a great deal of attention and are under active development due primarily to their low environmental impact, ability to suppress three-dimensional flammable liquid fires, and reduced water application rates relative to automatic sprinklers. Recent innovations include use of nitrogen with water mist to achieve inert gas extinguishing effects, and use of bi-fluid (air-water) nozzles to achieve ultrafine droplets and adjustable spray patterns (by varying the air-water ratio). The use of relatively small (10-100 μm) diameter water droplets as a gas phase extinguishing agent has been established for at least 40 years. Recent advances in nozzle design and improved theoretical understanding of fire suppression processes has led to the development of at least nine water mist fire suppression systems. Several systems have been approved by national authorities for use in relatively narrow application areas. To date, these applications include shipboard machinery spaces, combustion turbine enclosures, flammable and combustible liquid storage spaces as well as light and ordinary hazard sprinkler application areas.

Theoretical analysis of water droplet suppression efficiencies has indicated that water liquid volume concentrations on the order of 0.1 L of water per cubic meter of protected space is sufficient to extinguish fires. This represents a potential of two orders of magnitude efficiency improvement over application rates typically used in conventional sprinklers. The most important aspect of water mist technology is the extent to which the mist spray can be mixed and distributed throughout a compartment versus the loss rate by water coalescence, surface deposition, and gravity dropout. The suppression mechanism of water mist is primarily cooling of the flame reaction zone below the limiting flame temperature. Other mechanisms are important in certain applications; for example, oxygen dilution by steam has been shown to be important for suppression of enclosed 3-D flammable liquid spray fires.

The performance of a particular water mist system is strongly dependent on its ability to generate sufficiently small droplet sizes and distribute adequate quantities of water throughout the compartment. Factors that affect the ability of achieving that goal include droplet size and velocity, distribution, and spray pattern geometry, as well as the momentum and mixing characteristics of the spray jet and test enclosure effects. Hence, the required application rate varies by manufacturer for the same hazard. Therefore, water mist must be evaluated in the combined context of a suppression system and the risk it protects and not just an extinguishing agent.

There is no current theoretical basis for designing the optimum droplet size and velocity distribution, spray momentum, distribution pattern, and other important system parameters. This is quite analogous to the lack of a theoretical basis for nozzle design for total flooding, gaseous systems, or even conventional sprinkler and water spray systems. Hence, much of the experimental effort conducted to date is full-scale fire testing of particular water mist hardware systems which are designed empirically. This poses special problems for standards making and regulatory authorities.

There are currently two basic types of water mist suppression systems: single and dual fluid systems. Single fluid systems utilise water delivered at 40-200 bar pressure and spray nozzles which deliver droplet sizes in the 10 to 100 μm diameter range. Dual systems use air, nitrogen, or other gas to atomise water at a nozzle. Both types have been shown to be promising fire suppression systems. It is more difficult to develop single phase systems with the proper droplet size distribution, spray geometry, and momentum characteristics. This difficulty is offset by the advantage of requiring only a high pressure water source versus water and atomiser gas storage.

The major difficulties with water mist systems are those associated with design and engineering. These problems arise from the need to distribute the mist throughout the space while gravity and agent deposition loss on surfaces deplete the concentration and the need to generate, distribute, and maintain an adequate concentration of the proper size droplets. Engineering analysis and evaluation of droplet loss and fallout as well as optimum droplet size ranges and concentrations can be used effectively to minimise the uncertainty and direct the experimental program.

2.2.4.1 Physiological Effects

At the request of the US EPA, manufacturers of water mist systems and other industry partners convened a medical panel to address questions concerning the potential physiological effects of inhaling very small water droplets in fire and non-fire scenarios. Disciplines represented on the Panel included inhalation toxicology, pulmonary medicine, physiology, aerosol physics, fire toxicity, smoke dynamics, and chemistry, with members coming from commercial, university, and military sectors. The Executive Summary (draft "Water Mist Fire Suppression Systems Health Hazard Evaluation;" Halon Alternatives Research Corporation (HARC), US Army, NFPA; March 1995) states the following: "The overall conclusion of the Health Panel's review is that...water mist systems using pure water do not present a toxicological or physiological hazard and are safe for use in occupied areas. Thus, EPA is listing water mist systems composed of potable water and natural sea water as acceptable without restriction. However, water mist systems comprised of mixtures in solution must be submitted to EPA for review on a case-by-case basis".

2.2.4.2 Environmental Factors

Water mist does not contribute to stratospheric ozone depletion or to greenhouse warming of the atmosphere. Water containing additives may, however, offer other environmental contamination risks, e.g., foams, antifreeze and other additives.

2.2.5 Inert Gas Generators

Inert gas generators are pyrotechnic devices that utilise a solid material which oxidises rapidly, producing large quantities of carbon dioxide and/or nitrogen. Recent innovations include generators that produce high purity nitrogen or nitrogen and water vapour with little particulate content. The use of this technology to date has been limited to specialised applications such as dry bays on military aircraft. This technology has demonstrated excellent performance in these applications with space and weight requirements equivalent to those of halon 1301 and is currently being utilised in some US Navy aircraft applications.

2.2.5.1 Physiological Effects

Applications to date have included normally unoccupied areas only. The precise composition of the gas produced will obviously affect the response of exposed persons. Significant work is required to expand application of this technology to occupied areas.

2.2.5.2 Environmental Effects

Gases emitted by these products do not contribute to stratospheric ozone depletion or to greenhouse warming of the atmosphere except to the extent that they emit carbon dioxide, if any.

2.2.6 Fine Solid Particulate Technology

Another category of technologies being developed and introduced are those related to fine solid particulates and aerosols. These take advantage of the well-established fire suppression capability of solid particulates, with potentially reduced collateral damage associated with traditional dry chemicals. This technology is being pursued independently by several groups and is proprietary. To date, a number of aerosol generating extinguishing compositions and aerosol extinguishing means have been developed in several countries. They are in production and are used to protect a range of hazards.

One principle of these aerosol extinguishants is in generating solid aerosol particles and inert gases in the concentration required and distributing them uniformly in the protected volume. Aerosol and inert gases are formed through a burning reaction of the pyrotechnic charge having a specially proportioned composition. An insight into an extinguishing effect of aerosol compositions has shown that extinguishment is achieved by combined action of two factors such as flame cooling due to aerosol particles heating and vaporizing in the flame front as well as a chemical action on the radical level. Solid aerosols must act directly upon the flame. Gases serve as a mechanism for delivering aerosol towards the seat of a fire.

A number of enterprises have commercialised the production of aerosol generators for extinguishing systems that are installed at stationary and mobile industrial applications such as nuclear power station control rooms, automotive engine compartments, defence premises, engine compartments of ships, telecommunications/electronics cabinets, and aircraft nacelles.

Fine particulate aerosols have also been delivered in HFC/HCFC carrier gases. The compositions are low in cost and use relatively simple hardware. A wide range of research into aerosol generating compositions has been carried out to define their extinguishing properties, corrosion activity, toxicity, and effect upon the ozone layer as well as electronics equipment.

Solid particulates and chemicals have very high effectiveness/weight ratios. They also have the advantage of reduced wall and surface losses relative to water mist, and the particle size distribution is easier to control and optimise. However, there is concern of potential collateral damage to electronics, engines, and other sensitive equipment. Condensed aerosol generators, which produce solid particulates through combustion of a pyrotechnic material, are unsuitable for explosion suppression or inerting since pyrotechnic/combustion ignited aerosols can be re-ignition sources. These agents also have low extinguishing efficiency on smouldering materials. Technical problems including high temperature, high energy output of combustion generated aerosols and the inability to produce a uniform mixture of aerosol throughout a complex geometry remain to be solved.

Additional information on fine solid particulate technologies may be found in NFPA 2010 *Standard for Fixed Aerosol Fire Extinguishing Systems*.

2.2.6.1 Physiological Effects

There are several potential problems associated with the use of these agents. These effects include inhalation of particulate, blockage of airways, elevated pH, reduced visibility, and the products of combustion from combustion generated aerosols, such as HCl, CO, and NO_x. For these reasons, the majority of these technologies are limited to use in only unoccupied spaces.

2.2.6.2 Environmental Factors

Fine particulate aerosols themselves and associated inert gases from generators do not contribute to stratospheric ozone depletion or to greenhouse warming of the atmosphere. There may be ozone depletion or greenhouse gas effects, however, where aerosols are delivered with halocarbon carrier gases.

2.3 System Design Considerations for Fixed Systems

Care must be taken throughout the design process to assure satisfactory system performance. Hazard definition, nozzle location and design concentration must be specified within carefully defined limits. Further, a high degree of enclosure integrity is required. Design requirements are provided by national and international standards such as NFPA 2001 and ISO 14520. An outline of factors to be taken into consideration is given below:

2.3.1 Definition of the Hazard

- Fuel type(s)
- Fuel loading
- Room integrity (openings, ventilation, false ceilings, subfloors)
- Dimensions and Net Volume of the room
- Temperature extremes
- Barometric pressure (altitude above sea level for gas systems)

2.3.2 Agent Selection

- Statutory approvals
- Personnel safety
- Minimum concentration required (cup burner/full scale tests)
- Design concentration required with factor of safety
- NOAEL/LOAEL or limiting oxygen concentration. Is the agent design concentration within safe exposure limits over the range of feasible hazard temperatures and net volumes?
- Decomposition characteristics
- Replenishment availability

2.3.3 System Selection

- System intended for use with the agent selected
  - Pressures, elastomers, gauges, labels
- System has appropriate approvals as the result of third party testing
  - Strength tests (containers, valves, gauges, hoses, etc.)
  - Leakage tests
  - Cycle testing of all actuating components
  - Corrosion tests
  - Cylinder mounting device tests
  - Aging tests for elastomers
  - Flow tests (software verification, balance limitations)
  - Fire tests (nozzle area coverage, nozzle height limitations
- System has documented design, installation, maintenance procedures

2.3.4 System Design

- Automatic detection and control
  - Type of detection (smoke, heat, flame, etc.)
  - Logic (cross zoned, priority designated)
  - Control system features
  - Local and remote annunciation
  - Start up and shut down of auxiliary systems
  - Primary and back-up power supply
  - Manual backup and discharge abort controls
- Central agent storage, distributed or modular
- Electrical, pneumatic or electrical/pneumatic actuation
- Detector location
- Alarm and control devices location
- Class A (control loop) or Class B electrical wiring
- Electrical signal and power cable specifications
- Nozzle selection and location
- Piping distribution network with control devices
- Piping and other component hangers and supports
- Agent hold time and leakage
- Selection of an appropriate design concentration

- Agent quantity calculations
- Flow calculations
- Pipe size and nozzle orifice determination

2.3.5 System Installation

- Installed per design
- System recalculated to confirm "as built" installation
- Correct piping
  - Size
  - Routing
  - Number and placement of fittings
  - Pipe supports
  - Correct type, style, orifice size nozzle in each location
- Fan test to confirm tightness of protected volume and adequacy of pressure relief venting
- Acceptance functional test of full system without discharge
  - Test each detector's operation
  - Test system logic with detection operation
  - Test operation of auxiliary controls
  - Test local and remote annunciation
  - Test signal received at system valve actuators
  - Test system manual operators
- Test system abort discharge abilities

2.3.6 Follow Up

- Integrity of the protected space does not change
  - Walls, ceiling and floor intact
  - Any new openings sealed properly
- Net volume and temperature range of the space does not change
- Regular maintenance for detection, control, alarm and actuation system
- Regular verification of the agent containers' charged weight
- Regular cleaning of the detection devices
- Confirmation of back-up battery condition

2.4 Alternatives for Portable Extinguishers

2.4.1 Traditional Streaming Agents

2.4.1.1 Straight Stream Water

Straight stream water is suitable for use on fires of ordinary combustibles such as wood, paper and fabrics only. This type of extinguisher is unsuitable for use in extinguishing fires involving liquids or gases and in fact could spread a flammable liquid fuel. Straight stream water extinguishers are unsafe for use on fires where energised electrical circuits are present.

2.4.1.2 Water Fog (Spray)

Water spray extinguishers are most suitable for use on fires of ordinary combustibles such as wood, paper and fabrics. This type of extinguisher may be less effective on deep-seated fires. The spray stream is generally more effective on burning embers and may provide a very limited capability for fires involving combustible liquid fuels. Some water spray extinguishers can be used on fires where live electrical circuits are present. Users should ensure that the extinguisher has been tested and certified before use on live electrical circuits.

Some manufacturers have introduced “water mist” fire extinguishers into commerce.

2.4.1.3 Aqueous Film Forming Foam (AFFF)

Extinguishers using water and AFFF additives may be more effective than those using clean water only on fires of ordinary combustibles such as wood, paper and fabrics. Additionally, water with AFFF additives will have improved ability, over water alone, to extinguish fires involving flammable or combustible liquids. Also, this agent has the ability to reduce the likelihood of ignition when applied to the liquid surface of an unignited spill. The aqueous film forming foam reduces vapour propagation from the flammable liquid.

Depending upon the stream pattern, this type of extinguisher may not be safe for use on fires where live electrical circuits are present.

Contaminants from the AFFF and its delivery agent can pollute the environment. The molecule that remains after biodegradation of AFFF may be bioaccumulative and toxic. When PFC-containing AFFF has been repeatedly used in one location over a long period of time, the PFCs can move from the foam into soil and then into groundwater. The environmental impact must be weighed against the potential gain in efficacy when selecting a portable extinguisher for each specific application.

2.4.1.4 Carbon Dioxide (CO_2)

Carbon dioxide extinguishers use CO_2 stored as a liquefied compressed gas. Carbon dioxide is most suitable for use on fires involving flammable liquids. Carbon dioxide does not conduct electricity and can be used safely on fires involving live electrical circuits. In general, carbon dioxide extinguishers are less effective for extinguishing fires of ordinary combustibles such as wood, paper and fabrics.

2.4.1.5 Dry Chemical

Dry chemical extinguishers are of two types. Ordinary dry chemicals, usually formulations based on sodium or potassium bicarbonate, are suitable for fires involving flammable liquids and gases. Multipurpose dry chemicals, usually formulations of monoammonium phosphate (MAP), are suitable for use on fires of ordinary combustibles such as wood, paper and fabrics and fires involving flammable liquids and gases. Both ordinary and multipurpose dry chemicals may be safely used on fires where electrical circuits are present; however, after application dry chemical residue should be removed because in the presence of moisture it could provide an electrical path that would reduce insulation effectiveness.

2.4.2 Halocarbon Agents

Information on halocarbon streaming agents is contained in Table 2-10. These agents come closest to matching all the desirable properties of halon. For example they are effective on both solid and liquid fuel fires and they permeate well avoiding secondary damage. However, in general, they are more expensive than traditional fire protection agents and, on average require more agent.

Table 2-10: Halocarbon Streaming Agents for Portable Fire Extinguishers

Generic Name	Group	Storage State	Chemical Composition		Environmental Factors		
			Weight %	Species	ODP**	GWP*** 100 yr. (1)	Atmospheric Lifetime yr. (1)
Halon 1211	Halon	LCG*	CF_2ClBr		3	1,890	16
HCFC Blend B	HCFC & PFC Blend	CGS****	>96%	HCFC-123	0.02	77	1.3
			<4%	CF_4	0	7,390	>50,000
			<4%	Argon	0	n/a	n/a
HCFC-124	HCFC	LCG*	$CHClF\text{-}CF_3$		0.022	619	5.9
HCFC-123	HCFC	Liquid	$CHCl_2\text{-}CF_3$		0.02	77	1.3
HFC-236fa	HFC	LCG*	$CF_3CH_2CF_3$		0	9,820	242
HFC-227ea	HFC	LCG*	CF_3CHFCF_3		0	3,580	38.9

* LCG – Liquefied Compressed Gas
** ODP – Ozone Depletion Potential
*** GWP – Global Warming Potential
**** CGS – Compressed Gas in Solution
Note 1: Source: 2010 Scientific Assessment of Ozone Depletion

2.4.2.1 Toxicity

The toxicity of streaming agents is assessed based on the likely exposure of the person using the extinguisher. This is sometimes measured using breathing zone samples. All of the streaming agents in Table 2-10 are considered safe for normal use. Use of some of these agents in confined spaces may be a cause for concern.

2.4.2.2 Environmental Factors

The environmental factors for halocarbon streaming agent alternatives are the same as those discussed for halocarbon total flooding agents. Information on ODP, GWP and atmospheric lifetime are presented in Table 2-10. Traditional streaming agents do not present environmental concerns in the areas of ODP, GWP, or atmospheric lifetime but may offer other environmental risks associated with the use of additives, e.g., fluorosurfactants.

2.5 Assessment of Alternative Streaming Agents

The important features of alternative, manually applied fire extinguishing agents are described below. In general portable extinguishers are only used on actual fires and can be readily directed at the burning material.

2.5.1 Effectiveness on Ordinary Combustibles

This parameter considers the ability of the agent to extinguish fires in ordinary solid combustibles, including cellulosic materials. These are called Class A fires and the extinguisher should carry a rating categorising its Class A performance.

2.5.2 Effectiveness on Liquid Fuel Fires

This parameter considers the ability of the agent to extinguish liquid fuel fires (Class B). The extinguisher should carry a Class B rating.

2.5.3 Electrical Conductivity

Minimal conductivity is important in fighting fires where electricity is involved.

2.5.4 Ability to Permeate

This parameter reflects the ability of the agent to extinguish fires in locations where direct application to the fuel surface or flame reaction zone is not possible, for example, in the hidden void space in a commercial airliner.

2.5.5 Range

This parameter reflects the ability of the agent to maintain a coherent effective stream over a modest distance.

2.5.6 Effectiveness to Weight Ratio

This parameter considers the relative fire suppression capability across all fuels per unit weight of agent.

2.5.7 Secondary Damage

This category refers to the “clean agent” aspects of the agents, i.e., secondary damage caused by the suppressant agent itself.

2.6 Selection of an Alternative Streaming Agent

The performance of each alternative is summarised in Table 2-11. The relative importance of each parameter has not been rigorously derived and final selection depends on detailed knowledge of the risk to be protected.

Table 2-11: Portable Fire Extinguisher Capability Comparison

Type	Ordinary Combustibles	Flammable Liquids	Suitable on Energised Electrical Hazards	Ability to Permeate	Stream Range	Effective Weight	Secondary Damage
CO_2	Poor	Fair	Yes	Good	Fair	Poor	Good
Multi-purpose Dry Chemical	Good	Good	Yes	Fair	Good	Good	Poor
AFFF	Good	Fair	No	Poor	Good	Poor	Poor
Water Stream	Good	Poor	No	Poor	Good	Poor	Poor
Water Fog	Good	Fair	Yes	Fair	Fair	Fair	Fair
Halocarbon	Good	Good	Yes	Good	Good	Good	Good
Halon 1211	Good	Good	Yes	Good	Good	Good	Good
Sodium Bicarbonate Dry Chemical	Poor	Good	Yes	Fair	Good	Good	Poor
Potassium Bicarbonate Dry Chemical	Poor	Good	Yes	Fair	Good	Good	Poor

2.7 Conclusions

Alternative extinguishing agents and technologies are available for nearly all new fire protection applications that previously employed halons. An exception is the fire protection in cargo bays of civil aviation.

2.8 References

1. Halon Alternatives Research Corp., PBPK Model, ISO 14520-1, Annex G, 2nd Edition, 2006, http://www.harc.org/pbpkharc.pdf

2. U.S. Environmental Protection Agency (EPA), "Carbon Dioxide as a Fire Suppressant: Examining the Risks", EPA430-R-00-002, http://www.epa.gov/Ozone/snap/fire/co2/co2report.pdf

3.0 Climate Considerations for Halons and Alternatives

3.1 Introduction

Hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), and to a much lesser extent perfluorocarbons (PFCs), have been commercialised as replacements for halons. The development of these chemicals for use in fire and explosion suppression applications, as outlined in Chapter 2, was instrumental in achieving the halon production phase-out mandated by the Montreal Protocol. While the saturated HFCs and PFCs are not ozone-depleting substances, they have been identified by the Intergovernmental Panel on Climate Change (IPCC) as potent greenhouse gases with long atmospheric lifetimes and are part of the basket of six gases included in the United Nations Framework Convention on Climate Change. As part of efforts to reduce emissions of greenhouse gases (GHGs), there are currently under consideration both international and national proposals to control the production or emissions of HFCs, and some type of future regulation of these agents seems likely.

Emissions of HFCs and PFCs currently represent approximately 1% of total GHG emissions. Emissions of HFCs and PFCs from fire protection are estimated at less than 1% of total HFC and PFC emissions (or less than 0.01% of total greenhouse gas emissions) from all sources. The Technology and Economic Assessment Panel (TEAP) update of the Intergovernmental Panel on Climate Change (IPCC)/TEAP Special Report on Ozone and Climate estimates that as of 2009 about 20% of the former halon market for total flooding applications was replaced with HFCs, with about 50% of the market choosing not-in-kind alternatives and about 25% opting for zero/low GWP alternatives such as fluoroketone, inert gases, and carbon dioxide. PFCs made up less than 1% of the former halon market and are no longer installed in new fire protection applications. Annual emission rates for HFCs are estimated to be 2% for total flooding systems and 4% for portable extinguishers. The report concludes that the GHG reduction potential from fire protection is small due in part to the relatively low emission level and the significant shift to not-in-kind alternatives.

3.2 Proposed HFC Amendments

In 2009 and 2010 amendments were proposed that would add HFCs to the Montreal Protocol and slowly phase down their production.

The following are key elements of the proposals:

List 20 specified HFCs in a new Annex F to the Montreal Protocol.

- Use a baseline for non- Article 5 Parties of the average of 2004-2006 annual production and consumption of HFCs and HCFCs.
- Slowly phase down the production and consumption of HFCs in non-Article 5 Parties beginning with a 10–15% reduction in 2013–2014 and reaching an 85–90% reduction in 2028–2030.
- HFC phase down in Article 5 Parties would begin 3–6 years later and reach the 85–90% level 6–10 years later.

- Include provisions to strictly limit HFC-23 by-product emissions resulting from the production of HCFCs (e.g., HCFC 22).
- Require licensing of HFC imports and exports, and bans imports and exports to non-Parties.

The proposed HFC amendments were discussed but not approved at the 2009 and 2010 Meeting of Parties (MOP) to the Montreal Protocol. Similar proposals are likely to be considered at the 2011 MOP. The Parties may wish to consider that any future HFC amendments or adjustments include provisions for fire protection uses that have no alternatives other than ODS or the high GWP HFCs.

3.3 National Regulations and Proposals

Only a few countries such as Switzerland and Denmark currently have restrictions on the use of HFCs in fire protection. The European Union F-gas regulation (Regulation (EC) No. 842/2006) does not restrict the use of HFCs in fire protection, but instead requires containment, leak inspection, labelling, training, reporting, and recovery in order to reduce emissions. This regulation is up for review in 2011. In the United States, legislative proposals are being considered that would slowly phase down the production of HFCs in a manner similar to the proposed Montreal Protocol amendments outlined above.

3.4 TEAP Response to Decision XXI/9

In Decision XXI/9, the Parties requested the TEAP to inform them of uses for which low or zero GWP alternative technologies are or will soon be commercialised. The TEAP concluded that alternatives exist for most of the former uses of halons that have low or zero GWP. These alternatives are described in Chapter 2 and include fluoroketone, inert gases, carbon dioxide (non-occupied spaces), and not-in-kind alternatives such as water, dry chemical, and foam. There are a small number of fire protection applications that may still require halons, HCFCs, or HFCs such as Alaskan oil and gas production facilities, crew bays of armoured vehicles, military and civilian flight lines, and portable extinguishers on board civil aircraft.

3.5 Considerations

Environmental authorities were aware of the high GWPs of HFCs and PFCs when they were first approved as ODS replacements in the early 1990s. At that time the most important consideration was quickly eliminating the production of ODS so that the ozone layer could begin recovering, and it was necessary to have effective, efficient, and affordable alternatives in order to achieve that goal. Replacing a high ODP agent with a low or zero ODP agent with a similar global warming potential (GWP) was considered to be a good trade-off for the environment. In their 2007 paper, Velders et al., conclude that the phase out of ODS has already achieved significant climate benefits and additional benefits could be achieved by limiting future emissions of high GWP alternatives.

There are a few important fire protection applications such as oil and gas facilities in cold climates and crew bays of armoured vehicles where the only current options are to use recycled halon or a high GWP HFC. From a total environmental impact perspective, is it better to reuse an already produced, recycled, halon or produce a high GWP HFC for the application? This is a challenge that the Parties may wish to consider.

There are other applications such as military and civilian flight lines and portable extinguishers on board aircraft where the current options are recycled halons, HFCs, or a low ODP/low GWP HCFC. In response, the aviation industry is currently developing an unsaturated hydrobromofluorocarbon (HBFC) agent as a possible replacement for halon 1211 in portable extinguishers. It is possible that this agent could have a very low ODP even when released at higher altitudes. The Parties may wish to consider providing guidance on the viability of using a low GWP alternative that may have a non-zero but low ODP.

3.6 ODS Destruction

Halons have high direct GWPs that are generally in the same range as the HFCs that have replaced them. There has been an increased focus recently on the destruction of banks of unwanted used ODS, which would contribute to both ozone and climate protection. One way of providing incentives for ODS destruction that is under consideration would be to award GHG reduction credits on a GWP-weighted basis for destroying used ODS. There are voluntary protocols that have recently been completed that contain specifications for providing GHG credits for ODS destruction, and this approach is being considered as part of proposed cap-and-trade programs in the US and other countries.

Although halons have high direct GWPs that range from 1,640 for halon 2402 to 7,140 for halon 1301, as of February 2010, they have not been included in either of the two known voluntary ODS destruction protocols because of uncertainty related to their indirect GWPs. Owing to the fact that halons contain bromine and are potent ozone-depleting substances, it has been estimated that their indirect GWPs could be less than zero. If GHG reduction credits are provided in the future for destroying used halons, this could have a significant impact on the cost of recycled halon and its availability for important uses. In light of recent published data on the indirect GWPs of halons (Young et al., Atmos. Chem. Phys., 2009), the Parties may wish to consider requesting the Scientific Assessment Panel to clarify the extent of the climate benefits, if any, resulting from destroying banked halons.

3.7 References

1. TEAP Decision XX/8 Task Force Report, May 2009.

2. Proposed amendment to the Montreal Protocol (submitted jointly by Canada, Mexico and the United States of America) – UNEP/OzL.Pro.22/5.

3. Proposed amendment to the Montreal Protocol (submitted by the Federated States of Micronesia) – UNEP/OzL.Pro.22/6.

4. Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases.

5. G.J.M., Velders, S.O., Andersen, J.S., Daniel, D.W., Fahey, and M. McFarland, “The importance of the Montreal Protocol in protecting climate”, *Proceedings of the National Academy of Sciences*, March 2007.

4.0 Global Halon 1211 and 1301 Banking

4.1 Introduction

Halon banking is a critical part of the management of halons. Halon bank programmes must be accessible to all halon users or the risk of accelerated atmospheric emissions will escalate as users find themselves with redundant stock, and an increase in unsafe fire hazards could occur if end-users are unable to obtain vital refills.

A facility or organisation can either perform the banking function physically as a "physical" bank with halon actually stored and maintained in specific locations, or they can act as a clearinghouse where halon users can be facilitated in turning-in halon and/or obtaining halon. Virtual halon banking is a clearinghouse whereby halon transfer is facilitated between users.

A halon bank is all halons contained in fire extinguishing cylinders and storage cylinders within any organisation, country, or region. Likewise the 'global halon bank' is all halon presently contained in halon fire equipment and all halon stored at halon recycling centres, at fire equipment companies, at halon users premises, at halon producers' stores, etc., i.e., it is all halon produced but yet to be emitted or destroyed. The collection, reclamation, storage, and redistribution of halons are referred to as "Halon Banking".

For the purposes of this Assessment Report, "banking" is considered as all functions both physical and virtual that involve the use, recovery, recycling, reclamation, transfer, storage, and disposal of all halons used for fire protection.

This chapter is a synopsis of the current state of halon 1211 and 1301 banking globally.

4.2 Regional and National Halon Banking Programmes

Many Parties have halon banking programs that are fully operational. The early halon production phase-out schedule imposed on the non-Article 5 Parties resulted in early establishment of halon banking programs. As a result, their programs have been tested and have matured. Previous HTOC reports have covered the development, implementation, and operation of many successful halon banking programs within non-Article 5 Parties. A recent study has found that the CEIT's and Article 5 Parties are in many cases still struggling to establish halon banks or to set up protocols for participation in regional halon banks, see reference[1]. There remain many countries that have not yet implemented any regulations, procedures, or programs to facilitate the effective management of remaining halon inventories.

Table 4-1 is a list of country national and regional halon banking operations most of which were extracted from the *Final Evaluation Report on Halon Banking Projects for Countries with Low Volumes of Installed Capacities*, see reference [2]. Table 4-1 is not a globally comprehensive list of halon banking programs, but rather a list of those programs that were established or assisted utilising Multilateral Funds. Where "Recovery & Recycling" is indicated under the "Type of Management" column, there is not yet a national "Halon Bank". HTOC members attempted to contact all Parties listed in Table 4-1 during the development of this 2010 Assessment Report. For those Parties that did not respond, and whose halon management programme status was not known with certainty by HTOC members, the status "unknown" is given.

Table 4-1: Regional and National Article 5 Halon Banking Programmes

Country	Program	Type of Management	Functionality
Algeria	National	Physical Halon Bank	Began some R&R in 2007; Halon Bank not yet established as of 2009.
Argentina	National	Physical Halon Bank	Began operations in 2004.
Bahamas	Regional	Information Clearinghouse	Unknown.
Bahrain	National	Physical Halon Bank	Received R&R equipment; lacking funding to set up Halon Banking operations.
Barbados	Regional	Information Clearinghouse	Unknown.
Benin	Unknown	None Reported	Unknown.
Bosnia and Herzegovina	National	Physical Halon Bank	Not yet operational; working on setting up bank.
Botswana	Unknown	None Reported	Unknown.
Brazil	National	Halon Banking	Unknown.
Burkina Faso	Unknown	None Reported	Unknown.
Cameroon	Unknown	None Reported	Unknown.
Chile	National	Physical Halon Bank	Getting established; not operational yet.
China	National	1211 Recovery & Recycling 1301 R&R	1211: Facility established, but not operating. 1301: Facility under development.
Congo	Unknown	None Reported	Unknown.
Congo, DR	Unknown	None Reported	Unknown.
Croatia	National	Physical Halon Bank	Not yet fully operational; equipment still needed.
Czech Republic*	National	Physical Halon Bank	Operational beginning 2005.
Dominican Republic	National	Physical Halon Bank	Not yet fully operational; equipment still needed.
Ecuador	National	Recovery & Recycling	Unknown.
Egypt	National	Physical Halon Bank	Operational.
Estonia*	Regional	Halon Banking	Operational beginning 2002.
Ethiopia	Unknown	None Reported	Unknown.
Georgia	National	Physical Halon Bank	Operational for commercial users; experiencing difficulties.
Grenada	Regional	Information Clearinghouse	Unknown.
Guinea	Unknown	None Reported	Unknown.
Guyana	Regional	Information Clearinghouse	Unknown.
Hungary	National	Halon Banking	Operational beginning 1997; GEF project.
India	National	Halon Banking	Not Operational.
Indonesia	National	Physical Halon Bank	Operating; concerns regarding financial support.
Iran	National	Physical Halon Bank and Clearinghouse	Not yet operational; working on setting up physical bank.

Table 4-1: Regional and National Article 5 Halon Banking Programmes (Continued)

Country	Program	Type of Management	Functionality
Jamaica	Regional	Information Clearinghouse	Unknown.
Jordan	National	Halon Banking	Operational beginning 2005.
Kenya	Unknown	None Reported	Unknown.
Kyrgyzstan	National	Physical Halon Bank	Operational; equipment still needed.
Lebanon	Unknown	None Reported	Unknown.
Lesotho	Unknown	None Reported	Unknown.
Libya	National	Physical Halon Bank	Not yet operational.
Macedonia	National	Technical Assistance	No halon banking; very little halon left in country.
Malaysia	National	Halon Banking	Not operating; lack of halon availability and demand.
Mexico	Unknown	None Reported	Operating minimally.
Namibia	Unknown	None Reported	Unknown.
Nigeria	National/Regional	Physical Halon Bank	Operational; working on national and regional funding issues.
Oman	National	Recovery & Recycling	Awaiting UNIDO approval for purchase of R&R equipment.
Pakistan	National	Discontinued	No longer operational; minimally utilised due to financial issues.
Qatar	Unknown	None Reported	Unknown.
Romania	National	None	Halon management only.
Russia	National	Unknown.	Unknown.
Serbia and Montenegro	National	Physical Halon Bank	Operational beginning 2004; challenges due to lack of sufficient regulation.
South Korea	National	Recovery & Recycling	Not functional due to lack of regulation enforcement.
Syria	National	Physical Halon Bank	Operational beginning 2006.
South Africa	Regional	Physical Halon Bank	Operating in SA; willing to serve as regional.
Tanzania	Unknown	None Reported	Unknown.
Thailand	National	Information Clearinghouse	Operational.
Trinidad and Tobago	Regional	Information Clearinghouse	Unknown.
Turkey	National	Physical Halon Bank	Unknown.
Uruguay	National	Recovery & Recycling	Unknown.
Venezuela	National	Halon Banking	Operational with halon 1301 in stock.
Vietnam	National	None	Funding impediments.
Yemen	Unknown	None Reported	Unknown.
Zimbabwe	Unknown	None Reported	Unknown.

* These countries did not receive Multilateral Funds

The International Maritime Organisation (IMO) Sub-Committee on Fire Protection has provided information on the availability of halons at various ports of the world for existing maritime halon systems that may need to be recharged with recycled halons in compliance with the relevant requirements of the 1974 Safety of Life at Sea (SOLAS) Convention. Member Governments provided information on available halon banking facilities. Table 4-2 is an updated list of country facilities and their halon services available, extracted from IMO FP.1/Circular 40 dated 8 January 2010, see reference [3].

Table 4-2: Halon Banking and Reception Facilities at Various Ports around the World Available for Maritime Halon Needs

Country	Facilities	Type of Bank
Argentina	INTI	Virtual Halon Bank
Australia	Australian National Halon Bank	Full Service Halon Bank
Brazil	Two Facilities	Halon Receiving, Recharging, and Supply
Canada	Numerous commercial entities	Varies
Croatia	One Facility	Halon Bank
Egypt	Two Facilities	Halon Bank
Finland	Federation of Finnish Insurance Companies	Virtual Halon Bank
France	Numerous Facilities	Halon Recycling, Recovery, and Supply
Italy	Numerous Facilities	Halon Recycling, Recovery, and Supply
Norway	Numerous Facilities	Halon Recycling, Recovery, and Supply
Poland*	Savi Technologies and Poż-Pliszka	Halon Recovery, Recycling, Reclamation, and Supply
Russian Federation	One Facility	Halon Recycling, Recovery, and Supply
South Korea	One Facility	Halon Recycling, Recovery, and Supply
United States	Halon Recycling Corporation	Virtual Halon Bank
Hong Kong, China*	Environmental Protection Dept.	Virtual Halon Bank

* Not listed in the IMO Circular

4.2.1 Examples of Halon Management Programmes that are functioning successfully in Article 5 Parties

This section provides a few examples of Parties that have initiated halon management programmes which are currently operating successfully. Numerous additional examples are provided in Appendix C.

Jordan: The halon banking program was initiated by the Jordanian Government; a steering committee consisting of both private and public sectors commenced working on a halon bank concept in 1999. The halon bank of Jordan officially started in 2002, under the auspices of the Jordan Armed Forces and the Ministry of Environment. The halon bank of Jordan completed a Multilateral Fund project in 2005.

The steering committee originally intended for the bank to serve Jordanian halon needs and to build up strategic reserves for uses considered critical by Jordan.

The bank is a self-sustained organisation and is run by a management committee which is led by the Managing Director of the King Abdullah II Design and Development Bureau (a semi-governmental agency). Bank expenses are met by funds raised mainly by charges generated from recovery, recycling, and reclamation of halons. The accounts are audited annually by independent auditors.

No legislation has been proposed or implemented by the bank. Control of import or export of halons is regulated by the Customs Department. The strategy has been to rely on the Ministry of Environment to follow the intention of the Montreal Protocol and Amendments, with regard to halon consumption; whereby, halon is imported or exported with an authorisation by the Bank and with full coordination with the Ministry of Environment's Ozone Unit. The quality of the 'halon' is tested both before and after R&R via an independent party, the Royal Scientific Society Laboratories, to determine the purity.

A halon bank facility consisting of recovery, recycling, and reclamation machines for two kinds of halons (1211 and 1301) has been set up at the Jordan Industrial Estate Corporation, Abdullah II Ibn Alhussain Industrial City in Amman. The bank facility has been operational since May 2005. The recycling is provided as a charged service to users (of which many are governmental departments). The halon bank does stockpile halons to be provided to users for future uses considered critical by Jordon.

<u>South Africa</u>: The halon bank of South Africa has been in operation since 1995, under the auspices of the South African Government's Department of National Health. The main objective of the bank has been to manage consumption of halon down to zero, facilitate the return of halons from containers in the field, and to provide halons for end-uses considered to be critical by South Africa.

The halon bank of South Africa is a non-profit organisation and is run by two joint-managers; the Managing Director of the Fire Protection Association of South Africa, and a Consulting Fire Engineer, assisted by both companies' administration staff as required. The halon bank's expenses are met by funds raised mainly by levies on halon transactions and certification charges. The accounts are audited annually by independent auditors.

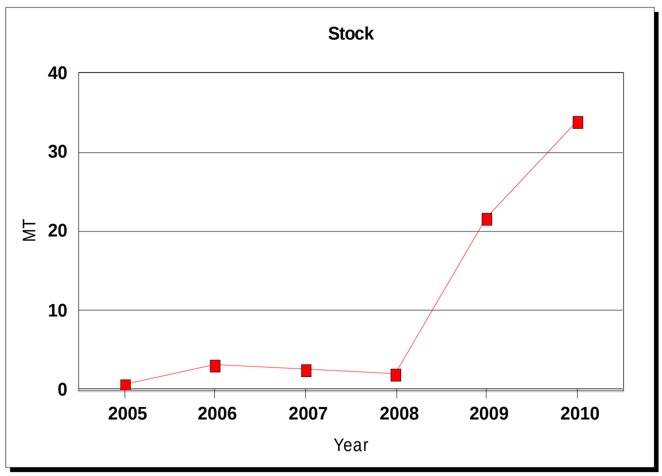
It acts as a clearing agent for sales and returns of used halon, 'lists and approves' companies that recycle used halons to a recognised specification, and acts as a link between South African users and halon banks in other countries. It also provides advice and investigations on all matters relating to halon and alternative fire protection methods, arranges for assay testing of halon samples, and issues a variety of certificates, for example a certificate of 'halon return' to end users.

The halon bank serves South Africa and neighbouring countries, such as Swaziland, Lesotho, Namibia, Botswana and Zimbabwe, although operational experience has been that these neighbouring countries have little halon refill needs or stock to return. It has also responded to returns applications from Nigeria, Cameroons and the Seychelles.

Control of import or export of halons is by the Customs Department. Legislation has recently been developed by the Department of Environmental Affairs to regulate the import, export, possession, trade, transaction and disposal of halons. This is expected to come into force in the near future, and will facilitate improvements in the management of halons in South Africa.

A containerised recycling plant, originally delivered to South Africa in 2005 by GTZ Proklima, was relocated to an alternative vendor in South Africa by the halon bank in early 2008. The equipment has since been re-commissioned and is now being used to decant into bulk tanks the build-up of portable containers returned to the halon bank that have accumulated during a number of years. Refills of halon containers are done by the approved vendor or by two end-users. Refills are usually from stock of halon saturated with nitrogen, i.e., the nitrogen is generally not fully extracted before refilling.

To date, the halon bank has authorised about 100 refills for uses considered to be important, and processed some 120 returns. Over 1,500 documents have been generated or processed in the course of the management of halons.



Since the last HTOC Assessment Report, the halon bank has experienced a significant increase in the quantity of halon returns (disposal by end-users). The graph to the right shows approximate stock levels increasing considerably during the past two years.

These sudden increases have been an unexpected burden, as additional storage space has been needed in a short period of time, with associated rental costs.

It is suggested that similar experiences may occur with other banks, together with unexpected and possibly unaffordable financial consequences. As a result, some banks could stop operating or require funding that was not forecasted from their related governments (Parties).

The previous HTOC Assessment Report stated that the bank had identified a destruction facility in Johannesburg. This facility has since closed, and currently there is no local capability authorised for the destruction or disposal of halons. Stock of non-recyclable halon is currently being kept in bulk containers, and there is thus an unknown financial liability in the form of an unresolved disposal issue. Other banks, particularly in under-developed countries, may encounter similar financial risks in the future and thus require unexpected financial support from their governments.

<u>Venezuela</u>: Venezuela received halon reclamation equipment and a gas chromatograph in 1996 with MLF assistance. A commercial entity was selected by the Venezuelan government to operate the national halon bank; they have five branch locations within the country one of which provides the halon recycling and storage. They have approximately 5 MT of halon 1301 in stock. Halon 1211 is not available locally except in fire extinguishers on a very few applications such as small ships, small planes, and helicopters; therefore, the expended extinguishers are being refilled with a halon alternative. The halon 1301 is used for recharging fire protection systems in military and civil aviation, subway transportation systems, and on some oil tanker ships. Venezuela prohibits the import and export of halons. Venezuela prohibits halon destruction as do most South American countries. There is information on halons in the web pages of the Ministries of Environment for most Latin American countries; however it may not be up-to-date. The Ministry of Environment of Venezuela has an organisation called FONDOIN which controls all ODS related activities. They have a website:

www.fondoin.org/uto/venezuela.php

whereby halon users are directed to the national bank to purchase, sell, or recycle halons. Since the bank is a commercial entity, this arrangement provides them with the opportunity to offer halon alternatives to the system users. Such an arrangement has been formed by many countries providing a successful pairing of a government organisation with the fire protection industry to enable halon phase-out while enriching business for the commercial entity. In the case of Venezuela, the commercial entity has five branches that cover the total Venezuelan market and serves a market of over 100 small distributors and fire extinguisher service companies. While turning over the national halon banking operations to a commercial entity provides a significant market advantage for the company, the selection of this particular company with its network of smaller businesses ensures a much higher likelihood of halon collection and transition. In terms of the banking systems operations, they do not buy contaminated halon. They perform a gas chromatography test of each halon cylinder/system before buying or receiving it as part of the payment for a new alternative fire suppression system. They test the halon after they have reclaimed it; however, they do not test stored halon unless a customer requires a certification. Most of their halon is stored in 2,000 lb horizontal tanks and they are in the process of purchasing new storage tanks from DuPont. A downside to this government/industry partnership is there is no compensation to the bank for taking in cross-contaminated halons and the country has no apparent procedures in place to handle those halons, so they are likely to be vented to the atmosphere. There are companies in other countries that will purchase and “clean” cross-contaminated halons; however, cross-contaminated halons are a financial liability in Venezuela because of the halon export prohibition.

4.2.2 Examples of Halon Management Programmes experiencing difficulties in Article 5 Parties

This section provides a few examples of Parties that have initiated halon management programmes which are currently having challenges. Several additional examples are provided in Appendix C.

Bahrain: Bahrain enacted comprehensive laws to control ozone depleting substances in 1999 which included control measures for halon use, imports, and exports. The Bahrain National Ozone Unit received recovery and recycling equipment in 2003 from an MLF project and began establishment of a government managed halon bank. It was originally envisioned that Bahrain would be participating in a regional halon bank management scheme; however, numerous issues such as lack of halon R&R equipment portability, lack of MOUs, the inability to sustain trained operators, and lack of governmental support inhibited the formation of a regional halon bank. The bank operations were set up within the Bahrain Defence Force (BDF). A workshop was provided to the BDF fire officers and the Civil Aviation at that time. During initial operations, they found that local ambient conditions such as high temperatures negatively impacted the operability of their off-the-shelf halon R&R equipment. They also found the equipment to be complicated to use and requiring numerous repairs; the manufacturer required the equipment be shipped to them for each repair further aggravating the situation. As of late 2009, the halon bank was still in need of funding for a building, infrastructure, and storage containers for the recovered halon. The NOO said they may need to export recovered halon 1301 in the next few years if storage space and cylinders do not become available. They are also in need of funding for refresher training if and when operations become fully active.

China: A halon 1211 recycling facility was established in 2005–2006 timeframe with assistance from the MLF. China encountered three problems: 1) the first halon 1211 collected was severely cross-contaminated so that the recycling equipment could not clean the halon, 2) a new regulation (2008), classifying halon as hazardous waste was issued by the Ministry of Environment, and 3) remaining stock of newly produced halon 1211 covered the demand for halon 1211 at a cost lower than the cost of recycled halon thus eliminating the demand for recycled halon 1211. China is now in the process of setting up a halon 1301 reclamation facility with assistance again from the MLF. China was producing halon 1301 up until the end of 2009 and therefore did not see a need for reclamation capabilities until after production cessation.

India: As stated in the HTOC 2006 Assessment Report, India received MLF assistance to purchase halon reclamation equipment for halon 1211, 1301, and 2402, and laboratory equipment to test and certify halon both before and after reclamation. They also received six half-ton capacity storage tanks and a“halon identifier”. A national bank was set up in 2004. An Awareness Campaign was completed in 2006 that included training and numerous workshops. At that time a website was established. A practical demonstration of the national banking equipment was provided to the facility engineers and technicians, and some of India’s important users such as the military, oil, power, aviation, fire services, communications, chemical and petrochemical industry, and the manufacturing industry. Indian regulations to control import and export of virgin halon came into force through a Government of India gazette notification. Initially (2004–2007) some halon, approximately 1 MT, was processed through the national halon banking facility, primarily for military organisations. Approximately 1 MT of new halon was imported for the bank, presumably just prior to the importation prohibition.

The bank’s management was non-responsive to HTOC attempts to contact them for an update on the operation of the bank, which may be having problems. It appears that the military, as well as the power and oil sector, have developed their own halon management programmes and facilities.

4.2.3 Examples of Article 5 Parties utilising Clearinghouses for Halon Bank Management

Below are a few examples of Parties that have opted for halon brokerages or clearinghouse programmes rather than halon banking operations. HTOC was not able to determine the progress or efficacy of the programmes described in this section.

Thailand: Initially, Thailand intended to establish a physical halon bank and received MLF assistance to do so. Upon further evaluation, they determined that the country would be better served by providing a halon clearinghouse. The clearinghouse policies on halon were summarised by the NOO, "The halon from non-essential users should be transferred to essential users, and if no essential users need the halon, then it will be exported to other countries. Destruction of halon that cannot be utilised is considered the last option". Transactions are tracked by a licensing system because Thailand chose to control halon under their Hazardous Substances Act so that the import or export of halons must be approved by the Ministry of Industry. In terms of the clearinghouse functions, the NOO noted they perform a supporting role and are strictly a coordinator; the halon trading negotiations are conducted directly between affected users:

> http://www.ozonediw.org/halon

Iran: Iran received MLF assistance to establish both a physical halon bank as well as a clearinghouse. Their clearinghouse is managed from the offices of the NOU. Under the established clearinghouse, the NOU is facilitating the exchange of information on the quantities of virgin, recovered, and recycled halons among the stakeholders and the halon users. The clearinghouse database currently operates "locally" meaning the data are accessible to Local Area Network users only. The NOU handles third party inquiries directly.

Caribbean Region: A number of Caribbean countries, with assistance from Environment Canada and the University of West Indies, set up a regional halon clearinghouse to manage halon inventories of the member countries. They have a website with extensive information and links regarding halon phase-out and they list the partnering countries along with the country inventories and direct points of contact for individual halon systems. The clearinghouse is not interactive, halon users do not contact the clearinghouse manager for their needs, but rather they go to the website and find contact information for direct exchanges. There are no fees and the clearinghouse is not a broker for users and sellers. The countries did not all provide the needed halon inventory and contact data, nor have they updated their information. Despite the shortcomings, the website is a good example for much of the information that should be contained in a clearinghouse website:

> http://sta.uwi.edu/fsa/HalonProject

4.3 Path to Halon Management and Banking

Halon banking comprises but a portion of an overall Montreal Protocol compliance programme. The other features of a comprehensive programme should occur before a halon bank is established. Examples of these features include:

- Establish governmental policy and program

- Implement Awareness Campaigns
- Choose appropriate replacements or alternatives
- Develop or adopt Standards for the Design, Installation, and Maintenance of fire protection systems (including halon and halon alternatives)
- Survey installed capacities & establish database of halon users
- Identify remaining mission-critical uses and quantity requirements
- Identify acquisitions or halon sources (recoverable and available for reclaiming) from uses not considered critical by the Party
- Identify & involve stakeholders
- Establish National Halon Steering Committee
- Open discussions with the military, civil aviation, shipping, & airlines
- Plan for decommissioning of halon systems

A decision can then be made whether to establish or join a halon bank to meet mission-critical uses.

Important policies that have been shown to help ensure successful implementation of a banking program include:

- Emphasise to stakeholders that supplies are limited with no future production
- Prohibit new halon systems in facilities or new equipment designs
- Prohibit halon emissions in testing and drills – use only on real fires
- Replace discharged halon systems with other forms of fire protection
- Require that all halon removed from retired systems be sent to the bank
- Prohibit purchases of halon on the market – all transactions via the bank – through regulations or voluntary agreements
- Exchange information and expertise regionally
- Develop halon regulations, e.g., importation of halons, a quota system.
- Develop and approve code of conduct/strategy

The Concept of Operation is as follows:

- The bank acts as a centralised warehousing and repair facility
- The bank becomes a "one stop shop" for all halon transactions; e.g., turn in, reclamation, storage and reissue
- All used halon is turned in to the bank
- Deliver the type and quantity of halon bottles where and when needed
- Bank provides clean halon for applications, as needed

- Bank provides testing of halon quality and certification
- Information available in the form of brochures, newsletter, website, phone, etc.

Record keeping and program management are greatly simplified by strict adherence to the banking concept because multiple, dispersed physical storage locations and information systems are eliminated. Bank users should be apprised of the benefits they derive from their participation in a banking program, such as consistent quality and predictable supplies of halon.

Options for setting up a halon bank include contractor-operated, government-operated or a combination of these. The combination option allows for a contractor to run ‘normal’ operations, but ownership and control of government halon is maintained by government personnel who monitor turn-ins and approve issues, as well as retaining overall program control.

A purely contracted operation would be less expensive to set up initially, but it may be more difficult for a private concern to obtain halon or ensure compliance with national policies than a government or military organisation would experience.

A purely government operated bank would ensure stricter control of quantities and availability of halon, but would likely be more expensive to set up and maintain. The expertise required to operate the halon bank may be difficult to obtain in a government organisation.

Halon bank rules should be clearly established up front and strictly adhered to during operation. The bank concept is that you can’t take out more than you put in. Issues will be limited to those required for authorised uses and not for convenience. Examples include aircraft, tactical vehicles, and shipboard uses. Some important command, control, and communications facilities could be included. A list of authorised users must be created and issues to those users should be made in approved quantities.

Halon removed from service <u>must</u> be sent to the bank for reuse. Owners are not allowed to sell, trade, give away or dispose of halon. The bank must provide shipping and containers free of charge. It must be easy and cost nothing to encourage field units to turn in used halon. After encouraging and facilitating all possible sources to turn in their halon, the Bank may then turn to commercial sources to obtain recycled halon. This can be expensive, but should be considered to meet necessary requirements.

The basic functions of the bank are to receive, test, recycle/reclaim and repackage, store, and issue halons. In addition, the bank must either refurbish cylinders in-house or contract out this function.

Safety is critical in the operation of a halon bank. Workers must be fully trained to know and avoid common safety problems when dealing with compressed gas cylinders. Hand held leak detectors should be used at receiving facilities. Each cylinder should be inspected for valve type and integrity to include all safety devices. Workers should <u>always</u> assume a cylinder is fully pressurised regardless of gauge reading.

Cylinders should always be chained down when being evacuated or worked on in any way. Workers need to be trained to know the different types of valves and how they activate, e.g., Burst Disk/Initiator, Mechanical/Cutter Valves, and Schrader Valves. Everyone working on halon cylinders needs to be fully trained to avoid fatal accidents.

In addition to safety training, workers need to be competent to perform the routine functions of the bank:

- Leak test incoming cylinders
- Verify product and possible contaminants
- Remove/recover all halon to specified level of vacuum
- Repackage into larger cylinders
- Clean halon to specification
- Repackage for storage and Issue
- Certify workers
- Use certified equipment

All incoming halon must be tested. Cylinders may not contain what the label states. Halon may be contaminated and unsuitable for use. Always test before repackaging as small impurities can contaminate large amounts of otherwise good halon. All halon that cannot be recovered should be sent to a nationally approved facility for destruction.

It is essential that the banking operations do more than “recover” the halon, which is simply the collection and storage of the halon prior to disposal. The bank should provide as a minimum halon recycling which is the reuse of halon after a basic cleaning process of filtering and drying. In this case nitrogen should not be vented but rather processed through a halon recycling unit in order to capture all halon. The optimum services for the bank to provide are analysis of the gases contained within the cylinder, reclamation of the halon followed by chemical analysis, and certification. Reclamation is recycling as previously defined followed by nitrogen separation in order to restore the halon to a minimum of 99.0% purity for halon 1211 and 99.6% for halon 1301 (see ISO 7201 and ASTM D5632, references [4] and [5]). Both recycled and reclaimed halons should be provided to users with certificates of analysis. Recycling/reclamation are core functions of a halon bank. Commercial recycling and reclamation machines are available on the market. Halon 1211, halon 1301, and halon 2402 are recyclable and reclaimable. Operator training is required. Reclamation equipment is more sophisticated and expensive. Reclamation is the preferred method and is usually not available at a servicing company, so it should be part of a national banking operation if at all possible. If the halon is found to have cross-contamination then it will need to be cleaned using a distillation process. HTOC members know of at least one source for this type of halon cleaning, see contact details for RemTec International in Chapter 10, Table 10-1.

Cylinders can be refurbished for reuse by undertaking the following steps:

- Visual inspection
- Hydrostatic test

- Sand blast, prime, and paint
- Valve removal and insertion
- Valve rebuilding
- Clean interior
- Pressurise in chamber/check expansion
- Steam dry
- Certify facility and workers

Cylinders that are out of test date should be recertified by a nationally approved testing facility.

During storage, halon should be colour-tagged to denote new versus recovered, type and quantity, ready for issue or not, and owner. Halon should be kept between 20 and 100 degrees F (-7 and 38 degrees C). Cooler is better. All halon, cylinders, and operating equipment should ideally be housed within a conditioned space. Security measures should include fencing, motion sensors, and video cameras. Areas housing halon storage tanks should be equipped with leak detection and alarm systems that allow rapid identification of leaking tanks, or should have a periodic leak detection procedure in place. Facilities should also be equipped to allow transfer of halon from a leaking tank to an empty tank to avoid loss of the entire contents.

In summary, halon banking is one part of an overall halon management program. Efforts to identify equipment using halon, select replacements, identify mission-critical uses, and monitor progress all need to be accomplished. Establishing and enforcing the bank rules is critical to success. Issues must be limited to authorised users for mission-critical applications only. Safety is paramount – unsecured halon vessels can kill! Leak detection and physical security protect scarce, valuable halon.

4.4 Current Situation

In reviewing the halon recycling component of a number of halon management programmes, there is very often a conflict between the policies introduced and enforced and the objectives the halon recycling activities envisaged. One example has been the introduction of policies and regulations banning or significantly limiting the use of halons (including recycled halons), and at the same time setting up a halon recycling program with the expectation that it be financially self-supporting, while at the same time the market for halons for servicing have been more or less eliminated through the policies and regulations. Another counterproductive policy is to require all halon users turn in decommissioned halon to the bank while requiring them to pay for the testing, transportation, storage, and/or cylinder disposal.

Halon management and recycling programmes differ considerably from country to country. They are very much based on national regulations and business requirements. In some countries the fire protection industry and some of the important halon users have established a national focal point as a broker function, where halon users and buyers can register their need for or surplus of halons so that those who want to sell can announce their halons and those who want to buy can find halon available and contact the seller. The focal point is not involved in the physical transfer of halon. The focal point is normally financed through a combination of membership fees and a fee for each transaction through the focal point. In general this method has worked well in the Article 5 countries where supportive infrastructure is in place. It is not working as well in the non-Article 5 countries. Many of these countries are not able to identify the quantities of halon or the users. They do not have a central office or focal point to collect the information needed and to provide it on a regular basis (for example, while collecting the data for this report NOO's changed or were unavailable for halon specific issues). Most countries indicated they are experiencing severe financial restrictions. Some countries reported they did not have adequate governmental fire support services and in one case they reported the state fire servicemen were unfamiliar with halon cylinders. In many cases, the "important" users such as the military and gas producers set up their own internal recycling because there are no focal points or comprehensive national programmes.

Awareness Campaigns have been demonstrated to be very helpful to the national halon banking programmes and in some cases they have played a major role in determining the success of the programme. The Jordanian halon bank is an example of the importance an Awareness Campaign can play. In 2009, the bank manager reported the halon owners were not turning their halons into the bank. The Ministry of Environment's Ozone Unit and the halon bank manager targeted the halon users in Jordan with Awareness Workshops addressing "availability of halon in the international market". As a result, most of the halon users started turning their halons into the national bank.

A number of recycling companies exist that have evolved over time. From manufacturing halon recycling equipment, or as fire equipment companies, or fire service companies, they have developed into international halon recycling centres on a strictly commercial basis. They buy halons from existing users and owners of halons and from other recycling centres and sell it to users. As they operate on a commercial basis, the operation cost is covered by selling recycled halons. The demand and availability of recycled halon is of course a key factor in the sustainability of the operation.

Recyclers listed in Chapter 10, Table 10-1 report the supply of halon 1211 is now limited and they anticipate this trend will continue. As we get further away from halon production cessation, the chance of halons becoming cross-contaminated increases as halon is recycled more than once, especially for halon 1211, and as older systems that may not have been charged properly or maintained properly are identified and decommissioned. Additionally, recyclers warn that as the price goes up due to lack of availability, the chances of having this material intentionally spiked with other substances also increases thus further limiting the amount of halon globally available and increasing the amount of halon needing destruction.

While halon 1301 seems to be more plentiful in availability and supply, the large individual sources of halon 1301 are getting more difficult to find. Major recyclers report the price of used halon 1301 has remained steady for the last several years.

Halon 2402 is reported to be available in at least one country, and major recyclers report there is still a demand for this material when it is located.

4.5 Challenges

The implementation of some of the projects in Article 5 Parties faced a number of challenges that limited and/or were the main reasons for failure of these projects. Below are some of these challenges:

- Competition within the fire protection industry in the country resulted in lack of general support from the rest of the fire protection industry. (Used as a platform for promotion of the company and replacement of halon fire equipment).
- Selection of a company with no prior experience within the fire protection industry.
- Selection of a company which only needed the halon for its own use.
- Regional centre concept is difficult to implement – transportation of halon or recycling equipment severely problematic.
- Not enough business to sustain operation.
- Slow or delayed programme implementation resulted in bulk of halon being removed from country prior to banking operations coming on line.
- The bulk of the project funding is exhausted in the purchase of halon recovery and recycling equipment.
- The ability of some host countries to operate and maintain halon recovery and recycling equipment centres have been problematic (sustainability of the banks).
- Finding excessive quantities of contaminated halons in some countries, particularly in Africa. As venting would be unacceptable, shipping to and cleaning up at a reclamation facility would be needed; however, it remains to be determined how to cover such costs.
- Selection of inappropriate recycling and recovery equipment and inadequate operators' training.
- Data on the installed base and stored inventories of halon is poor.
- Coordination with military branches is not being done.
- Exchange of data and information are not adequate.
- Overly restrictive national regulations that prevented the free flow of recycled halon.
- Lack of regulations in support of halon banking and phase-out.
- Lack of enforcement of existing regulations.
- No focal point for halon programme management including frequent turnover of NOOs.
- Little or no Awareness Campaign.
- Insufficient workshops and training and not including all stakeholders.
- Lack of Business Plan and/or lack of Halon Bank Management Plan

There has been an unanticipated lag in the establishment of halon banking and management programs globally. Whereas some countries and organisations were proactive, many are just now beginning implementation or the consideration of legislation and implementation. Nonetheless, despite global turmoil, changing political parties, and lack of infrastructure, the progress of halon phase-out is steady, and with continued support, the Montreal Protocol processes will allow for the utilisation of halons in the remaining important uses while minimising unnecessary emissions to the atmosphere.

4.6 Conclusions

Halon banking operations can play a significant role in ensuring the quality and availability of recycled halon, in managing the consumption down to zero, and in assisting with emission data by providing regional estimates that should be more accurate than global estimates. National or regional banking schemes that maintain good records offer the opportunity to minimise the uncertainty in stored inventory and stock availability. Parties may wish to encourage such national halon banking schemes in order to ensure that the needs deemed critical by a Party are met.

4.7 References

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2. *Final Evaluation Report on Halon Banking Projects for Countries with Low Volumes of Installed Capacities*, UNEP/OzL.Pro/ExCom/44/10, 2 November 2004, http://www.multilateralfund.org/evalution_document_library_.htm

3. *Halon Banking and Reception* Facilities, International Maritime Organisation, IMO FP.1/Circular 40, 8 January 2010.

4. Fire protection – Fire extinguishing media – Halogenated hydrocarbons – Part I: Specifications for halon 1211 and halon 1301, ISO 7201-1:1989, International Organisation for Standardisation, 1989.

5. Standard Specification for Halon 1301, Bromotrifluoromethane (CF_3Br), ASTM D5632 – 08, ASTM International, 2008.

5.0 Global Halon 2402 Banking

5.1 Introduction

Halon 2402 had been produced nearly exclusively in the former USSR, and production was continued by the Russian Federation after 1991 until the end of 2000. The bank of halon 2402 was very small at the time of production phase-out and therefore, through Decision VIII/9, from 1996 through 2000 production was continued under the essential use exemption procedure approved by the Parties to the Montreal Protocol. The objective being to build a bank of halon 2402 that existing applications could rely on for the remaining useful life of their equipment.

However, as reported in the 2006 HTOC Assessment Report, the inventory of this bank was significantly reduced owing to the use of halon 2402 as a process agent in the chemical industry during the period 2002-2003, when the average price of halon 2402 was low. More recently, halon 2402 has been commercialised for the Russian market as an encapsulated component of a flame retardant material, which can be used as a painting or coating, further reducing the inventory for existing uses.

Equipment associated with halon 2402 systems was almost exclusively manufactured in the USSR until its dissolution in 1991, and in the Russian Federation and the Ukraine since. In other countries of the former Eastern Bloc (e.g., Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, and Slovakia) use of halon 2402 was associated with the use of Russian military equipment and civilian aircraft. However, now many of these are no longer used. Halon 2402 based fire protection equipment was also exported to some Asian countries together with Russian products, mostly military vehicles, ships and aircrafts.

5.2 Countries That Still Use Halon 2402

Countries that still use halon 2402 as a fire protection agent can be grouped as follows:

- Russian Federation, Ukraine, Belarus;
- Former USSR and other countries of the former Eastern Bloc:

  Caucasus: Armenia, Azerbaijan, Georgia;

  Central Asia: Kazakhstan, Kyrgyzstan, Tadzhikistan, Turkmenistan, Uzbekistan;

  Non-EU states of East-South Europe: e.g., former Yugoslavia;

  EU member states: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia; and
- South-East and East Asia: India, Vietnam, Japan.

Some military and aviation equipment employing halon 2402 may still be in use in countries that purchased equipment from the USSR, and later from Russia, e.g., Afghanistan, Algeria, China, Cuba, Egypt, Libya, Mongolia and Syria.

5.3 Halon 2402 Banking

5.3.1 Russia

In 2009 it was estimated that merchant shipping and commercial uses of halon 2402 would cease by 2015, but military demand would increase.

Approximately 120 MT of halon 2402 were recycled during 2010, and current prices have become higher compared with 2006 (approximately US$ 40/kg compared to US$ 23/kg to US$ 25/kg). These data show that the cost increase and shortage of availability of halon 2402 has resulted in the latter no longer being used as a process agent in Russia

Four Russian companies offer recycling and banking services, with at least 20 companies operating as collecting agencies. In addition, the military sector and Gazprom have banking facilities to support their own needs. Maximum recycling capacity is about 800 MT/year. The recycling facilities could be used by any company or Party.

Russian national regulations restrict the export of ozone depleting substances (ODSs), including halons. According to the Decision of the Russian Government No. 1368 (adopted 9th December 1999), export requires special permission from the Ministry of Natural Resources and is allowed only for uses deemed critical by the Russian Federation. Similarly, the installation of halon 2402 in new fire suppression systems in the Russian Federation is allowed for such uses only. In such cases an application for special permission from the Ministry of Natural Resources is also required.

As reported by IMO (International Maritime Organisation) in the document FP.1/Circ. 40 (Ref. T4/4.01) dated 8th January 2010, and titled Halon Banking and Reception Facilities", currently the company "Ozone" in St. Petersburg grants availability of reclaimed halon 2402 in the amount of 10 MT.

Finally, a new application for halon 2402 was commercialised for the Russian market as an encapsulated component of a flame retardant material, which can be used as the painting or coating. This material was certified and approved for the use in electrical equipment having a volume up to 15 dm^3. The area of application of the material is expected to increase. This new application is of concern to the HTOC as it goes against the philosophy of not introducing ODS into new applications, and is likely to reduce the availability of halon 2402 for existing applications.

5.3.2 Ukraine

Ukraine is the second largest consumer of halon 2402 after the Russian Federation. A halon 2402 collection, recycling and reclamation facility was established at the Spetsavtomatika Institute at Lugansk. Spetsavtomatika collected halon from various locations and returned reclaimed and purified halon to users. For the period 2005 to 2008, the total quantity of recovered, reclaimed and reused halon was about 3 MT of halon 2402. As opposed to the situation in Russian market, there are no signs of the usage of the halon 2402 as a processing agent in the Ukraine.

At least one local company offers recycling and banking services to the market. Approximately 6-7 MT of halon 2402 were recycled during 2007. Ukrainian national regulations restrict the export of ozone depleting substances, including halons. Export is allowed to support the important needs of Article 5 Parties, but special permission of the Ukrainian government is required for the export. At this time the situation in Ukraine can be considered to be similar to that in Russia.

(*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 223–242)

5.3.2 Belarus

The Parties to the Montreal Protocol endorsed the provision of international assistance to Belarus at its 7th Meeting. The Global Environment Facility (GEF) provided financial assistance to Belarus.

A small subproject financed a national workshop to provide technical assistance to stakeholders in the fire protection sector to discuss technology options for the conversion of halon-based fire protection systems. One of the main conclusions of the workshop was that Belarus needed to develop a system to recover, reclaim and recycle halon. The cost of this was outside of the current project's scope and a halon recycling system has not yet been established with national funds. Halon 2402 continues to be used in Belarus in the petrochemical industry, aviation and military. Notwithstanding that some end-users utilise recycling and reclamation equipment, the absence of centralised halon bank management creates the risk of avoidable and unavoidable emissions of halon to the atmosphere.

The total 1996 consumption of halon was 24 ODP tons and was reduced to zero in 2000. (*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 25–36). According to a Decision of the Belarusian Government No. 1741 (adopted 13th November 1998), export/import operations of ozone depleting substances are banned in Belarus. The main users of the halon 2402 are the military sector, oil – gas industry and civil aviation. At least one local company offers recycling and banking services to the market. Information on the Belarusian halon bank is unavailable.

At this time bureaucratic procedures have inhibited communication and work on these subjects with Belarus

5.3.3 Caucasus: Armenia, Azerbaijan, Georgia

Armenia: The Country Programme (CP) was prepared by the Ministry of Nature Protection, UNEP and UNDP with financial assistance from the GEF. Upon a request from the National Ozone Unit of Armenia, a technical assistance mission on the status of halons management was carried out in Armenia in July 2007. The technical assistance mission demonstrated that there was a clear lack of awareness concerning halon management and available alternatives among the main halon stakeholders and parties with important uses/applications of halon 2402, such as the Armed Forces, the Fire Service and the Civil Aviation. The Armed Forces, the Fire Service and the Civil Aviation expressed their concern and need for further capacity building and technical awareness relating to halon management and suitable available alternatives. (*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 1–14).

Azerbaijan: The initial country programme for the phase-out of ODS was compiled in 1997 at the initiative of the UNEP/IE, based on the data survey of ODS consumption in various sectors, conducted by the National Ozone Team. Azerbaijan reported halon consumption of 501.2 ODP tons, but UNDP later determined that this might be installed in equipment rather than consumed. The GEF (Global Environment Facility) paid $135,000 of financial assistance to establish a Halon Bank and to implement halon recovery and recycling. The Fire Department was identified as being the operator of the national facility. The facility was designed to be operated under the guidelines that were to be developed by the Fire Department as part of the Azerbaijan Country Programme, with the assistance in the beginning from UNDP. It was not possible to obtain any meaningful information on the outcome of this subproject, which was completed in June 2001.

(*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 15-24).

Georgia: Based on other countries' experiences, it should be assumed that a demand for halon 2402 for the servicing of operating equipment exists and that halon from outside sources will be required.

5.3.4 Central Asia: Kazakhstan, Kyrgyzstan, Tadzhikistan, Turkmenistan, Uzbekistan

Generally speaking, all these countries have substantial halon 2402 stocks and needs related to the oil industry, but no coordinated information is actually available.

Kazakhstan: The GEF budgeted $163,231 for equipment that would allow halon to be recovered and reclaimed. Although halon consumption has been reported as zero from 1 January 2003, the programme for collecting and safely storing halon has been in abeyance for at least 5 years, which increased the prospects for unintentional halon emissions (*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 93-110).

Kyrgyzstan: On behalf of the Government of Kyrgyzstan, in March 2006 UNIDO submitted a project aimed at establishing and implementing a national halon management programme to support Kyrgyzstan in meeting its obligations under the Montreal Protocol (*Source*: United Nations Environment Programme, UNEP/OzL.Pro/ExCom/48/34, 3 March 2006).

There were no data available concerning halon stockpiles, contaminated halons and uses of halon. The project proposal indicated that Kyrgyzstan had potential halon users including the military, the national airlines, hydropower facilities, gold mines, oil and gas industry.

<u>Uzbekistan</u>: The GEF provided financial assistance to Uzbekistan in order to assist it to become compliant with the requirements of the Montreal Protocol. Uzbekistan banned the import of halons except those intended for vital uses from 1st January 2000. Omitting plans to manage halon decommissioning and bank formation appeared to be an oversight in Uzbekistan's Country Plan, particularly as the country required the use of halon for about 22 aircraft. Thus Uzbekistan should develop a Halon Management Plan as soon as possible. The Plan should include decommissioning halon uses where alternatives are available, and storing the decommissioned halon for uses of halon that do not have an alternative, such as those uses in aircraft. Reclamation and banking equipment would be essential in order to stock as much decommissioned halon as possible.

SJSC Tapoich (TAPC) supplies halon-2402 fire extinguishing equipment for use on 3 types of aircraft that are used for fire and explosion suppression. The fire extinguishers and systems are used in different parts of the aircraft such as the engine nacelles, wings, cargo hold and crew-passenger compartments. The last of the halon stocks held by TAPC were depleted in 1996.

The National Ozone Unit (NOU) only discovered the need for halon after 2002 when an aircraft assembly plant requested a licence to import halon-2402, as well as halon-1211 and halon-1301. A total of about 1.9 MT was requested in 2002, 2003 and 2004. The Parties to the Montreal Protocol did not approve Uzbekistan's request, but instead recommended that the halon be imported from the Russian Science Federation (in St. Petersburg). The halon has been imported and the quantities stored at each location are known to the NOU.

(*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 243–262).

5.3.5 European Union

In general there is only a minor demand for halon 2402 in some Member States of the European Union: Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia. The majority of former halon 2402 applications have been switched to other agents and technologies, but a small sector of industry and the military sector continue to employ halon 2402.

<u>Poland</u>: Halons were imported from Russia and Western European countries. The majority of these halons, and the halon-based fire equipment, were imported in the late 1980s, meaning that the halon systems and other halon-based fire equipment installed in Poland are relatively new. Halon-2402 was imported from the Russian Federation (in relatively small quantities), mostly for military equipment. Fire protection codes require fire-extinguishing systems in some categories of public and industrial buildings however they do not specify the type of the system that must be used. Halon-2402 has been used in fixed systems in military equipment and in portable fire equipment used for military applications. A small amount of halon-2402 is in use in the aviation sector on aircraft produced in Russia (*Source*: "Eliminating Dependency on Halons – Case Studies", UNEP DTIE Ozone Action Programme under the Multilateral Fund for the Implementation of the Montreal Protocol).

In 1998 there were three companies in Poland that were licensed to recover, reclaim and manage a halon bank. However, only two companies were equipped with halon reclamation equipment, which they financed themselves. There is no database held by the government that records the quantity of banked halon, so this could not be reported (*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 139–154).

Hungary: A GEF/World Bank Project, which was approved on 9 November 1995 and completed at the end of 1998, provided financial assistance to Hungary to phase out ODS. Within this project, Fajro Ltd – a small company that installs ODS-free fire protection equipment in Hungary – recovered and reclaimed halon. Reclaimed halon was used for refilling fire protection systems that Hungary qualified as ‘critical’ – that is, those uses that were without an alternative. Fajro reported that the costs of halon reclamation had increased to €6-8/kg, depending on the time required, because of increased energy (electrical, transport fuel) costs.

Czech Republic: The Czech Republic was one of the first eligible for GEF grant funds to launch a comprehensive ODS phase-out program, and it became the first project on ozone-layer protection approved by the GEF. In a sub-project, the reclamation centres were not supplied with equipment to recover halon. After the completion of the Project, decommissioned halon was collected, recovered and recycled, and stored by ESTO Cheb. These activities were supported by Czech legislation. Esto Cheb was also a partner in the Phare Program 2000 “Transfer of Advanced Fire and Explosion Protection Technologies”, which financially supported the implementation of halon alternatives in the Czech Republic. (*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 53–64).

Estonia, Latvia, and Lithuania: Halon 2402 is the most widely used halon in all three countries and seems to have been used in blends as well as more conventionally as a neat agent. This agent was used very little outside the former Russian sphere of influence, and as a consequence there was almost no international installed base to give rise to a market for trade in recycled agent. The Russian Federation was the major supplier of halon for these countries.

(*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 65–71).

A *UNDP/UNEP* Project (the “Project”) was approved on 9 February 2000 and completed in December 2007, after 3 extensions, when additional time was necessary to finalise subproject implementation. The project’s objective was to provide a (Baltic) regional centre for the recovery and reclamation of halon-2402, as well as of halon-1301 and halon-1211. In May 2002, a halon seminar was conducted on halon decommissioning and alternatives to halon, and technicians were trained in the use of halon recycling equipment. A Reclamation Centre was established to receive and store Estonian ODS. The Centre was also a regional base for receiving, reclaiming and storing halon 2001, 2402 and 1301 that had been decommissioned from fire protection equipment held in Estonia, Latvia and Lithuania. Halon that cannot be reclaimed will be sent to

Sweden (Sakab AB) for destruction when sufficient quantities have been accumulated to make an economic shipment, but so far none has been shipped. The cost was €4-5/kg in 2005.

Eight Estonian-flagged ships were fined for not decommissioning halon, which has encouraged them and other ships to replace the halon with alternatives. There are 4–5 companies operating in Estonia that install non-halon alternatives on ships when they arrive at the port for a refit. As of May 2009, the NOU reported that there are no known ships flagged to Estonia that have halon on board, and only halon deemed as necessary remains in aircraft and military equipment.

(*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 72–76).

Lithuania reported that halon for fire protection has been replaced by ODS-free alternatives where possible, thereby eliminating almost all uses.

Slovakia: The Country Program for Czechoslovakia was undertaken in 1992. The total halon consumption was less than 10 MT. The country was qualified for assistance from the GEF. In Slovakia halon is used only for uses that are critical in accordance with EU Regulations in the following applications: aircraft and the military and petrochemical sector. The halon will be gradually replaced by acceptable and available alternatives and then stored in the Halon bank.

(*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 155–160).

Cyprus: 144 kg of halon 2402 are installed in aircraft (Mi-35P) protection, while no halon bank exists in this country.

(*Source*: Ministry of Agriculture, Natural Resources and Environment – Cyprus, 2008).

Italy: In 2007, Italy reported to EC Environment Directorate that about 7 MT of halon 2402 were available to satisfy the market needs – no data was available for 2008.

5.3.6 India

In India, halon 2402 is only used in military applications. India has used substantial amounts of halon 2402 and its blends, e.g., halon 2402 and ethyl bromide, in its military equipment purchased from the former Soviet Union. Examples are armoured fighting vehicles, e.g., T-54, T-60, T-70, T-80 produced in the 1990s.

Licenses are needed to import halon, but there are no other barriers. In 2007, India received 9 MT of halon 2402 from the Russian Ministry of Defence. These quantities were necessary to support those users who still need to maintain their fire protection systems for which effective alternatives have not been identified.

There were about 50 fire equipment and system manufacturing companies using halon 2402 in both portable fire extinguishers and fixed manual and automatic fire protection systems, spread across the country, but mostly concentrated in large cities and industrial towns. However, little or no recycling has taken place and a difficult situation currently exists in India where there is growing concern over the capability of Russia and Ukraine to continue to support India's servicing needs of halon 2402.

Current requests have had some responses from the US and Europe. To overcome their problems, the military is also looking at conversion to halon 1301 in the crew/engine compartments of ground vehicles and at halon 1211 pressurised with carbon dioxide for portables. Other alternatives (e.g., HFC-236fa) are being tested. As such, the shortage of halon 2402 in India for servicing has eased.

5.3.7 Vietnam

In 2005, the Government of Vietnam requested financial support from the MLF for a project to cover part of their phase-out costs over a period of five years (from 2005 to 2010). Vietnam has experienced difficulty in sourcing halon 2402 from international markets, but the project should provide halon 2402 recovery and recycling equipment and also technical assistance to identify proper non-halon alternatives for those applications where alternatives are already available.

Vietnam needs to set up a halon bank for halon 2402 particularly for the petroleum industry. Currently no information is available about this project.

Vietnam also has a demand for halon 2402 to support important applications in the military sector. Information on the amount of requested halon is unavailable, but it is known that an attempt to find the product in the Russian market was unsuccessful.

5.3.8 Japan

Halon 2402 is mainly used for floating roof tank protection in the petrochemical industry. It was also used for explosion suppression but these may have already been replaced. When replaced the halon was collected and some was destroyed. The cost of destruction was close to 10 USD/kg.

Halon 2402 is a vital material for the fire safety of oil tanks in Japan and, as the timing of decommission/replacement of halon 2402 fire protection systems is not clear, there are no plans to export halon 2402.

5.3.9 Afghanistan, Algeria, China, Cuba, Egypt, Libya, Mongolia and Syria

Information on the installed capacity and demand for halon 2402 in Afghanistan, Algeria, Egypt, China, Cuba, Mongolia, Libya and Syria is not currently available. However, it is reasonable to assume that in these countries a demand for halon 2402 for the servicing of operating equipment exists and that halon from outside sources is required, in particular from Russia and Ukraine.

As previously said, currently the purchase of halon 2402 from Russia appears to be virtually impossible, since Russia itself had to acquire 15 MT of halon 2402 from the USA to satisfy its internal demand.

5.3.10 USA

The US has a limited amount of excess halon 2402 available for export. This halon was likely from a non-fire extinguishing application. The product is ready for purchase and can be used to support the needs of any customer. The supplier is responsible for all export paperwork and duties while the buyer is responsible for import paperwork, taxes and duties.

5.3.11 Iraq

In June 2009, on behalf of the Government of Iraq, UNEP submitted a national phase-out plan (NPP) for consideration by the Executive Committee at its 58th Meeting.

(*Source*: United Nations Environment Programme, UNEP/OzL.Pro/ExCom/58/36, 3rd June 2009).

The project proposed to introduce and promote sustainable and safe use of halon alternatives by providing technical assistance to the fire protection industry and fire authorities; establishing a halon users' database; training programs on halon management, alternative technologies for fire fighting and proper maintenance of halon equipment; and developing and implementing public awareness and education activities. However, no banking or recycling facilities have been proposed.

5.4 Conclusions

Emissions, transformation and consumption of halon 2402 by the chemical industry as a process agent has substantially reduced the total bank of halon 2402, and new uses in non-traditional applications are a cause for concern to the HTOC. While there is no apparent shortage of halon 2402 on a global basis, there are regional shortages today that Parties may wish to address.

The demand for halon 2402 from outside sources ranges from a minor demand in some EU Member States to the Indian demand estimated as 7–9 MT/year. Little or no recycling has taken place in India and a difficult situation currently exists, where there is growing concern over the capability of Russia and Ukraine to continue to support India's servicing needs of halon 2402. However, the shortage of halon 2402 in India for servicing has had some recent responses in the US and Europe, and the situation has eased. The needs of some Parties for halon 2402 cannot be estimated due to the unavailability of market information, but it should be assumed that a demand for halon 2402 for the servicing of operating equipment exists and that halon from outside sources will be required, as banking and recycling facilities do not exist.

The Russian Federation and Ukraine traditionally recognised as potential sources of halon 2402 for other Parties, still own a large installed capacity of halon 2402, but their markets can be estimated as currently well balanced with no surplus available for outside customers. Analysis shows that the USA may be able to support the current needs of other Parties. Information regarding substantial amounts of halon 2402 in halon banks of some EU Member States is subject to confirmation.

6.0 Global/Regional Supply and Demand Balance

The demand for new halons has been eliminated through the availability of substitute fire extinguishing agents and alternatives, and through halon recycling programs. Based on a review of the situation in a large number of the Parties, with the exception of aviation, it has been concluded that generally halons have been replaced by substitutes for all new applications where halons were traditionally used. However, the demand for recycled halons remains high for existing applications in some Parties.

In Decision XXI/7 the Parties were requested to report their projected needs for and shortages of halons to the Ozone Secretariat for use by the HTOC. To date the Parties have not indicated to the Ozone Secretariat that they are unable to obtain halons to satisfy their needs. However, some Parties have expressed cost concerns to HTOC members.

Australia has reported through the Ozone Secretariat that it has an excess of Halon 1211 that it is willing to offer to other Parties to satisfy shortages. The HTOC, through the Ozone Secretariat, recommended that they offer the halon through the UNEP Halon Trader, a web-based tool.

Based on current data reported to the Ozone Secretariat, HTOC concludes that there is no global halon imbalance at this time, i.e., demand is being satisfied by the available supply. However, the continued needs outlined in Chapter 7 indicate there may be global or regional problems in the future. Without additional data on projected needs/shortages/surpluses from the Parties, the HTOC cannot quantify potential imbalances.

7.0 Continued Reliance on Halons

7.1 Introduction

Halon production for fire protection purposes has ceased in all Parties. However, most Parties have allowed recycled halons to be used to maintain and service existing equipment. This has permitted users to retain their initial equipment investment and allowed halons to continue to be used in applications where alternatives are not yet technically and/or economically viable.

Recently questions have been raised regarding the use of high global warming potential (GWP) hydrofluorocarbons (HFCs) as replacements for halons 1211, 1301 and 2402. Although the halons have relatively high GWPs, these are eclipsed by the GWPs of some of the replacements, particularly when you factor in the increased amount of the alternative agent required.

Of particular concern are the situations where the only viable alternative to halon is a high GWP HFC. From a total environmental impact perspective, is it better to reuse an already produced, recycled, halon or produce a high GWP HFC for the application? This question is one that Parties need to seriously consider.

The following subsections describe fire protection applications that need to continue to rely on the global halon bank, the alternatives that have been looked at, and the future outlook.

7.2 Civil Aviation

7.2.1 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 halon are among the most demanding uses of the agents, and require every one of their beneficial characteristics. Particularly important are the following:

- Dispersion and suppression effectiveness, which must be maintained even at the low temperatures encountered at high altitude.
- 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.
- Weight and space requirements of the agent and associated hardware.

Also significant are short and long term damage to aircraft 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; effectiveness on the hidden fire; and the installed cost of the system and its maintenance over its life. It is no surprise, therefore, that this is an area which is proving technically difficult to satisfy.

While alternative methods of fire suppression for ground-based situations have been implemented, the status of halon in the civil aircraft sector must be viewed in three different contexts: existing aircraft, newly produced aircraft of existing models, and new models of aircraft. All of them continue to depend on halon for the majority of their fire protection applications. Given the anticipated 25–30 year lifespan of civil aircraft, this dependency is likely to continue well beyond the time when recycled halon is readily available. The civil aviation industry must look either to their own stockpiles of halon or to the limited amounts of recycled halon available on the open market to avoid grounding aircraft because of a lack of appropriate fire protection.

The 2006 Assessment noted that the current understanding of the status of halon supplies indicated that the time available for making the transition to halon alternatives may be much less than many in the civil aviation industry realise. The Parties to the Montreal Protocol requested HTOC to cooperate with the International Civil Aviation Organisation (ICAO) (Decision XXI/7) on developing an action plan for the aviation sector. Resolution A36-12, adopted at the ICAO 36th Assembly in September 2007, requested the ICAO Council, and thereafter the Contracting States, to consider a mandate to require a scheduled halon replacement in certain applications where alternatives were available. HTOC has continued its cooperation with ICAO in its development of a revised resolution for the ICAO 37th Assembly in September 2010 that has revised halon replacement dates agreed to by industry.

Another critical development since the last assessment report is the finding of contaminated halons making their way into the civil aviation industry as reported by the UK Civil Aviation Authority (CAA) to the European Aviation Safety Agency (EASA) in 2009. This has raised significant concerns on the acceptability of the remaining banks of halon, the standards for testing and ensuring the quality of recycled halons, and the importance of the overall transition away from halons where alternatives are available.

7.2.2 Estimated Halon Usage and Emissions

A study reviewed data on the number of aircraft produced worldwide by the major airframe manufacturers (not including Russian-built aircraft), projected sales, and quantity of halon installed per aircraft for each application in order to estimate the quantity of halon installed in and emitted from mainline and regional passenger and freighter aircraft for each year from 2005 to 2020. Table 7-1 presents a summary of the total number of each type of aircraft in service in 2005, 2010, 2015, and 2020; the table only includes aircraft produced by major manufacturers. The global fleet is projected to grow over 60% in the period 2005 to 2020.

Table 7-1: Estimated Number of Aircraft in Service 2005 to 2020 (Excludes Russian-built Aircraft)

	2005	**2010**	**2015**	**2020**
Mainline Passenger Aircraft	13,784	16,078	19,172	22,265
Regional Passenger Aircraft	3,927	4,527	5,398	6,269
Mainline Freighter Aircraft	960	896	1,011	1,126
Regional Freighter Aircraft	1,007	970	1,095	1,220
Total Passenger and Freighter Aircraft	**19,678**	**22,471**	**26,676**	**30,880**

(ICF, 2009)

The quantity of halon 1301 and 1211 installed in and emitted from civil aircraft is expected to increase over the time period 2005 to 2020 as presented in Table 7-2, assuming that no halon alternatives are implemented in the applications addressed in this report. The total quantity of halon 1301 installed in civil aircraft is estimated to increase from about 1,800 MT in 2005 to over 2,500 MT in 2020, or a greater than 40% increase. The total quantity of halon 1211 is estimated to increase from more than 170 MT to greater than 270 MT, or about a 60% increase. It is projected that an increasing quantity of halon 1301 and 1211 will also be emitted into the atmosphere from civil aircraft over the modelling period. Annual emissions of halon 1301 from civil aircraft are estimated to increase from approximately 35 MT in 2005 to more than 50 MT by 2020. Annual emissions of halon 1211 are projected to grow from 10 MT to about 16 MT by 2020.

Table 7-2 also compares the estimated quantities of halon 1301 and 1211 installed in and emitted from civil aircraft to the projected worldwide inventories and emissions of halon 1301 and 1211 (HTOC, 2006). In general, the proportion of worldwide inventories and emissions associated with civil aircraft is expected to increase over the time period modelled, even as these inventories are expected to decrease over time with the end of global halon production. Global inventories of halon 1301 and 1211 are projected to decrease by approximately 40% and 60% over the period 2005 to 2020, respectively. It is estimated that the percentage of halon 1301 installed in civil aircraft will increase from about 4% to 8% of the total worldwide halon installed across all inventory from 2005 to 2020. As a result, emissions of halon 1301 will increase from 2% to almost 6% of total halon 1301 emissions from 2005 to 2020. The total quantity of halon 1211 installed in handheld extinguishers on civil aircraft is expected to increase from approximately 0.2% to 0.8% of the worldwide halon 1211 inventory from 2005 to 2020. Resulting emissions of halon 1211 are projected to increase from 0.2% to approximately 0.7% of all halon 1211 emissions worldwide.

Table 7-2: Estimated Quantity and Emissions of Halon 1301 and 1211 Associated with Civil Aviation Applications from 2005 to 2020*

	2005	**2010**	**2015**	**2020**
HALON INSTALLED (kg)				
Halon 1301 Installed:				
Engine Nacelle Application	865,373	992,603	1,179,366	1,366,130
APU Application	93,456	106,860	126,886	146,912
Baggage/Cargo Compartment	789,358	784,545	899,854	1,015,163
Lavex System	7,481	8,679	10,336	11,994
TOTAL	1,755,669	1,892,687	2,216,443	2,540,199
TOTAL – Percentage of Total Inventory	*3.51%*	*4.44%*	*6.09%*	*8.01%*
Halon 1211 Installed:				
Handheld Extinguisher	170,323	196,411	233,659	270,907
Handheld Extinguisher – Percentage of Total Inventory	*0.19%*	*0.30%*	*0.50%*	*0.79%*
HALON EMITTED (kg/yr)				
Halon 1301 Emitted:				
Engine Nacelle Application	17,307	19,105	23,587	27,323
APU Application	1,869	2,137	2,538	2,938
Baggage/Cargo Compartment	15,787	15,691	17,997	20,303
Lavex System	150	174	207	240
TOTAL	35,113	37,107	44,329	50,804
TOTAL – Percentage of Total Emissions across All Installed Halon	*1.82%*	*2.50%*	*4.01%*	*6.10%*
Halon 1211 Emitted:				
Handheld Extinguisher	10,219	11,785	14,020	16,254
Handheld Extinguisher %Total Emissions across All Installed Halon	*0.17%*	*0.27%*	*0.45%*	*0.72%*

(ICF, 2009)

* These estimates do not include Russian-built aircraft or flight line halon applications.

It has not been possible to estimate the emissions of halon 1301, 1211 and 2402 from Russian-built aircraft as their inventory has been static or declined since 2005. They are no longer produced by their historical manufacturers; new aircraft for the Russian market are now produced by the same airframe manufacturers that supply the rest of the world. Table 7-3 shows the estimated number of Russian-built aircraft in 2005 and the estimated inventory of halons 1211, 1301 and 2402.

Table 7-3: Estimated Number of Russian-Built Aircraft In-Service In 2005 and Installed Quantities of Halon 1301, 1211 and 2402

In-service Russian-built Aircraft, 2005	HALON INSTALLED (kg)		
	Halon 1301	**Halon 1211**	**Halon 2402**
2,820 (2200 Mainline & Regional passenger aircraft, & 620 Mainline freighter aircraft)	20,000	45,000	160,000

(ICF, 2006)

7.2.3 Halon Banks

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 long before the aircraft now being built and fitted with halon systems are retired.

Civil aviation operators who have not already done so are strongly advised to:

- Consider whether the installed stocks of halon they own are sufficient to meet their long-term needs (taking into account the contaminated halon that may have penetrated their own stocks),
- Ascertain whether these stocks are being properly managed to ensure they are available for their needs,
- Determine whether it is necessary to procure and store additional agent now, while it is relatively easy to do so, to meet long-term demands, and
- Continue to implement policies that eliminate or minimise discharge in testing, training, and maintenance.

7.2.4 Status of Halon Replacement Options

Halons are used for fire suppression on civil aircraft in:

- Lavatory trash receptacle extinguishing systems;
- Handheld extinguishers;
- Engine nacelle/auxiliary power unit (APU) protection systems; and
- Cargo compartment extinguishing systems.

All new installations of fire extinguishing systems for engines and cargo compartments use halon 1301, and all new installations of handheld extinguishers use halon 1211. With the exception of lavatory trash receptacles, there has been no retrofit of halon systems or portable extinguishers with available alternatives in the existing worldwide fleet of aircraft.

Key to the acceptance of one or more of the approved substitutes has been their ability to demonstrate fire extinguishing performance equivalent to halon in specific applications. As such, substitutes for halons in civil aviation fire extinguishing systems are evaluated and approved according to the relevant Minimum Performance Standards (MPS) and testing scenarios developed by the International Aircraft Systems Fire Protection Working Group (IASFPWG), originally established in 1993 by the Federal Aviation Administration (FAA) and cooperating agencies and known then as the International Halon Replacement Working Group. The status of the development of these MPS for the above applications and the alternatives tested to these MPS are discussed below.

7.2.4.1 Lavatory Trash Receptacle

Halon 1301 has historically been used in lavatory extinguishing (lavex) systems, which are designed to extinguish trash receptacle fires in the lavatories of pressurised cabins. Trash receptacles are required to be installed with a lavex system that automatically discharges into the container in the event of a Class A fire (i.e., involving paper materials). All lavex systems using halon alternatives must meet the Minimum Performance Standard (DOT/FAA/AR-96/122) that includes the ability to extinguish a Class A fire and in the case of discharge, not create an environment that exceeds the chemical agent's no observable adverse effect level (NOAEL).

A finalised MPS for lavex systems was completed in February 1997. Research and testing has shown that there are suitable alternative suppression systems available for this application that meet the criteria for space and weight, the toxicological factors, and cost the same or less than the halon systems being replaced. Currently all Boeing and Airbus new production aircraft are installed with non-halon lavatory systems that contain either HFC-227ea or HFC-236fa. In addition, some airlines such as Lufthansa are replacing existing halon 1301 lavex systems with these alternative systems during scheduled maintenance operations.

7.2.4.2 Handheld Extinguishers

All handheld extinguishers intended to replace halon 1211 extinguishers must meet the Minimum Performance Standard (DOT/FAA/AR-01/37) to ensure their performance and safety. These standards require that any handheld extinguisher for final use be listed by UL or an equivalent listing organisation. To be listed, the extinguisher must be able to disperse in a manner that allows for a hidden fire to be suppressed and does not cause any unacceptable visual obscuration, passenger discomfort, and toxic effects where people are present.

The MPS was published in August 2002. As of 2003, three halon alternatives, HFC-227ea, HFC-236fa and HCFC Blend B, have successfully completed all of the required handheld UL and MPS tests and are commercially available. These units have different volume and weight characteristics compared to existing halon 1211 extinguishers and the development of new brackets and supports may be required for new airframes and/or retrofit. Qualification and installation certification by airframe manufacturers and regional authorities is needed prior to airline use, however to date this has not happened despite the extinguishers being available since 2003. The change to an alternative suppression agent will also require that a new training program be developed for flight crew/attendants. Currently, no alternative agents have replaced halon 1211 in handheld fire extinguishers in passenger compartments on current aircraft models or new airframe designs.

Boeing is currently doing testing on a "low GWP" unsaturated HBFC known as 3,3,3-trifluoro-2-bromo-prop-1-ene or 2-BTP with the potential of lower space and weight impact compared to other alternatives. This agent could be commercialised in the next few years to meet aviation needs for a handheld extinguisher replacement because a significant part of the required testing has already taken place.

7.2.4.3 Engine and APU Compartment

Halon 1301 is typically used in engine nacelles and APUs to protect against Class B fires. The requirements of fire suppression systems for engine nacelle and APUs are particularly demanding, since these compartments contain fuels and other volatile fluids in close proximity to high temperature surfaces. The surrounding environment also typically has complex airflows at low temperature and pressure, making most non-halon agents ineffective. Although alternatives have been implemented in military aircraft, to date there have been no examples of the replacement of halon 1301 in the engine nacelles or APUs of civil aircraft.

A finalised MPS for engine nacelle/APU protection should be available within the next two years. Three potential replacement agents, HFC-125, FIC-13I1, and FK-5-1-12 were tested based on a draft version of the MPS and halon 1301 equivalent concentrations were determined. Airbus and Pacific Scientific are currently developing an engine nacelle system for the A350 using FK-5-1-12. FAA is currently doing MPS testing of an engine nacelle system being developed by Boeing and Kidde Aerospace based on the use of dry powder.

7.2.4.4 Cargo Compartments

Cargo compartments are typically located below the passenger compartment, or below the main deck on freighter aircraft. In the case of a fire, a quick discharge of halon is deployed into the protected space to suppress the fire, which is followed by a discharge that is released slowly to maintain a concentration of halon to prevent re-flame. The slow discharge is maintained until the plane is landed to protect against any reduction in the concentration of halon caused by ventilation or leakage. Cargo compartment fire suppression systems must be able to meet the requirements of four fire tests required in the Cargo Compartment Minimum Performance Standard (DOT/FAA/AR-00/28). The system must be able to suppress a Class A deep-seated fire for at least 30 minutes and a Class A fire inside a cargo container for at least 30 minutes. The system must be able to extinguish a Class B fire (Jet-A fuel) within 5 minutes, and prevent the explosion of a hydrocarbon mixture, such as found in aerosol cans. In addition, the system must have sufficient agent/suppression capability to be able to provide continued safe flight and landing from the time a fire warning occurs, which could be in excess of 200 minutes, depending on the aircraft type and route planned. In the most recent version of the MPS, published in 2003, the aerosol explosion protocol was modified to allow the inclusion of a non-gaseous system such as water spray.

To date, there have been no cases of halon 1301 replacement with an alternative agent in cargo compartments of civil aircraft. MPS testing of halocarbon agents has shown that they are not technically or economically feasible due to the space and weight requirements of maintaining the high concentrations of these agents that would be necessary to meet the MPS. A combination of water mist and nitrogen has been tested to and met the requirements of the current MPS. Commercial development of a water mist/nitrogen cargo fire suppression system is in the early stages.

7.2.5 ICAO Activities and Response to Decision XXI/7

At the request of the ICAO Secretariat, HTOC participated in a three-day meeting, 1-3 December 2009, to discuss progress on eliminating halons in civil aviation. This meeting was a follow up to the ICAO General Assembly Resolution (equivalent to a Montreal Protocol decision of the Parties) A36-12 that requested the ICAO Council to consider a mandate to require halon alternatives for lavatory, handheld extinguisher and engine/auxiliary power unit fire protection systems. Others represented at the meeting included the Ozone Secretariat, the International Coordinating Council of the Aerospace Industries Associations (ICCAIA), Boeing, Airbus, the International Air Transport Association (IATA), FAA, Air Transport Canada, European Aviation Safety Agency (EASA), and commercial industry suppliers of aviation fire protection equipment.

The working group developed draft text for consideration as a Resolution for the 37th General Assembly in September of 2010. The dates in the new draft Resolution were up to three years delayed from those originally agreed upon in Resolution A36-12. ICAO had not yet adopted any changes to their Annexes, which would need to be made in order to require implementation of halon alternatives. The reason for the proposed changes is that the Chicago Convention requires a minimum of three years, from the date of a change to required aircraft design criteria, called Annex 8, to implement the change. The earliest that the ICAO Secretariat could make the change and get the Annex approved through their system would be 2011. Therefore, the earliest date that we could require halon alternatives to be implemented would be 2014. This same three-year implementation requirement does not apply to changes to their Annex 6, which covers provisioning. Therefore it was agreed to keep the original 2011 date for implementation of halon alternatives in lavatory waste bin fire protection.

Subsequent to the meeting, ICCAIA, Boeing and Airbus requested that ICAO consider a two-year delay in the installation of halon alternative handheld fire extinguishers for new production aircraft. The reason for the delay is to allow for the further development of a "low GWP" unsaturated HBFC, known as 3,3,3-trifluoro-2-bromo-prop-1-ene or 2-BTP. This was the agent mentioned in the fire protection section of the TEAP response to Decision XX/8 that could be commercialised in the short term as a significant part of the required testing had already taken place. In their request to ICAO to consider a two-year delay, ICCAIA, Boeing and Airbus agreed that even should 2-BTP prove unsuitable, they would meet the 2016 date to implement non-halon handheld extinguishers using existing alternatives. These are the two high GWP HFCs already approved and the HCFC-123 blend also approved but subject to Montreal Protocol production and consumption phase-out. HTOC was concerned with granting another two-year delay. ICAO recommended a compromise to accept the two-year delay in exchange for strengthening the requirement from "consider a mandate" to "establish a mandate". ICCAIA, Airbus and Boeing agreed to the following compromise language that was adopted at the 37th Session of the ICAO Assembly in September 2010 as Resolution A37/9:

The Assembly:

1. *Agrees* with the urgency of the need to continue developing and implementing halon alternatives for civil aviation;

2. *Urges* States to intensify development of acceptable halon alternatives for fire extinguishing systems in cargo compartments and engine/auxiliary power units, and to continue work towards improving halon alternatives for hand-held fire extinguishers;
3. *Directs* the Council to establish a mandate for the replacement of halon:
   - in lavatory fire extinguishing systems used in aircraft produced after a specified date in the 2011 timeframe;
   - in hand-held fire extinguishers used in aircraft produced after a specified date in the 2016 timeframe; and
   - in engine and auxiliary power unit fire extinguishing systems used in aircraft for which application for type certification will be submitted after a specified date in the 2014 timeframe.
4. *Directs* the Council to conduct regular reviews of the status of potential halon alternatives to support the agreed upon implementation dates given the evolving situation regarding the suitability of potential halon alternative agents as they continue to be identified, tested, certified and implemented;
5. *Urges* States to advise their aircraft manufacturers, approved maintenance organisations, air operators, chemical suppliers, and fire-extinguishing companies to verify the quality of halon in their possession or provided by suppliers through effective testing or certification to an international or State recognised quality standard. States are also urged to require that the quality systems of air operators, approved maintenance organisations, and manufacturers provide a means for requesting from halon suppliers certification documentation attesting to the quality of halon to an established and recognised international standard;
6. *Encourages* ICAO to continue collaboration with the International Aircraft Systems Fire Protection Working Group and the United Nations Environment Programme's (UNEP) Ozone Secretariat through its Technology and Economic Assessment Panel's Halons Technical Options Committee on the topic of halon alternatives for civil aviation;
7. *Urges* States to inform ICAO regularly of their halon reserves and directs the Secretary General to report the results to the Council. Further, the Council is directed to report on the status of halon reserves at the next ordinary session of the Assembly;
8. *Resolves* that the Council shall report to the next ordinary session of the Assembly on progress made developing halon alternatives for cargo compartments and engine/auxiliary power unit fire extinguishing systems as well as the status of halon alternatives for hand-held fire extinguishers; and
9. *Declares* that this resolution supersedes Resolution A36-12.

The HTOC is currently working with ICAO on the corresponding amendments to Annex 6 – Operation of Aircraft, and Annex 8 – Airworthiness of Aircraft, of the Chicago Convention that must be agreed upon by the Air Navigation Commission at its 185th and 186th meetings prior to being sent to the ICAO Council for approval. In order for ICAO to meet the dates in the agreed upon mandate, the Council must approve the changes to the Annexes by early July 2011.

7.2.6 European Union

The European Union banned all non-critical uses of halons in 2003. Critical uses are listed in the current Annex VI to Regulation (EC) No. 1005/2009. All current on-board uses of halons in aviation are included on the critical use list under the EC regulation. Annex VI was revised in 2010 as per Commission Regulation (EU) No 744/2010 of 18 August 2010) and now contains "cut-off dates" for the use of halons in new equipment or facilities and "end dates" when all halon systems or extinguishers in a particular application must be decommissioned (see Table 7-4 below). This differs from the approach that was supported by HTOC for the ICAO resolution, which focuses on eliminating the use of halon in new production aircraft and new designs only. HTOC has strong concerns about the technical and economic feasibility of requiring the retrofit of fire protection systems on existing aircraft. Important safeguards have been put in place in Regulation (EC) No 1005/2009 and in Annex VI to avoid adverse impacts on safety and excessive costs: there are provisions for case by case derogations and for periodic reviews of the annex in order to account for the technological progress and the technical feasibility in terms of retrofit.

Table 7-4: Aviation Halon Phase Out Dates in EC Reg. 1005/2009 Annex VI

Purpose	Type of Extinguisher	Type of Halon	Cut-off Date: Application for New Type Certification	End Date: All Halons Decommissioned
Normally unoccupied cargo compartments	Fixed system	1301 1211 2402	2018	2040
Cabin and crew compartments	Portable extinguisher	1211 2402	2014	2025
Engine nacelles and APU	Fixed system	1301 1211 2402	2014	2040
Inerting of fuel tanks	Fixed system	1301 2402	2011	2040
Lavatory waste receptacles	Fixed system	1301 1211 2402	2011	2020
Protection of dry bays	Fixed system	1301 1211 2402	2011	2040

7.2.7 Contaminated Recycled Halons

In 2009, the UK Civil Aviation Authority (CAA) reported to EASA that contaminated halons had made their way into the civil aviation industry. It is alleged that a UK halon recycler falsified third party laboratory test reports that indicated contamination to show that the halon met specification. The halon was then sold to aviation fire protection equipment suppliers. The concern is primarily halon 1211, but contaminated halon 1301 has also been found.

Contaminants found in halon 1211 include CFC-11, CFC-12, and HCFC-141b. These have been found in varying quantities, and in some cases the total contaminant content is in excess of 50%. This has the potential to impact fire extinguishing efficiency, the toxicity of the agent and its combustion by-products, and the performance of the extinguisher or system due to orifice clogging, cylinder corrosion, etc.

Based on investigations by EASA and CAA, it was determined that 17 companies were potentially affected by the contaminated halons. These companies were contacted and the suspect halon batches and affected extinguishers were identified. As the quantity of suspect halon is considerable, it was not practical to remove all affected extinguishing equipment from use. It was decided to take immediate actions for contaminated halon 1211 when the purity level was below 90%. As a result, EASA has issued 7 Airworthiness Directives (ADs) and FAA has issued 3 ADs (see Appendix D) covering the following halon 1211portable extinguishers:

- Fire Fighting Enterprises Limited (FFE) - total number of extinguishers around 5000
- SICLI H1-10 AIR (formerly General Incendie MAIP) - total number of extinguishers around 1400
- L'Hotellier (ATR, Eurocopter and Socata) - total number of extinguishers around 1800

EASA has not yet taken a position on how to address halon 1211 with a purity of 90% or greater that does not meet specification. For halon 1301, testing of suspect batches is on-going and the level of risk is still under assessment.

In addition to these ADs, a number of other actions are being taken to address the problem of contaminated halons. In January, ICAO issued a State letter (reference AN 3/25.1-10/2) urging States to ensure their aviation industry utilise halon that has been recycled to an international or State-recognised performance standard. EASA is considering a rulemaking task to develop acceptable means of compliance (AMC) applicable to production and maintenance organisations in order to give guidance on how to perform the necessary tests to verify the quality of halon. EASA is convinced that certification documentation accompanying the products is not enough on its own to guarantee the proper quality of halon supplied and only adequate tests performed at the user's incoming inspection can ensure halon conforms to recognised international standards.

The HTOC recommends that the analysis of the halon purity be done according to the recommendations in Chapter 9.0, following one of the recognised standards referenced there. The HTOC recommends strict adherence to these standards to avoid potential risks from reduced fire extinguishing performance or increased agent toxicity.

7.2.8 New Generation Aircraft

New airframe designs should take into account the availability of the alternative fire suppression agents that have been tested and approved by regulatory authorities. The civil aviation industry and regulatory authorities should closely monitor and ensure that the testing and approval of alternatives for engine nacelle and cargo compartment applications is completed in the near-term for new airframe designs. The timing of the inclusion of the available halon alternatives in new aircraft designs remains uncertain, and unless the processes of designing, conforming, qualifying and certifying new extinguishing systems on civil aircraft are made a priority by the airframe manufacturers and approval authorities – and expedited accordingly – these will represent significant barriers to the transition away from halons. The fact that alternatives are used only in the lavatory fire extinguishing systems of new Airbus and Boeing aircraft is a disappointing result given the extensive research and testing efforts that have been expended on aviation applications since 1993.

7.2.9 References

1. ICF International, Inc., "Estimated Usage and Emissions of Halon 1301, 1211, 2402 in Civil Aircraft Worldwide", June 2006 and updated executive summary, November 2009.

2. Marker, T., "Development of a Minimum Performance Standard for Lavatory Trash Receptacle Automatic Fire Extinguishers", DOT/FAA/AR-96/122, Final Report, February 1997.

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7.3 Military Applications

7.3.1 Current Uses of Halons in the Military Sector

Prior to the Montreal Protocol, halons found widespread use by militaries throughout the world due to their effectiveness against the wide range of fire hazards that exist in military equipment and facilities.

As in the civilian sectors, halons were used in defence department offices, military headquarters, command centres, computer and communication centres and research and test facilities. Non-Article 5 Parties have converted the majority of these halon systems to water sprinkler, HFC, inert gas or carbon dioxide alternatives. Nearly all halon portable extinguishers in facilities 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 lesser extent, portable extinguishers, protect personnel and the operational capability of front-line weapons systems (aircraft and helicopters, naval vessels, and armoured vehicles) from fires caused by hostile actions or equipment failures. Many of these hazards, and the difficulties that must be overcome to replace the halons, are unique to the military sector.

The need for effective fire protection for military personnel and their equipment is universal. However, the methods used to counter these hazards vary with the type of equipment and the country of origin.

While halons 1301 and 1211 are the most common choices of agent, halon 2402 is frequently found in Eastern Europe and other countries where Soviet Union-manufactured equipment is used. Halon 1301 and halon 1211 use in Russia has been largely confined to military and special applications, but fire protection in those sectors has been dominated by halon 2402. In other countries of the former Eastern Bloc (e.g., Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, and Slovakia) halon 2402 was associated with the use of Russian military equipment and civilian aircraft. Halon 2402 based fire protection systems were also exported to some Asian countries (e.g., India and Vietnam) as part of Russian equipment, mostly military vehicles (including the T-54, T-60, T-70, and T-80 tanks), ships and aircraft. Halon 2402 may also still be employed in countries that purchased equipment from the USSR, and later from Russia (e.g., Afghanistan, Algeria, China, Cuba, Egypt, Libya, Mongolia and Syria). Halon 2402 blends, including “BF-2” (a mixture of 37% Halon 2402 and 63% Methyl Bromide (Brometil)) and a mixture of 85% carbon dioxide with 15% Halon 2402, are also found in niche military applications.

The difficulties of identifying and implementing acceptable alternatives have proven to be formidable, and defence forces of virtually all nations continue to use halons in many front-line applications. Although the number and types of halon applications vary from nation to nation, the following important uses may be found in current combat or peacekeeping forces:

- In armoured fighting vehicles, engine compartments have been protected by fixed, total flooding, halon 1301, 1211, or 2402 systems designed to extinguish fires caused by ignition of leaked fuel, lubricant or hydraulic fluid. The crew compartments of some vehicle types are also fitted with halon 1301 or 2402 systems that can discharge in a few tens of milliseconds to suppress the ignition of fuel or hydraulic fluid that is vaporized by a penetrating round. Vehicles may also be equipped with portable halon 1211, 1301 or 2402 extinguishers for use on interior or exterior equipment fires.

- Multi-engine aircraft employ halons to protect their engine nacelles and auxiliary power units from fires caused by fuel leaks or other equipment failures or damage. Many aircraft and helicopters are also fitted with portable halon 1211, 1301, or 2402 extinguishers. Cargo bays on some transport aircraft are protected by halon 1301 systems designed to contain a 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 facing a high probability of ballistic attack, dry bays (the void spaces surrounding fuel tanks) are protected by automatic halon 1301 or 2402 systems to suppress an explosion caused by the ignition of fuel ejected from a fuel tank by an incoming round. Some US-designed aircraft types utilise halon 1301 systems to prevent explosions by pre-emptively inerting the vapour space (ullage) in their fuel tanks. Standard policy is that these systems are to be activated by the pilot prior to combat operations only. On airfields, some forces continue to use halon extinguishers for flight lines and crash rescue vehicles.
- Naval vessels, whether surface ships, submarines, or auxiliary vessels, have fixed halon systems to extinguish fires caused by equipment faults or hostile action. These systems protect engine rooms, machinery spaces, gas turbine and diesel engine enclosures, fuel pump rooms and flammable liquid storerooms from flammable liquid fires. On some vessels, operations rooms, command centres and electrical compartments also have dedicated halon systems. Some aircraft carriers and smaller vessels carrying aircraft or helicopters are also equipped with halon flight line extinguishers to fight fires on flight decks and in hangar bays. The machinery space systems on larger ships can be among the largest of all military halon systems, in some cases containing installed charges of several MT of halon.

7.3.2 Alternative Fire Extinguishants and Fire Protection Methods

The militaries of many Parties have committed themselves to reducing and eventually eliminating use of halons in equipment and facilities wherever technically and economically feasible. These efforts include:

- Design of new weapons platforms such that halon systems are no longer required;
- Removal of halon systems where active fire suppression is no longer considered necessary;
- Replacement of halons in existing equipment with alternative means of fire protection; and
- Introduction of policies and procedures to reduce halon emissions during the maintenance, testing, and support of applications that remain in service.

The militaries of many Parties have devoted considerable effort and resources towards the assessment and implementation of alternative extinguishants and fire protection technologies.

7.3.3 New Designs of Equipment

The long lead-times required to develop and procure military equipment means that some equipment being built to an established design is still being procured with halon systems on board. However, extensive research, development and testing have all but eliminated the need for halons in new equipment designs.

A few weapons systems, such as the UK variant of the Typhoon aircraft, have been developed and introduced with enhanced passive fire protection such that an active fire suppression system is no longer considered necessary. Elsewhere, acceptable solutions for new equipment include traditional extinguishants such as foams, dry powders, carbon dioxide, halocarbon alternatives, and new technologies such as water mist/fine water spray, fine particulate aerosols and inert gas generators. Specific examples that have been, or are being, implemented include:

- In armoured fighting vehicles, HFC-125, HFC-227ea, nitrogen, or dry powders are being used for the engine compartment of: Challenger 2, Warrior and other vehicles being manufactured in the UK; Leopard 2 vehicles in Germany; US vehicles including the M1 Abrams tank, Stryker armoured vehicles, Bradley Fighting Vehicles, Light Armoured Vehicles (LAV), and Mine Resistant Ambush Protected (MRAP) vehicles. A hybrid HFC-227ea/dry chemical system has been introduced for crew compartment explosion suppression on several US vehicles. Russia stopped using halon 2402 and its blends in their new generation tanks in the mid-1990s – the T-90 is now equipped with halon 1301 systems for both crew and engine compartments. The US Army has adopted carbon dioxide extinguishers to replace the halon 1301 portables installed in all of its combat vehicles except the M1 Abrams tank, where water/potassium acetate extinguishers are being fitted. Portable extinguishers for armoured fighting vehicles in the former Soviet Union used CO_2, halon 2402, or halon 2402 blends through the early 1990s – new equipment now uses carbon dioxide or dry chemical portable extinguishers. India has used halon 2402 and its blends, e.g., halon 2402 and ethyl bromide, in its military equipment purchased from the former Soviet Union. Owing to limited access to supplies of 2402, the Indian military is also looking at converting the crew and engine compartments of its ground vehicles to halon 1301 and to replace its 2402 portables with halon 1211 pressurised with carbon dioxide; other alternatives (e.g., HFC-236fa) are also being tested.
- In US military aircraft, the F/A-18E/F Super Hornet, the F-22 Raptor, the V-22 Osprey tilt-rotor aircraft, and the H-92, UH-1Y and AH-1Z upgraded helicopters employ HFC-125 to protect their engine nacelles. Pyrotechnic inert gas generators now protect dry bays on the V-22 and F/A-18E/F. Further, on-board inert gas generating systems or explosion suppression foams are being used to inert the fuel tanks of the V-22 and the F/A-18E/F, and the F/A-35 Lightning II Joint Strike Fighter.
- In naval vessels, HFC-227ea, fine water spray, hybrid HFC-227ea/water spray, foam or carbon dioxide systems are being used for the main machinery and other spaces of new EU and US vessels.

In many cases, adoption of alternatives has not been without trade-offs. These may include weight and/or space penalties that may affect platform or fire extinguishant performance, or introduce a toxicity hazard that must be managed. Foams or powders also require the decontamination of protected areas before the return of equipment to service after a system has been discharged. In all cases, operational and maintenance procedures and associated documentation must be changed and personnel properly trained.

Militaries tend to procure commercial, off-the-shelf, equipment or variants of such equipment where practical. Benefits may include lower development and procurement costs, quicker delivery of the equipment, and access to a well-established support infrastructure. Civilian standards and regulations relating to halon use and replacement may be adopted or specified by the contractor, which might be problematic where defence requirements are more stringent. The implications of this approach for fire protection and safety must be considered very carefully and civilian standards may need to be adapted to ensure adequate safety and performance in combat conditions.

Multilateral procurement collaborations are now commonplace. Each collaborating nation may have different performance objectives and requirements for the fire protection systems. The consequence is often for a new design to incorporate the "easiest" fire protection solution, which may include the continued use of halons. An example of "commercial standards" procurement is the new A400M transport aircraft being purchased by a number of Member States of the European Union where halon systems have been specified for a new airframe.

Any selection of a halon in new military equipment or facilities should and can be avoided by a clear policy commitment and up-front investment in alternatives. The additional cost should be balanced against the need for an assured long-term supply of the halon and the potential need for conversion or retrofit before the end of the equipment's service life should halon supplies become threatened or regulations on continued use be implemented.

7.3.4 Existing, In-service Equipment

Conversion of halon systems in existing equipment is almost always more difficult than accommodating alternative solutions in new weapons platforms. The extent to which conversion programs for existing equipment have been implemented varies from country to country. Important factors include the unique characteristics of each nation's forces, the technical difficulty of possible solutions, and the political will to finance the conversion programmes. 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 toxicity of halon alternatives is especially important to the military sector because there is significant risk that personnel will be exposed to extinguishing concentrations of the agents or high levels of their breakdown products in operational situations. The type and level of halocarbon agent acid-gas decomposition products and the associated risks to personnel and equipment must be carefully addressed. Therefore, conversion of halon systems for normally-occupied spaces is significantly more challenging than for those protecting unoccupied spaces such as engine compartments.

The feasibility of conversion of in-service systems will depend significantly on whether the work can be accomplished during routine maintenance periods or whether the withdrawal of equipment from service is necessary. If conversion requires major modifications, the work will probably be technically and economically feasible only 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 in advance and cannot readily be changed. 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 programs can therefore often be lengthy and any unforeseen operational commitments could delay their completion.

Despite all of these difficulties, good progress has been made in many areas and by some countries, especially in applications protecting normally unoccupied spaces:

- Use of halons in engine compartments of existing armoured fighting vehicles is diminishing as many nations implement conversion programmes. The UK identified HFC-227ea or a dry chemical as the preferred alternatives and has completed a fleet-wide conversion program. The US Army has converted its Bradley and several other vehicle engine systems to HFC-227ea while Abrams tanks are being converted to a sodium bicarbonate system during scheduled maintenance cycles. The engine compartments of Germany's Leopard tanks 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 other 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 compartments of its vehicles. The armies of the US, the Netherlands and Australia have replaced most of their vehicle portable extinguishers with carbon dioxide. The UK has replaced portable extinguishers mounted on the outside of its vehicles with dry chemical alternatives but retains halon 1211 portable extinguishers for the crew compartment interiors. A manually-operated fixed halon 1301 system for the crew compartments of the US Marine Corps LAV has been replaced with an automatic HFC-227ea/sodium bicarbonate system. This blend is also used on the US Army Stryker, MRAP, and HMMWV vehicles. However, retrofit of crew compartment automatic fixed explosion suppression systems has so far proven prohibitively costly for most applications.
- On existing naval vessels, a number of conversion programs are underway for 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 an HFC-227ea/water spray hybrid system. Australia and Germany began converting main machinery space halon systems to 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. In Denmark, where HFCs are not acceptable because of national legislation, nitrogen systems are being installed to protect the engine compartments of surface ships.
- The opportunity to convert existing aircraft halon systems, whether military or civilian, remains limited. A number of studies, including use of FK-5-1-12 fire extinguishing fluid, are underway and considerable investment in potential alternatives continues. Several aircraft engine nacelle conversions are being evaluated in the US and UK. HFC

alternatives for lavatory waste receptacles have been adapted as a “drop-in” solution. Similarly, HFC-based and HCFC-based portable extinguishers that meet civilian minimum performance standards are now available. A number of countries have evaluated the available extinguishers for suitability.

- The US Army and many European militaries have replaced halon 1211 flight line extinguishers with carbon dioxide, dry chemical, compressed air foams (CAF), or aqueous film-forming foam (AFFF) units. However, these alternatives are not acceptable to some military authorities because of concerns about compatibility with jet engine designs.

Table 7-5 summarises where halons are used in military applications and alternatives that have been implemented by various Parties to convert existing equipment and facilities and in new designs.

Generally, 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 lives of certain equipment. In some circumstances this could be until the mid-21st Century.

7.3.5 Responsible Management – Assurance of Supplies and Minimisation of Halon Emissions

For applications where an acceptable alternative has not yet been implemented, operational and maintenance procedures and training can and have been improved to minimise emissions and conserve the limited supplies of recyclable materials that are available.

In non-Article 5(1) countries, discharge testing to certify systems has been virtually eliminated – acceptable alternative methods of testing are now routinely available. Training procedures for military fire-fighters no longer stipulate use of halons. Recovery equipment and procedures have been introduced to minimise losses during maintenance procedures. Analysis of discharge patterns and reporting of non-fire discharges have identified “weak points” on equipment (e.g., connections, valves, switches, or bad practice in the field) that can then be addressed. Relatively simple, cost-effective changes such as these have had a significant impact on usage and emissions. Thus emissions from most military uses are now small relative to the size of the installed base.

Supplies of halons from converted and decommissioned systems and extinguishers, both from within military organisations and from the open market, have been banked by many Parties to support their critical uses where alternatives are not available or have not yet been implemented. This approach has helped to ensure adequate stocks and also facilitates good management and effective usage control. The reliance of defence departments on stocks of halons will continue for at least the next thirty years to support some equipment which has a long anticipated service life. While the quantities and range of equipment involved will steadily reduce in magnitude over time, military users must periodically review their stocks and usage rates to ensure that they have adequate supplies to meet projected needs.

Table 7-5: Continuing Uses of Halons and Examples of Implemented Alternatives in the Military Sector

Application	Protected Space	Primary Protected Risk	Halon	Implemented Alternatives: In conversions of Existing Equipment	Implemented Alternatives: In New Designs and Major Modifications of Equipment
Armoured Fighting Vehicle	Engine Compartment	Class B	1301, 1211, 2402	HFC-227ea, Dry Chemical, Inert Gas	HFC-227ea, HFC-125, Dry Chemical
	Crew Compartment	Class B (explosion)	1301, 2402	None	HFC-227ea+Dry Chemical (hybrid system)
	Portable Extinguisher	Class A, B, electrical	1211, 1301, 2402	CO_2, Dry Chemical, Water/Potassium Acetate	CO_2, Dry Chemical, Water/Potassium Acetate
Aircraft	Engine Nacelle	Class B	1301, 1211, 2402	None	HFC-125
	APU	Class B	1301, 1211, 2402	None	HFC-125
	Dry Bay	Class B (explosion)	1301, 2402	None	IGG
	Cargo Bay	Class A (deep-seated)	1301, 2402	None	None
	Fuel Tank Inerting	Class B	1301, 2402	None	OBIGGS, Fire Suppression Foam
	Cabin Portable Extinguisher	Class A, B, electrical	1211, 1301, 2402	None	None
	Lavatory (waste bin)	Class A	1301	None	None
Airfield	Hardened Aircraft Shelter	Class B	1301	Foam	Foam
	Crash Rescue Vehicle	Class B	1211	Dry Chemical, Foam, HCFC Blend B	Dry Chemical, Foam, HCFC Blend B
	Flight Line (Portable) Extinguisher	Class B	1211	CO_2, Dry Chemical, Foam, HCFC Blend B	Dry Chemical, Foam, HCFC Blend B

Table 7-5: Continuing Uses of Halons and Examples of Implemented Alternatives in the Military Sector (Continued)

Application	Protected Space	Primary Protected Risk	Halon	Implemented Alternatives	
				In conversions of Existing Equipment	In New Designs and Major Modifications of Equipment
Naval Vessel (Surface Ship)	Main Machinery Space (normally occupied)	Class B	1301, 2402	HFC-227ea, CO_2, HFC-227ea/Water Spray	HFC-227ea, CO_2, HFC-227ea/Water Spray, Water Mist, Foam
	Engine Space/Module (normally unoccupied)	Class B	1301, 1211	HFC-227ea, CO_2, Dry Chemical	HFC-227ea, CO_2, PGA
	Flammable Liquid Storeroom	Class B	1301, 2402	Dry Chemical	HFC-227ea, HFC-227ea/Water Spray
	Electrical Compartment	Class A, Electrical	1301, 2402	Inert Gas	HFC-227ea, Inert Gas
	Fuel Pump Room	Class B	1301	None	Foam, HFC-227ea
	Command Centre	Class A, Electrical	1301, 2402	None	None
	Flight Line/Hangar	Class B	1211, 2402	Foam	Foam
Naval Vessel (Submarine)	Machinery Space	Class B	1301, 2402	None	Foam, Water Mist
	Diesel Generator Space	Class B	1301, 2402	None	Foam, Water Mist
	Electrical Compartment	Class A, Electrical	1301, 2402	None	None
	Command Centre	Class A, Electrical	1301	None	None
Facilities (Fixed Systems)	Command Centre	Class A, Electrical	1301, 2402	HFC-227ea, CO_2	Water Sprinkler, CO_2, Inert Gas, HFC-227ea
	Research Facility	Class A, B, Electrical	1301	Water Sprinkler, CO_2, Inert Gas, HFC-227ea	Water Sprinkler, CO_2, Inert Gas, HFC-227ea
	Computer Centre	Class A	1301, 1211, 2402	Water Sprinkler, CO_2, Inert Gas, HFC-227ea	Water Sprinkler, CO_2, Inert Gas, HFC-227ea

7.3.6 Military-sponsored Research into Novel Halon Alternatives

Owing to the need for additional solutions to enable the conversion of important in-service uses where current alternatives are not feasible, military organisations continue to sponsor studies of novel fire extinguishants. One example is the US Department of Defense's Next Generation Fire Suppression Technology Program (NGP). The program focused on developing and demonstrating feasible, retrofitable, fire protection solutions to replace halon 1301 in both new and existing aircraft. It provided an increased understanding of flame suppression processes and chemistry and evaluations of novel fire suppressants and agent delivery techniques. Results of the program and a summary of its outputs can be found on the NGP website at:

http://www.bfrl.nist.gov/866/NGP

The Advanced Agent Working Group (AAWG), a US/UK industry and government collaboration, aimed to find and characterise total-flooding alternatives to halon 1301. This work focused primarily on bromine-containing tropodegradable halocarbons which laboratory testing showed are effective extinguishants with minimal ODP and GWP. The UK MOD also contributed a study of phosphorus-containing compounds. However, the chemicals' high toxicities and high boiling points led to the completion of this work without a promising candidate agent. The AAWG program culminated in the characterisation of (2-BTP) as a potential total flooding agent for non-occupied areas, or a streaming agent for applications such as aircraft portable extinguishers or military flight line units. Commercial development of this compound is currently underway.

In 2006, the US Navy and Air Force launched a joint program to identify a replacement for halon 1211 flight line extinguishers. The testing evaluated agents against spilled fuel fires, hidden fires, and running fuel fires. The objective of the program was to find a suitable existing agent, or one that would require limited research and development to commercialise. To date, no alternative agent/hardware solution has been identified that approaches the performance of the current extinguishers. However, testing continues to determine if these less effective alternative agent/hardware solutions are adequate to protect against the most common fire threats.

The UK MOD investigated the feasibility of using pyrotechnically generated aerosols (PGA) for fire protection of naval vessel main machinery spaces, high voltage electrical spaces and engine enclosures. Real-scale tests gave a much better understanding of the design and performance criteria for these systems. However, due to engineering issues associated with their implementation, the project concluded that the technology was not yet sufficiently developed for implementation on UK vessels.

The US Army completed research in 2010 to further evaluate alternatives to halon 1301 for ground vehicle crew compartment automatic fire extinguishing systems (AFES). Among other key findings, the following results were noted. Further testing in a stowed combat vehicle configuration is planned later in 2010 with a down-selected list of candidate agents and delivery systems.

- It was reconfirmed that HFC-227ea with 5% sodium bicarbonate powder performs equivalently to halon 1301 with respect to fire extinguishing capability, by-product levels, etc.

- FK-5-1-12 was able to extinguish fast-growth fires in approximately the same time as 1301, but the resulting by-product levels were significantly higher. While adding sodium bicarbonate powder to the FK-5-1-12 significantly reduced the by-product levels as it does with other fluorinated agents, the levels were still well above acceptable crew exposure limits.
- An equivalent weight of water with additives took somewhat longer to extinguish the test fires than other agents, but temperatures and other parameters were within acceptable limits. Further testing is required to see if adequate agent distribution can be achieved in a cluttered compartment encountered in actual vehicle operations.
- Halon 1301 with sodium bicarbonate powder (equivalent to $80 g/m^3$) successfully performed at significantly lower concentrations than any other agent tested. Less than half of the agent weight was required compared to straight halon 1301 or HFC-227ea/powder and by-product levels were often below detection limits. This approach may lead to a simple and cost-effective way to improve the performance of AFESs and extend the life of limited halon reserves.

A survey of extinguishing agents used in automatic fire extinguishing systems in over 154,000 military ground vehicles representing 35 countries worldwide was obtained by HTOC in 2010 and the results are summarised in Table 7-6. The data show that halons are no longer the primary agents for these platforms. It is also clear that there is a strong reliance on HFC agents to protect occupied areas (e.g., crew compartments) as well as engine compartments and other unoccupied areas. While the majority of unoccupied spaces that have fire protection rely on non-HFC and non-halon agents (e.g., dry powders and inert gases), no occupied areas do. Restrictions on HFC production or use would have a significant impact on the military sector. Any phase-out of HFC fire suppression agents would therefore require substantial investments, and would likely jeopardise the protection of occupied areas.

Table 7-6: Agent Use in Military Vehicle Fire Protection Systems

	Agent			
Protected Area	Halons	HFCs	Other	None
Occupied	19.2%	66.1%	0.0%	14.7%
Unoccupied	11.7%	16.2%	19.9%	52.3%

Overall, the efforts and resources being devoted to fundamental research aimed at identifying novel halon alternatives have reduced appreciably in the last few years. The most promising substances and technologies have largely been identified and evaluated. There is no “universal solution” on the horizon but a considerable amount of knowledge has been gained. Research efforts have been refocused on improving the performance and characteristics of existing alternatives and evaluating the performance of the most promising options in specific applications and platforms.

7.4 Other Applications

7.4.1 Pipelines/Oil and Gas Industry

The use of halon 1301 and halon 2402 systems in this industry for explosion prevention (inertion) and fire protection has been focused on inhospitable locations such as the Alaskan North Slope in the United States, the North Sea in Europe, and parts of the former Soviet Union, where facilities have had to be enclosed due to the harsh climatic conditions. The process areas in the production modules and the oil and gas 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 in the USA and Europe, and halon 2402 in the Russian Federation and Ukraine. When reviewing the reliance on existing halon banks, there are two distinct cases to consider, existing facilities and new facilities.

7.4.1.1 Existing Facilities

In most cases, existing facilities were designed and constructed with halon fixed systems as an integral part of the safety system design as well as the physical layout of the facility. As with civil aviation, after extensive research, it has been determined that in some cases 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 these facilities will likely rely on existing halon banks for their operating lifetimes. However, in order to reduce the impact on the halon banks, measures have been taken to reduce emissions through either of two methodologies, which can be summarised as follows:

1) Reassess the hazards and evaluate whether the potential for an explosion still exists.

   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. In others, advantage can be taken of the high winds that prevail in the area to assist in the exhausting of any gas accumulation from a hydrocarbon release. In both cases, the result may be a fire hazard but not an explosion hazard and so the original fixed halon system can often be decommissioned, the halon recycled, and an alternative fire suppression system installed.

2) 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 the fire and the gas detection systems to utilise modern technologies. Such systems are immune to common false alarms such as hot carbon dioxide emissions, reflections from flare radiation, black body radiation, hot work such as welding, and other problems that affect older technology detectors.

7.4.1.2 New Facilities

For new facilities, companies are now adopting an inherently safe design approach to the protection of their facilities. 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 mentioned above are employed to shut-down 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 effects 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 has been replaced by HFC-23 or FK-5-1-12, if temperatures permit, as part of the facility protection design. As HFC-23 is the only alternative where very low temperatures are encountered, a similar question to the one mentioned at the beginning of this section raises its head, i.e., should such a high GWP agent be diverted from destruction to replace an existing, recycled halon?

7.4.2 Commercial/Industrial and Agricultural Sectors

Outside of the oil and gas industry, halon has been used to suppress explosions in applications such as aerosol fill rooms, grain silos, paper production and milk powder processing plants. Halons are no longer necessary to meet explosion protection requirements in industrial or agricultural applications and are not sold into new explosion suppression systems. However, legacy explosion suppression units originally containing halons remain in service and thus rely on the halon banks.

Halon systems were used to protect delicate and important computer based equipment in the Telecommunication and Electrical Industries as well as priceless/irreplaceable artefacts in museums. As new clean agent products are introduced and installed these industries become less reliant on the existing stocks of halons that are available and provide surplus halons from decommissioned systems. However the cost to re-engineer systems to replace the existing systems can be very expensive. In many cases unless industry is mandated to replace the system, or the cost of maintaining the existing systems becomes cost prohibitive, industry will continue to operate their existing halon systems and also rely on the halon banks to supply their needs.

7.4.3 Merchant Shipping

In its 2006 Assessment, the HTOC detailed the status of the use of halon and their alternatives on board Merchant ships. Essentially the situation now is unchanged other than less ships are dependent upon halon owing to decommissioning of ships in the intervening period. The following summarises the Merchant shipping situation.

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

In general, since the 1992 International Maritime Organisation (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.

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. 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:

- Continue operating with the halon systems, hoping they will not discharge and – if they do – it will happen somewhere where replenishment halon is available.
- 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.
- Incur a slightly lower cost than in option 2 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 (option 1 above) on this matter. While this may change, replenishment halon is readily available worldwide. IMO has published a circular identifying international sources for replenishment halon. In addition, IMO has developed and published 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.

In light of the above, the industry appears to have concluded that this problem, if not solved, is certainly manageable for the near future.

8.0 Estimated Inventories of Halons

As in previous assessment reports, the HTOC is providing the most current estimates of inventories for halon 1211 and halon 1301 based on modelling of known production and estimated emissions. Very little has changed with halons 1211 and 1301 on the global level since the 2006 Assessment. Therefore, the global estimate of inventories and emissions for halons 1211 and 1301 provided in this report is the same as provided in the 2006 Assessment. Some additional information on regional estimates of emissions for halons 1211 and 1301 has become available and is provided in a separate section within this chapter. For halon 2402, there remains little open literature information available on inventories and emissions. The HTOC has provided updated information and created a rough global estimate of banks and emissions.

8.1 Emissions and Inventories of Halon 1301

Table 8-1 provides the HTOC 2006 Assessment of current estimates of inventories for halon 1301. Figure 8-1 provides the regional distribution of the global inventory of halon 1301. According to the HTOC Model for halon 1301, as shown in Table 8-1 and Figure 8-1, over 35% of the current inventory of halon 1301 is projected to be in Japan. Although the regional disparity in the distribution of halon itself does not constitute necessarily a regional imbalance, it is anticipated that regional imbalances may result in shortage in one country or region with excesses in other countries and regions.

Table 8-1: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1301

HALON 1301 SUMMARY (All quantities are provided in metric tonnes) Year	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
ANNUAL PRODUCTION												
North America, Western Europe and Japan	10.0	20.0	30.0	40.0	50.0	60.0	100.0	200.0	550.0	839.0	1292.0	1461.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ANNUAL PRODUCTION	10.0	20.0	30.0	40.0	50.0	60.0	100.0	200.0	550.0	839.0	1292.0	1461.0
ANNUAL PRODUCTION ALLOCATION												
North America	3.0	6.0	9.0	12.0	15.0	18.0	30.0	60.0	165.0	251.7	387.6	438.3
Western Europe and Australia	2.5	5.0	7.5	10.0	12.5	15.0	25.0	50.0	137.5	209.8	323.0	365.3
Japan	2.2	4.4	6.6	8.8	11.0	13.2	22.0	44.0	121.0	184.6	284.2	321.4
CEIT	0.3	0.6	0.9	1.2	1.5	1.8	3.0	6.0	16.5	25.2	38.8	43.8
Article 5(1)	2.0	4.0	6.0	8.0	10.0	12.0	20.0	40.0	110.0	167.8	258.4	292.2
TOTAL ANNUAL PRODUCTION ALLOCATION	10.0	20.0	30.0	40.0	50.0	60.0	100.0	200.0	550.0	839.0	1292.0	1461.0
ANNUAL EMISSIONS												
North America	1.4	2.4	3.2	3.7	5.3	7.0	10.7	18.8	43.9	75.4	123.1	165.6
Western Europe and Australia	1.2	2.0	2.6	3.0	4.4	5.9	8.9	15.7	36.5	62.8	102.6	138.0
Japan	0.3	0.8	1.4	2.1	2.9	3.8	5.8	10.2	24.0	40.5	65.9	87.8
CEIT	0.1	0.2	0.3	0.4	0.5	0.7	1.1	1.9	4.4	7.5	12.3	16.6
Article 5(1)	0.9	1.6	2.1	2.5	3.6	4.8	7.2	12.7	29.5	50.8	83.0	111.9
TOTAL ANNUAL EMISSIONS	3.9	7.1	9.6	11.6	16.6	22.2	33.7	59.2	138.2	237.1	386.9	520.0
CUMMULATIVE PRODUCTION												
North America, Western Europe and Japan	10.0	30.0	60.0	100.0	150.0	210.0	310.0	510.0	1060.0	1899.0	3191.0	4652.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL CUMMULATIVE PRODUCTION	10.0	30.0	60.0	100.0	150.0	210.0	310.0	510.0	1060.0	1899.0	3191.0	4652.0

Table 8-1: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1301 (Continued)

HALON 1301 SUMMARY (All quantities are provided in metric tonnes) Year	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**
CUMMULATIVE PRODUCTION ALLOCATION												
North America	3.0	9.0	18.0	30.0	45.0	63.0	93.0	153.0	318.0	569.7	957.3	1395.6
Western Europe and Australia	2.5	7.5	15.0	25.0	37.5	52.5	77.5	127.5	265.0	474.8	797.8	1163.0
Japan	2.2	6.6	13.2	22.0	33.0	46.2	68.2	112.2	233.2	417.8	702.0	1023.4
CEIT	0.3	0.9	1.8	3.0	4.5	6.3	9.3	15.3	31.8	57.0	95.7	139.6
Article 5(1)	2.0	6.0	12.0	20.0	30.0	42.0	62.0	102.0	212.0	379.8	638.2	930.4
TOTAL CUMMULATIVE PRODUCTION ALLOCATION	10.0	30.0	60.0	100.0	150.0	210.0	310.0	510.0	1060.0	1899.0	3191.0	4652.0
CUMMULATIVE EMISSIONS												
North America	1.4	3.8	6.9	10.6	15.9	22.9	33.6	52.4	96.2	171.6	294.7	460.4
Western Europe and Australia	1.2	3.2	5.8	8.8	13.2	19.1	28.0	43.6	80.2	143.0	245.6	383.6
Japan	0.3	1.1	2.5	4.6	7.5	11.3	17.1	27.4	51.4	91.9	157.7	245.5
CEIT	0.1	0.4	0.7	1.1	1.6	2.3	3.4	5.2	9.6	17.2	29.5	46.0
Article 5(1)	0.9	2.5	4.6	7.1	10.7	15.4	22.6	35.3	64.8	115.5	198.5	310.5
TOTAL CUMMULATIVE EMISSIONS	3.9	11.0	20.5	32.2	48.8	71.0	104.7	163.9	302.1	539.2	926.1	1446.1
INVENTORY (BANK)												
North America	1.6	5.2	11.1	19.4	29.1	40.1	59.4	100.6	221.8	398.1	662.6	935.2
Western Europe and Australia	1.4	4.3	9.2	16.2	24.3	33.4	49.5	83.9	184.8	331.7	552.1	779.4
Japan	1.9	5.5	10.7	17.4	25.5	34.9	51.1	84.8	181.8	325.9	544.3	777.9
CEIT	0.2	0.5	1.1	1.9	2.9	4.0	5.9	10.1	22.2	39.8	66.3	93.5
Article 5(1)	1.1	3.5	7.4	12.9	19.3	26.6	39.4	66.7	147.2	264.3	439.7	619.9
GLOBAL INVENTORY (BANK)	6.1	19.0	39.5	67.8	101.2	139.0	205.3	346.1	757.9	1359.8	2264.9	3205.9

Table 8-1: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1301 (Continued)

HALON 1301 SUMMARY (All quantities are provided in metric tonnes) Year	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**
ANNUAL PRODUCTION												
North America, Western Europe and Japan	2019.0	3172.0	3550.0	4015.0	4718.0	4877.0	5694.0	7565.0	7386.0	8692.0	9781.0	11076.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	30.0	30.0
Article 5(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0	94.4	127.5
TOTAL ANNUAL PRODUCTION	2019.0	3172.0	3550.0	4015.0	4718.0	4877.0	5694.0	7565.0	7386.0	8792.0	9905.4	11233.5
ANNUAL PRODUCTION ALLOCATION												
North America	605.7	951.6	1065.0	1204.5	1415.4	1463.1	1708.2	2269.5	2215.8	2607.6	2934.3	3322.8
Western Europe and Australia	504.8	793.0	887.5	1003.8	1179.5	1219.3	1423.5	1891.3	1846.5	2173.0	2445.3	2769.0
Japan	444.2	697.8	781.0	883.3	1038.0	1072.9	1252.7	1664.3	1624.9	1912.2	2151.8	2436.7
CEIT	60.6	95.2	106.5	120.5	141.5	146.3	170.8	227.0	221.6	290.8	323.4	362.3
Article 5(1)	403.8	634.4	710.0	803.0	943.6	975.4	1138.8	1513.0	1477.2	1808.4	2050.6	2342.7
TOTAL ANNUAL PRODUCTION ALLOCATION	2019.0	3172.0	3550.0	4015.0	4718.0	4877.0	5694.0	7565.0	7386.0	8792.0	9905.4	11233.5
ANNUAL EMISSIONS												
North America	231.3	301.0	362.9	418.7	476.3	560.1	667.2	831.1	937.4	1095.6	1262.9	1451.8
Western Europe and Australia	192.8	250.8	302.4	348.9	396.9	466.7	556.0	692.6	781.2	913.0	1052.4	1209.8
Japan	123.3	167.3	203.4	238.6	296.2	321.1	384.4	481.0	539.0	632.0	729.3	839.9
CEIT	23.1	34.4	38.4	44.7	51.2	54.7	59.3	75.1	85.0	104.0	121.6	141.1
Article 5(1)	156.3	231.9	235.7	300.1	372.1	433.4	512.9	634.3	715.0	843.0	976.8	1129.1
TOTAL ANNUAL EMISSIONS	726.8	985.4	1142.8	1351.1	1592.6	1836.0	2179.7	2714.2	3057.7	3587.6	4143.0	4771.6
CUMMULATIVE PRODUCTION												
North America, Western Europe and Japan	6671.0	9843.0	13393.0	17408.0	22126.0	27003.0	32697.0	40262.0	47648.0	56340.0	66121.0	77197.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	60.0	90.0
Article 5(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.0	164.4	291.9
TOTAL CUMMULATIVE PRODUCTION	6671.0	9843.0	13393.0	17408.0	22126.0	27003.0	32697.0	40262.0	47648.0	56440.0	66345.4	77578.9

Table 8-1: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1301 (Continued)

HALON 1301 SUMMARY (All quantities are provided in metric tonnes) Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
CUMMULATIVE PRODUCTION ALLOCATION												
North America	2001.3	2952.9	4017.9	5222.4	6637.8	8100.9	9809.1	12078.6	14294.4	16902.0	19836.3	23159.1
Western Europe and Australia	1667.8	2460.8	3348.3	4352.0	5531.5	6750.8	8174.3	10065.5	11912.0	14085.0	16530.3	19299.3
Japan	1467.6	2165.5	2946.5	3829.8	4867.7	5940.7	7193.3	8857.6	10482.6	12394.8	14546.6	16983.3
CEIT	200.1	295.3	401.8	522.2	663.8	810.1	980.9	1207.9	1429.4	1720.2	2043.6	2405.9
Article 5(1)	1334.2	1968.6	2678.6	3481.6	4425.2	5400.6	6539.4	8052.4	9529.6	11338.0	13388.6	15731.3
TOTAL CUMMULATIVE PRODUCTION ALLOCATION	6671.0	9843.0	13393.0	17408.0	22126.0	27003.0	32697.0	40262.0	47648.0	56440.0	66345.4	77578.9
CUMMULATIVE EMISSIONS												
North America	691.7	992.7	1355.6	1774.3	2250.6	2810.6	3477.8	4309.0	5246.4	6342.0	7604.9	9056.6
Western Europe and Australia	576.4	827.2	1129.7	1478.6	1875.5	2342.2	2898.2	3590.8	4372.0	5285.0	6337.4	7547.2
Japan	368.8	536.1	739.5	978.1	1274.3	1595.5	1979.9	2460.8	2999.9	3631.8	4361.2	5201.0
CEIT	69.2	103.5	142.0	186.7	237.9	292.6	351.8	426.9	511.9	616.0	737.6	878.7
Article 5(1)	466.8	698.7	934.3	1234.4	1606.5	2039.9	2552.8	3187.1	3902.1	4745.2	5721.9	6851.1
TOTAL CUMMULATIVE EMISSIONS	2172.9	3158.2	4301.0	5652.1	7244.7	9080.7	11260.5	13974.6	17032.4	20620.0	24763.0	29534.6
INVENTORY (BANK)												
North America	1309.6	1960.2	2662.3	3448.1	4387.2	5290.3	6331.3	7769.6	9048.0	10560.0	12231.4	14102.5
Western Europe and Australia	1091.3	1633.5	2218.6	2873.4	3656.0	4408.6	5276.1	6474.7	7540.0	8800.0	10192.8	11752.0
Japan	1098.8	1629.3	2207.0	2851.6	3593.4	4345.2	5213.5	6396.8	7482.7	8763.0	10185.4	11782.3
CEIT	131.0	191.8	259.8	335.6	425.9	517.5	629.1	781.0	917.5	1104.2	1306.0	1527.2
Article 5(1)	867.4	1269.9	1744.3	2247.2	2818.7	3360.7	3986.6	4865.3	5627.5	6592.8	7666.6	8880.2
GLOBAL INVENTORY (BANK)	4498.1	6684.8	9092.0	11755.9	14881.3	17922.3	21436.5	26287.4	30615.6	35820.0	41582.4	48044.2

Table 8-1: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1301 (Continued)

HALON 1301 SUMMARY (All quantities are provided in metric tonnes) Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ANNUAL PRODUCTION												
North America, Western Europe and Japan	11604.0	12551.0	11152.0	9115.0	7326.0	4884.0	2442.0	0.0	0.0	0.0	0.0	0.0
CEIT	35.0	30.0	30.0	1100.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	192.8	214.1	227.1	359.8	571.6	511.1	738.4	700.0	750.0	800.0	750.0	535.0
TOTAL ANNUAL PRODUCTION	11831.8	12795.1	11409.1	10574.8	7947.6	5445.1	3180.4	700.0	750.0	800.0	750.0	535.0
ANNUAL PRODUCTION ALLOCATION												
North America	3481.2	3765.3	3345.6	2734.5	2197.8	1465.2	732.6	0.0	0.0	0.0	0.0	66.4
Western Europe and Australia	2901.0	3137.8	2788.0	2278.8	1831.5	1221.0	610.5	0.0	0.0	-0.2	-4.6	-70.8
Japan	2552.9	2761.2	2453.4	2005.3	1611.7	1074.5	537.2	0.0	0.0	0.0	0.0	0.0
CEIT	383.1	406.5	364.6	1373.5	269.8	196.5	73.3	0.0	0.0	0.0	0.0	0.0
Article 5(1)	2513.6	2724.3	2457.5	2182.8	2036.8	1487.9	1226.8	700.0	750.0	800.0	750.0	535.0
TOTAL ANNUAL PRODUCTION ALLOCATION	11831.8	12795.1	11409.1	10574.8	7947.6	5445.1	3180.4	700.0	750.0	799.8	745.4	530.6
ANNUAL EMISSIONS												
North America	1455.1	1645.9	1737.8	1767.7	1762.7	1693.7	1086.2	878.7	841.4	805.6	771.4	739.9
Western Europe and Australia	1352.6	1352.6	1439.7	1465.2	1461.6	1404.6	960.0	726.1	695.2	665.7	637.3	608.7
Japan	939.0	1050.3	1038.9	1053.1	959.0	709.2	387.6	185.7	36.5	36.1	36.0	36.0
CEIT	159.5	178.4	177.5	323.1	247.1	223.6	192.9	147.9	140.1	133.4	127.0	121.0
Article 5(1)	1275.9	1431.4	1515.9	1564.5	1602.0	1488.3	1431.7	1287.1	1235.0	1192.4	1151.9	1099.6
TOTAL ANNUAL EMISSIONS	5182.0	5658.5	5909.8	6173.8	6032.4	5519.4	4058.3	3225.5	2948.1	2833.2	2723.7	2605.1
CUMMULATIVE PRODUCTION												
North America, Western Europe and Japan	88801.0	101352.0	112504.0	121619.0	128945.0	133829.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0
CEIT	125.0	155.0	185.0	1285.0	1335.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0
Article 5(1)	484.6	698.7	925.8	1285.6	1857.3	2368.3	3106.7	3806.7	4556.7	5356.7	6106.7	6641.7
TOTAL CUMMULATIVE PRODUCTION	89410.6	102205.7	113614.8	124189.6	132137.3	137582.3	140762.7	141462.7	142212.7	143012.7	143762.7	144297.7

Table 8-1: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1301 (Continued)

HALON 1301 SUMMARY (All quantities are provided in metric tonnes) Year	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
CUMMULATIVE PRODUCTION ALLOCATION												
North America	26640.3	30405.6	33751.2	36485.7	38683.5	40148.7	40881.3	40881.3	40881.3	40881.3	40881.3	40947.7
Western Europe and Australia	22200.3	25338.0	28126.0	30404.8	32236.3	33457.3	34067.8	34067.8	34067.8	34067.5	34062.9	33992.1
Japan	19536.2	22297.4	24750.9	26756.2	28367.9	29442.4	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6
CEIT	2789.0	3195.6	3560.1	4933.6	5203.4	5399.9	5473.1	5473.1	5473.1	5473.1	5473.1	5473.1
Article 5(1)	18244.8	20969.1	23426.6	25609.4	27646.3	29134.1	30360.9	31060.9	31810.9	32610.9	33360.9	33895.9
TOTAL CUMMULATIVE PRODUCTION ALLOCATION	89410.6	102205.7	113614.8	124189.6	132137.3	137582.3	140762.7	141462.7	142212.7	143012.5	143757.9	144288.5
CUMMULATIVE EMISSIONS												
North America	10511.7	12157.7	13895.5	15663.2	17426.0	19119.6	20205.8	21084.5	21925.9	22731.5	23502.8	24242.8
Western Europe and Australia	8899.8	10252.3	11692.0	13157.2	14618.8	16023.4	16983.4	17709.4	18404.7	19070.4	19707.6	20316.3
Japan	6140.0	7190.3	8229.2	9282.3	10241.3	10950.6	11338.2	11523.9	11560.3	11596.4	11632.5	11668.4
CEIT	1038.2	1216.5	1394.0	1717.1	1964.3	2187.8	2380.7	2528.5	2668.6	2802.0	2929.0	3050.0
Article 5(1)	8126.9	9558.3	11074.2	12638.7	14240.7	15729.1	17160.7	18447.9	19682.8	20875.2	22027.2	23126.8
TOTAL CUMMULATIVE EMISSIONS	34716.6	40375.1	46284.9	52458.7	58491.1	64010.5	68068.8	71294.2	74242.3	77075.5	79799.2	82404.3
INVENTORY (BANK)												
North America	16128.6	18247.9	19855.7	20822.5	21257.5	21029.1	20675.5	19796.8	18955.4	18149.8	17378.5	16704.9
Western Europe and Australia	13300.5	15085.7	16434.0	17247.5	17617.4	17433.9	17084.4	16358.3	15663.1	14997.2	14355.3	13675.8
Japan	13396.2	15107.2	16521.7	17473.9	18126.6	18491.8	18641.4	18455.7	18419.3	18383.2	18347.2	18311.2
CEIT	1750.9	1979.0	2166.1	3216.4	3239.1	3212.0	3092.4	2944.6	2804.5	2671.1	2544.1	2423.1
Article 5(1)	10117.9	11410.8	12352.4	12970.7	13405.5	13405.1	13200.2	12613.1	12128.1	11735.7	11333.8	10769.1
GLOBAL INVENTORY (BANK)	54694.0	61830.6	67329.9	71730.9	73646.2	73571.9	72694.0	70168.5	67970.4	65937.0	63958.7	61884.2

Table 8-1: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1301 (Continued)

HALON 1301 SUMMARY (All quantities are provided in metric tonnes) Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
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	0.0	0.0	0.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	475.0	475.0	590.0	650.0	650.0	711.0	650.0	200.0	200.0	200.0	200.0	0.0
TOTAL ANNUAL PRODUCTION	475.0	475.0	590.0	650.0	650.0	711.0	650.0	200.0	200.0	200.0	200.0	0.0
ANNUAL PRODUCTION ALLOCATION												
North America	165.7	266.5	202.4	81.8	99.5	78.4	152.3	1061.6	0.0	0.0	0.0	0.0
Western Europe and Australia	-172.7	-305.8	-213.5	-88.6	-318.0	-283.0	-122.3	-1061.6	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	0.0	0.0	0.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	-30.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	459.7	475.0	583.9	650.0	650.0	711.0	650.0	200.0	200.0	200.0	200.0	0.0
TOTAL ANNUAL PRODUCTION ALLOCATION	452.7	435.6	572.8	643.2	431.6	506.3	650.0	200.0	200.0	200.0	200.0	0.0
ANNUAL EMISSIONS												
North America	713.3	692.0	672.7	650.3	626.4	603.6	582.8	582.7	581.8	557.1	533.4	510.7
Western Europe and Australia	577.8	543.2	509.0	645.8	599.5	548.0	505.8	427.0	380.4	359.7	339.9	321.2
Japan	35.9	35.8	35.7	35.7	35.6	35.5	35.5	35.4	35.3	35.3	35.2	35.1
CEIT	115.2	109.7	104.5	99.5	94.8	90.3	85.2	80.5	76.7	73.0	69.6	66.2
Article 5(1)	1041.4	987.7	946.7	917.0	734.0	726.1	721.8	693.7	655.7	620.5	588.1	548.2
TOTAL ANNUAL EMISSIONS	2483.6	2368.5	2268.6	2348.2	2090.3	2003.5	1931.1	1819.3	1729.9	1645.5	1566.2	1481.5
CUMMULATIVE PRODUCTION												
North America, Western Europe and Japan	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0
CEIT	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0
Article 5(1)	7116.7	7591.7	8181.7	8831.7	9481.7	10192.7	10842.7	11042.7	11242.7	11442.7	11642.7	11642.7
TOTAL CUMMULATIVE PRODUCTION	144772.7	145247.7	145837.7	146487.7	147137.7	147848.7	148498.7	148698.7	148898.7	149098.7	149298.7	149298.7

Table 8-1: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1301 (Continued)

HALON 1301 SUMMARY (All quantities are provided in metric tonnes) Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CUMMULATIVE PRODUCTION ALLOCATION												
North America	41113.4	41379.9	41582.3	41664.1	41763.6	41842.0	41994.3	43055.9	43055.9	43055.9	43055.9	43055.9
Western Europe and Australia	33819.4	33513.6	33300.1	33211.6	32893.6	32610.6	32488.2	31426.6	31426.6	31426.6	31426.6	31426.6
Japan	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6
CEIT	5473.1	5473.1	5473.1	5473.1	5473.1	5473.1	5443.1	5443.1	5443.1	5443.1	5443.1	5443.1
Article 5(1)	34355.7	34830.7	35414.5	36064.5	36714.5	37425.5	38075.5	38275.5	38475.5	38675.5	38875.5	38875.5
TOTAL CUMMULATIVE PRODUCTION ALLOCATION	144741.2	145176.8	145749.7	146392.9	146824.5	147330.8	147980.8	148180.8	148380.8	148580.8	148780.8	148780.8
CUMMULATIVE EMISSIONS												
North America	24956.0	25648.0	26320.7	26970.9	27597.4	28201.0	28783.8	29366.5	29948.3	30505.4	31038.8	31549.5
Western Europe and Australia	20894.1	21437.3	21946.3	22592.1	23191.6	23739.6	24245.4	24672.4	25052.8	25412.4	25752.4	26073.6
Japan	11704.3	11740.1	11775.9	11811.6	11847.2	11882.7	11918.2	11953.6	11988.9	12024.2	12059.4	12094.5
CEIT	3165.2	3274.9	3379.4	3479.0	3573.7	3664.0	3749.2	3829.7	3906.4	3979.4	4049.0	4115.2
Article 5(1)	24168.2	25155.9	26102.6	27019.6	27753.6	28479.7	29201.6	29895.3	30550.9	31171.5	31759.5	32307.7
TOTAL CUMMULATIVE EMISSIONS	84887.9	87256.3	89524.9	91873.2	93963.5	95967.0	97898.1	99717.5	101447.3	103092.9	104659.0	106140.5
INVENTORY (BANK)												
North America	16157.4	15731.8	15261.6	14693.1	14166.2	13640.9	13210.5	13689.4	13107.6	12550.5	12017.1	11506.4
Western Europe and Australia	12925.3	12076.3	11353.8	10619.5	9702.0	8871.0	8242.9	6754.2	6373.8	6014.2	5674.2	5353.0
Japan	18275.3	18239.5	18203.7	18168.1	18132.4	18096.9	18061.4	18026.0	17990.7	17955.4	17920.2	17885.1
CEIT	2307.9	2198.2	2093.7	1994.2	1899.4	1809.1	1693.9	1613.4	1536.7	1463.7	1394.2	1327.9
Article 5(1)	10187.4	9674.7	9311.9	9044.9	8960.9	8945.8	8874.0	8380.2	7924.6	7504.1	7116.0	6567.8
GLOBAL INVENTORY (BANK)	59853.3	57920.5	56224.8	54519.7	52860.9	51363.8	50082.6	48463.3	46933.5	45487.9	44121.8	42640.3

Table 8-1: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1301 (Continued)

HALON 1301 SUMMARY (All quantities are provided in metric tonnes) Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
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	0.0	0.0	0.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ANNUAL PRODUCTION	0.0	0.0	0.0	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	0.0	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	0.0	0.0	0.0
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ANNUAL PRODUCTION ALLOCATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANNUAL EMISSIONS												
North America	489.0	468.2	448.3	429.3	411.0	393.6	376.8	360.8	345.5	330.8	316.8	303.3
Western Europe and Australia	303.4	286.6	270.7	255.5	241.2	227.7	214.9	202.8	191.3	180.5	170.3	160.6
Japan	35.1	35.0	34.9	34.8	34.8	34.7	34.6	34.6	34.5	34.4	34.4	34.3
CEIT	63.1	60.1	57.2	54.5	51.9	49.5	47.1	44.9	42.7	40.7	38.8	36.9
Article 5(1)	505.9	466.9	431.0	397.8	367.1	338.8	312.7	288.6	266.4	245.9	226.9	209.5
TOTAL ANNUAL EMISSIONS	1396.5	1316.9	1242.1	1171.9	1106.1	1044.3	986.2	931.7	880.5	832.3	787.1	744.6
CUMMULATIVE PRODUCTION												
North America, Western Europe and Japan	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0
CEIT	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0
Article 5(1)	11642.7	11642.7	11642.7	11642.7	11642.7	11642.7	11642.7	11642.7	11642.7	11642.7	11642.7	11642.7
TOTAL CUMMULATIVE PRODUCTION	149298.7	149298.7	149298.7	149298.7	149298.7	149298.7	149298.7	149298.7	149298.7	149298.7	149298.7	149298.7

Table 8-1: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1301 (Continued)

HALON 1301 SUMMARY (All quantities are provided in metric tonnes) Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
CUMMULATIVE PRODUCTION ALLOCATION												
North America	43055.9	43055.9	43055.9	43055.9	43055.9	43055.9	43055.9	43055.9	43055.9	43055.9	43055.9	43055.9
Western Europe and Australia	31426.6	31426.6	31426.6	31426.6	31426.6	31426.6	31426.6	31426.6	31426.6	31426.6	31426.6	31426.6
Japan	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6
CEIT	5443.1	5443.1	5443.1	5443.1	5443.1	5443.1	5443.1	5443.1	5443.1	5443.1	5443.1	5443.1
Article 5(1)	38875.5	38875.5	38875.5	38875.5	38875.5	38875.5	38875.5	38875.5	38875.5	38875.5	38875.5	38875.5
TOTAL CUMMULATIVE PRODUCTION ALLOCATION	148780.8	148780.8	148780.8	148780.8	148780.8	148780.8	148780.8	148780.8	148780.8	148780.8	148780.8	148780.8
CUMMULATIVE EMISSIONS												
North America	32038.5	32506.8	32955.1	33384.4	33795.4	34189.0	34565.8	34926.7	35272.1	35603.0	35919.7	36223.0
Western Europe and Australia	26377.0	26663.6	26934.3	27189.8	27431.1	27658.8	27873.7	28076.4	28267.8	28448.3	28618.6	28779.2
Japan	12129.6	12164.5	12199.5	12234.3	12269.1	12303.8	12338.4	12373.0	12407.5	12442.0	12476.3	12510.6
CEIT	4178.3	4238.4	4295.6	4350.2	4402.1	4451.5	4498.7	4543.5	4586.3	4627.0	4665.7	4702.7
Article 5(1)	32813.6	33280.6	33711.5	34109.3	34476.4	34815.2	35128.0	35416.6	35683.0	35928.9	36155.8	36365.3
TOTAL CUMMULATIVE EMISSIONS	107537.0	108853.9	110096.0	111268.0	112374.1	113418.3	114404.5	115336.2	116216.7	117049.0	117836.2	118580.8
INVENTORY (BANK)												
North America	11017.4	10549.2	10100.8	9671.5	9260.5	8866.9	8490.1	8129.2	7783.8	7452.9	7136.2	6832.9
Western Europe and Australia	5049.6	4763.0	4492.3	4236.8	3995.5	3767.9	3553.0	3350.2	3158.8	2978.3	2808.0	2647.4
Japan	17850.1	17815.1	17780.2	17745.3	17710.5	17675.8	17641.2	17606.6	17572.1	17537.7	17503.3	17469.0
CEIT	1264.8	1204.7	1147.5	1093.0	1041.0	991.6	944.5	899.6	856.9	816.2	777.4	740.5
Article 5(1)	6061.9	5595.0	5164.0	4766.2	4399.1	4060.3	3747.6	3458.9	3192.5	2946.7	2719.7	2510.3
GLOBAL INVENTORY (BANK)	41243.8	39926.9	38684.8	37512.8	36406.7	35362.5	34376.3	33444.6	32564.1	31731.8	30944.6	30200.0

Table 8-1: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1301 (Continued)

HALON 1301 SUMMARY (All quantities are provided in metric tonnes) Year	2023	2024	2025	2026	2027	2028	2029	2030
ANNUAL PRODUCTION								
North America, Western Europe and Japan	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
Article 5(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ANNUAL PRODUCTION	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
Western Europe and Australia	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
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ANNUAL PRODUCTION ALLOCATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANNUAL EMISSIONS								
North America	290.4	278.1	266.2	254.9	244.1	233.7	223.8	214.3
Western Europe and Australia	151.5	142.9	134.8	127.1	119.9	113.0	106.6	100.5
Japan	34.2	34.2	34.1	34.0	34.0	33.9	33.8	33.8
CEIT	35.2	33.5	31.9	30.4	29.0	27.6	26.3	25.0
Article 5(1)	193.3	178.4	164.7	152.0	140.3	129.5	119.5	110.3
TOTAL ANNUAL EMISSIONS	704.6	667.1	631.7	598.5	567.2	537.7	510.0	483.9
CUMMULATIVE PRODUCTION								
North America, Western Europe and Japan	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0	136271.0
CEIT	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0	1385.0
Article 5(1)	11642.7	11642.7	11642.7	11642.7	11642.7	11642.7	11642.7	11642.7
TOTAL CUMMULATIVE PRODUCTION	149298.7	149298.7	149298.7	149298.7	149298.7	149298.7	149298.7	149298.7
CUMMULATIVE PRODUCTION ALLOCATION								
North America	43055.9	43055.9	43055.9	43055.9	43055.9	43055.9	43055.9	43055.9
Western Europe and Australia	31426.6	31426.6	31426.6	31426.6	31426.6	31426.6	31426.6	31426.6
Japan	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6	29979.6
CEIT	5443.1	5443.1	5443.1	5443.1	5443.1	5443.1	5443.1	5443.1
Article 5(1)	38875.5	38875.5	38875.5	38875.5	38875.5	38875.5	38875.5	38875.5
TOTAL CUMMULATIVE PRODUCTION ALLOCATION	148780.8	148780.8	148780.8	148780.8	148780.8	148780.8	148780.8	148780.8
CUMMULATIVE EMISSIONS								
North America	36513.4	36791.5	37057.7	37312.6	37556.7	37790.4	38014.2	38228.5
Western Europe and Australia	28930.7	29073.6	29208.4	29335.5	29455.3	29568.3	29674.9	29775.4
Japan	12544.9	12579.1	12613.2	12647.2	12681.2	12715.1	12748.9	12782.7
CEIT	4737.8	4771.3	4803.3	4833.7	4862.6	4890.2	4916.4	4941.5
Article 5(1)	36558.6	36737.0	36901.7	37053.7	37194.0	37323.5	37443.0	37553.3
TOTAL CUMMULATIVE EMISSIONS	119285.4	119952.5	120584.2	121182.7	121749.8	122287.5	122797.5	123281.4
INVENTORY (BANK)								
North America	6542.5	6264.4	5998.2	5743.3	5499.2	5265.5	5041.7	4827.4
Western Europe and Australia	2495.9	2353.0	2218.2	2091.1	1971.3	1858.3	1751.7	1651.2
Japan	17434.7	17400.6	17366.5	17332.4	17298.4	17264.5	17230.7	17196.9
CEIT	705.3	671.8	639.9	609.5	580.5	552.9	526.7	501.7
Article 5(1)	2316.9	2138.5	1973.8	1821.8	1681.5	1552.0	1432.5	1322.2
GLOBAL INVENTORY (BANK)	29495.4	28828.3	28196.6	27598.1	27031.0	26493.3	25983.3	25499.4

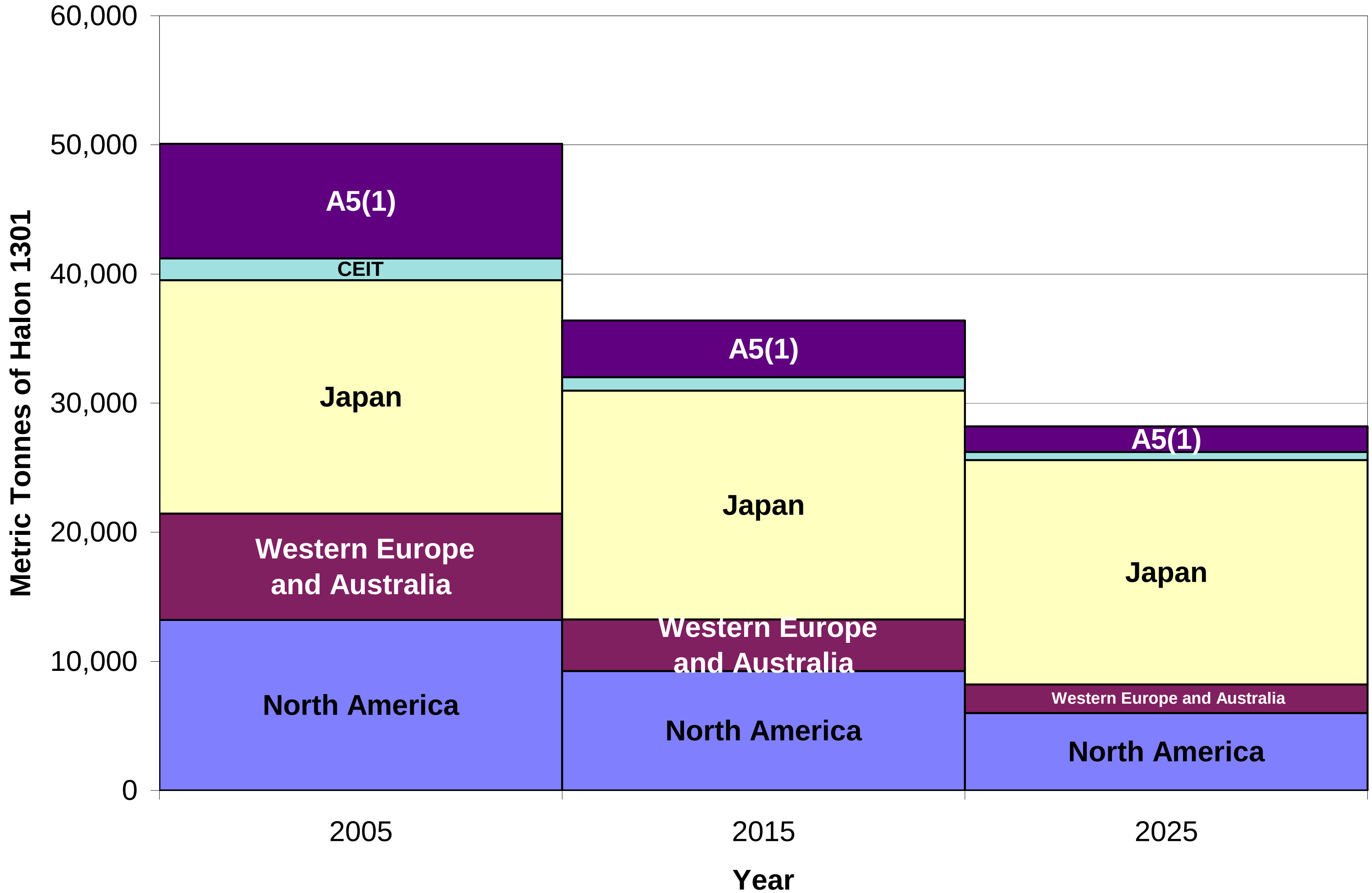

Figure 8-1: Breakout of Global Inventories (Bank) of Halon 1301 by HTOC Model Regions

8.2 Emissions and Inventories of Halon 1211

Table 8-2 provides the HTOC 2010 Assessment of current estimates of inventories for halon 1211. Figure 8-2 provides the regional distribution of the global inventory of halon 1211. As shown in Table 8-2 and Figure 8-2, over 60% of the current inventory of halon 1211 is projected to be in Article 5 countries with the clear majority being in handheld extinguishers and unused stocks in China. As halon 1211 handheld fire extinguishers can no longer be produced or sold in China as of the end of 2005, and it is mandatory to retire in-service halon fire extinguishers after 10 years of service, it is anticipated that unwanted halon 1211 stocks continue to build-up in China. Efforts should be made to recover the halon 1211 from these retired handheld fire extinguishers in order to avoid unnecessary emissions. The HTOC is aware that a number of Parties are seeking recycled halon 1211 for important applications and are having difficulties in finding it.

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211

HALON 1211 SUMMARY
(All quantities are metric tonnes)

Year	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**
ANNUAL PRODUCTION												
North America, Western Europe and Japan Production	50.0	100.0	200.0	300.0	500.0	700.0	900.0	1260.0	1700.0	2200.0	2750.0	3300.0
CEIT Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1) Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL PRODUCTION	50.0	100.0	200.0	300.0	500.0	700.0	900.0	1260.0	1700.0	2200.0	2750.0	3300.0
ANNUAL PRODUCTION ALLOCATION												
North America	10.0	20.0	40.0	60.0	100.0	140.0	180.0	252.0	340.0	440.0	550.0	660.0
Western Europe and Australia	15.0	30.0	60.0	90.0	150.0	210.0	270.0	378.0	510.0	660.0	825.0	990.0
Japan	2.5	5.0	10.0	15.0	25.0	35.0	45.0	63.0	85.0	110.0	137.5	165.0
CEIT	2.5	5.0	10.0	15.0	25.0	35.0	45.0	63.0	85.0	110.0	137.5	165.0
Article 5(1)	20.0	40.0	80.0	120.0	200.0	280.0	360.0	504.0	680.0	880.0	1100.0	1320.0
TOTAL ANNUAL PRODUCTION ALLOCATION	50.0	100.0	200.0	300.0	500.0	700.0	900.0	1260.0	1700.0	2200.0	2750.0	3300.0
ANNUAL EMISSIONS												
North America	0.8	2.4	5.5	9.9	17.3	27.3	39.8	57.1	80.2	109.6	145.5	187.6
Western Europe and Australia	1.2	3.5	8.0	14.5	25.3	40.0	58.4	83.8	117.8	161.0	213.9	275.8
Japan	0.1	0.5	1.1	2.1	3.8	6.1	9.1	13.2	18.6	25.7	34.4	44.8
CEIT	0.2	0.6	1.4	2.5	4.3	6.8	9.9	14.3	20.0	27.4	36.4	46.9
Article 5(1)	1.7	5.2	12.2	22.5	39.2	62.4	91.5	131.1	184.2	251.9	334.9	431.9
TOTAL ANNUAL EMISSIONS	4.0	12.2	28.1	51.5	89.9	142.7	208.7	299.5	420.9	575.6	765.2	987.0
CUMMULATIVE PRODUCTION												
North America, Western Europe and Japan	50.0	150.0	350.0	650.0	1150.0	1850.0	2750.0	4010.0	5710.0	7910.0	10660.0	13960.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL CUMMULATIVE PRODUCTION	50.0	150.0	350.0	650.0	1150.0	1850.0	2750.0	4010.0	5710.0	7910.0	10660.0	13960.0

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211 (Continued)

HALON 1211 SUMMARY
(All quantities are metric tonnes)

Year	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**
CUMMULATIVE PRODUCTION ALLOCATIONS												
North America	10.0	30.0	70.0	130.0	230.0	370.0	550.0	802.0	1142.0	1582.0	2132.0	2792.0
Western Europe and Australia	15.0	45.0	105.0	195.0	345.0	555.0	825.0	1203.0	1713.0	2373.0	3198.0	4188.0
Japan	2.5	7.5	17.5	32.5	57.5	92.5	137.5	200.5	285.5	395.5	533.0	698.0
CEIT	2.5	7.5	17.5	32.5	57.5	92.5	137.5	200.5	285.5	395.5	533.0	698.0
Article 5(1)	20.0	60.0	140.0	260.0	460.0	740.0	1100.0	1604.0	2284.0	3164.0	4264.0	5584.0
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	50.0	150.0	350.0	650.0	1150.0	1850.0	2750.0	4010.0	5710.0	7910.0	10660.0	13960.0
CUMMULATIVE EMISSIONS												
North America	0.8	3.2	8.7	18.6	35.8	63.1	102.9	160.0	240.2	349.8	495.3	682.9
Western Europe and Australia	1.2	4.7	12.7	27.2	52.5	92.6	150.9	234.8	352.6	513.6	727.5	1003.2
Japan	0.1	0.6	1.7	3.8	7.6	13.7	22.8	36.0	54.6	80.3	114.7	159.6
CEIT	0.2	0.8	2.2	4.6	9.0	15.8	25.7	40.0	60.0	87.4	123.8	170.7
Article 5(1)	1.7	6.9	19.1	41.5	80.7	143.1	234.6	365.7	549.9	801.8	1136.7	1568.6
TOTAL CUMMULATIVE EMISSIONS	4.0	16.2	44.2	95.8	185.6	328.3	537.0	836.5	1257.3	1832.9	2598.0	3585.0
INVENTORY												
North America	9.2	26.8	61.3	111.4	194.2	306.9	447.1	642.0	901.8	1232.2	1636.7	2109.1
Western Europe and Australia	13.8	40.3	92.3	167.8	292.5	462.4	674.1	968.2	1360.4	1859.4	2470.5	3184.8
Japan	2.4	6.9	15.8	28.7	49.9	78.8	114.7	164.5	230.9	315.2	418.3	538.4
CEIT	2.3	6.7	15.3	27.9	48.5	76.7	111.8	160.5	225.5	308.1	409.2	527.3
Article 5(1)	18.3	53.1	120.9	218.5	379.3	596.9	865.4	1238.3	1734.1	2362.2	3127.3	4015.4
TOTAL INVENTORY	46.0	133.8	305.8	554.2	964.4	1521.7	2213.0	3173.5	4452.7	6077.1	8062.0	10375.0

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211 (Continued)

HALON 1211 SUMMARY (All quantities are metric tonnes) Year	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**
ANNUAL PRODUCTION												
North America, Western Europe and Japan Production	3800.0	4356.0	5000.0	5650.0	6280.0	6910.0	6689.0	7485.0	8259.0	10408.0	12491.0	13731.0
CEIT Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	30.0	30.0
Article 5(1) Production	0.0	0.0	0.0	210.1	265.7	336.2	425.2	537.9	680.4	1060.7	1341.8	1658.3
TOTAL PRODUCTION	3800.0	4356.0	5000.0	5860.1	6545.7	7246.2	7114.2	8022.9	8939.4	11498.7	13862.8	15419.3
ANNUAL PRODUCTION ALLOCATION												
North America	760.0	871.2	1000.0	1130.0	1256.0	1382.0	1337.8	1497.0	1651.8	2081.6	2498.2	2746.2
Western Europe and Australia	1140.0	1306.8	1500.0	1695.0	1884.0	2073.0	2006.7	2245.5	2477.7	3122.4	3747.3	4119.3
Japan	190.0	217.8	250.0	282.5	314.0	345.5	334.5	374.3	413.0	520.4	624.6	686.6
CEIT	190.0	217.8	250.0	282.5	314.0	345.5	334.5	374.3	413.0	550.4	654.6	716.6
Article 5(1)	1520.0	1742.4	2000.0	2470.1	2777.7	3100.2	3100.8	3531.9	3984.0	5223.9	6338.2	7150.7
TOTAL ANNUAL PRODUCTION ALLOCATION	3800.0	4356.0	5000.0	5860.1	6545.7	7246.2	7114.2	8022.9	8939.4	11498.7	13862.8	15419.3
ANNUAL EMISSIONS												
North America	234.3	286.3	344.6	408.7	477.9	551.8	616.0	687.9	766.6	874.0	1006.7	1148.7
Western Europe and Australia	344.6	421.3	507.3	601.9	704.1	833.4	929.2	1036.7	1154.4	1315.1	1513.7	1726.5
Japan	56.6	69.7	84.2	100.4	117.9	136.6	154.4	172.1	191.7	216.5	248.2	284.3
CEIT	58.6	71.6	86.2	102.2	119.5	137.9	154.0	172.0	191.7	221.0	249.8	287.3
Article 5(1)	540.0	659.3	792.2	955.7	1137.2	1332.8	1514.6	1713.7	1938.5	2252.5	2651.2	3098.2
TOTAL ANNUAL EMISSIONS	1234.1	1508.2	1814.5	2168.9	2556.5	2992.5	3368.1	3782.4	4242.9	4879.0	5669.6	6545.1
CUMMULATIVE PRODUCTION												
North America, Western Europe and Japan	17760.0	22116.0	27116.0	32766.0	39046.0	45956.0	52645.0	60130.0	68389.0	78797.0	91288.0	105019.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	60.0	90.0
Article 5(1)	0.0	0.0	0.0	210.1	475.8	812.0	1237.2	1775.1	2455.5	3516.3	4858.1	6516.4
TOTAL CUMMULATIVE PRODUCTION	17760.0	22116.0	27116.0	32976.1	39521.8	46768.0	53882.2	61905.1	70844.5	82343.3	96206.1	111625.4

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211 (Continued)

HALON 1211 SUMMARY (All quantities are metric tonnes) Year	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
CUMMULATIVE PRODUCTION ALLOCATIONS												
North America	3552.0	4423.2	5423.2	6553.2	7809.2	9191.2	10529.0	12026.0	13677.8	15759.4	18257.6	21003.8
Western Europe and Australia	5328.0	6634.8	8134.8	9829.8	11713.8	13786.8	15793.5	18039.0	20516.7	23639.1	27386.4	31505.7
Japan	888.0	1105.8	1355.8	1638.3	1952.3	2297.8	2632.3	3006.5	3419.5	3939.9	4564.4	5251.0
CEIT	888.0	1105.8	1355.8	1638.3	1952.3	2297.8	2632.3	3006.5	3419.5	3969.9	4624.4	5341.0
Article 5(1)	7104.0	8846.4	10846.4	13316.5	16094.2	19194.4	22295.2	25827.1	29811.1	35035.1	41373.3	48524.0
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	17760.0	22116.0	27116.0	32976.1	39521.8	46768.0	53882.2	61905.1	70844.5	82343.3	96206.1	111625.4
CUMMULATIVE EMISSIONS												
North America	917.2	1203.5	1548.1	1956.9	2434.8	2986.6	3602.5	4290.5	5057.1	5931.1	6937.8	8086.5
Western Europe and Australia	1347.9	1769.2	2276.4	2878.3	3582.4	4415.8	5345.0	6381.6	7536.0	8851.1	10364.8	12091.3
Japan	216.1	285.8	370.0	470.4	588.3	724.9	879.3	1051.4	1243.2	1459.6	1707.9	1992.1
CEIT	229.3	300.9	387.0	489.2	608.7	746.6	900.6	1072.6	1264.3	1485.2	1735.1	2022.4
Article 5(1)	2108.6	2767.9	3560.2	4515.9	5653.1	6985.8	8500.4	10214.1	12152.6	14405.1	17056.2	20154.5
TOTAL CUMMULATIVE EMISSIONS	4819.1	6327.3	8141.8	10310.7	12867.3	15859.8	19227.8	23010.2	27253.1	32132.1	37801.7	44346.8
INVENTORY												
North America	2634.8	3219.7	3875.1	4596.3	5374.4	6204.6	6926.5	7735.5	8620.7	9828.3	11319.8	12917.3
Western Europe and Australia	3980.1	4865.6	5858.4	6951.5	8131.4	9371.0	10448.5	11657.4	12980.7	14788.0	17021.6	19414.4
Japan	671.9	820.0	985.8	1167.9	1364.0	1572.9	1753.0	1955.1	2176.3	2480.2	2856.5	3258.8
CEIT	658.7	804.9	968.8	1149.1	1343.6	1551.2	1731.6	1933.9	2155.2	2484.6	2889.3	3318.6
Article 5(1)	4995.4	6078.5	7286.2	8800.6	10441.2	12208.5	13794.8	15613.0	17658.6	20630.0	24317.1	28369.6
TOTAL INVENTORY	12940.9	15788.7	18974.2	22665.3	26654.5	30908.2	34654.4	38894.9	43591.4	50211.2	58404.4	67278.6

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211 (Continued)

HALON 1211 SUMMARY (All quantities are metric tonnes) Year	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
ANNUAL PRODUCTION												
North America, Western Europe and Japan Production	17058.0	20181.0	16182.0	14852.0	11882.0	7921.0	3960.0	0.0	0.0	0.0	0.0	0.0
CEIT Production	35.0	35.0	80.0	700.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1) Production	2049.3	2545.0	3074.0	3716.5	4646.0	7002.0	8713.0	10447.5	11250.0	14180.0	12124.0	8175.0
Total Production	19142.3	22761.0	19336.0	19268.5	16578.0	14973.0	12673.0	10447.5	11250.0	14180.0	12124.0	8175.0
ANNUAL PRODUCTION ALLOCATION												
North America	3411.6	4036.2	3236.4	2970.4	2376.4	1584.2	792.0	0.0	0.0	0.0	0.0	0.0
Western Europe and Australia	5117.4	6054.3	4854.6	4455.6	3564.6	2376.3	1188.0	0.0	0.0	-1.0	0.0	-6.5
Japan	852.9	1009.1	809.1	742.6	594.1	396.1	198.0	0.0	0.0	0.0	0.0	0.0
CEIT	887.9	1044.1	889.1	1442.6	644.1	446.1	198.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	8872.5	10617.4	9546.8	9657.3	9398.8	10170.4	10297.0	10447.5	11250.0	14180.0	12124.0	8175.0
TOTAL ANNUAL PRODUCTION ALLOCATION	19142.3	22761.0	19336.0	19268.5	16578.0	14973.0	12673.0	10447.5	11250.0	14179.0	12124.0	8168.5
ANNUAL EMISSIONS												
North America	1333.5	1554.2	1691.6	1796.1	1396.0	1384.3	1042.5	1001.7	954.2	909.0	865.9	824.8
Western Europe and Australia	2003.4	2334.3	2540.1	2696.5	2723.0	2675.2	1519.5	1447.8	1379.1	1313.7	1251.4	1192.0
Japan	327.8	381.5	470.1	483.4	485.7	474.5	262.1	248.3	235.9	224.1	212.9	202.3
CEIT	334.7	391.0	453.8	522.9	524.7	514.3	291.2	277.3	265.7	254.7	244.0	233.9
Article 5(1)	3658.9	4340.9	4830.4	5256.5	5624.8	5990.2	6364.7	5144.4	5224.3	8525.8	9096.6	9315.0
TOTAL ANNUAL EMISSIONS	7658.3	9001.9	9986.0	10755.3	10754.2	11038.5	9479.9	8119.4	8059.3	11227.3	11670.9	11768.0
CUMMULATIVE PRODUCTION												
North America, Western Europe and Japan	122077.0	142258.0	158440.0	173292.0	185174.0	193095.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0
CEIT	125.0	160.0	240.0	940.0	990.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0
Article 5(1)	8565.7	11110.7	14184.7	17901.2	22547.2	29549.2	38262.2	48709.7	59959.7	74139.7	86263.7	94438.7
TOTAL CUMMULATIVE PRODUCTION	130767.7	153528.7	172864.7	192133.2	208711.2	223684.2	236357.2	246804.7	258054.7	272234.7	284358.7	292533.7

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211 (Continued)

CUMMULATIVE PRODUCTION ALLOCATIONS												
North America	24415.4	28451.6	31688.0	34658.4	37034.8	38619.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0
Western Europe and Australia	36623.1	42677.4	47532.0	51987.6	55552.2	57928.5	59116.5	59116.5	59116.5	59115.5	59115.5	59109.0
Japan	6103.9	7112.9	7922.0	8664.6	9258.7	9654.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8
CEIT	6228.9	7272.9	8162.0	9604.6	10248.7	10694.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8
Article 5(1)	57396.5	68013.9	77560.7	87218.0	96616.8	106787.2	117084.2	127531.7	138781.7	152961.7	165085.7	173260.7
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	130767.7	153528.7	172864.7	192133.2	208711.2	223684.2	236357.2	246804.7	258054.7	272233.7	284357.7	292526.2
CUMMULATIVE EMISSIONS												
North America	9420.0	10974.3	12665.9	14461.9	15857.9	17242.3	18284.7	19286.5	20240.7	21149.7	22015.6	22840.4
Western Europe and Australia	14094.7	16429.0	18969.1	21665.6	24388.6	27063.8	28583.2	30031.0	31410.2	32723.9	33975.3	35167.3
Japan	2319.9	2701.4	3171.5	3654.9	4140.6	4615.1	4877.1	5125.4	5361.3	5585.4	5798.4	6000.7
CEIT	2357.0	2748.1	3201.9	3724.8	4249.5	4763.8	5055.0	5332.3	5598.0	5852.7	6096.7	6330.6
Article 5(1)	23813.4	28154.2	32984.7	38241.1	43865.9	49856.2	56220.9	61365.2	66589.6	75115.4	84211.9	93526.9
TOTAL CUMMULATIVE EMISSIONS	52005.1	61007.0	70993.0	81748.3	92502.6	103541.1	113021.0	121140.4	129199.7	140427.0	152097.9	163865.8
INVENTORY												
North America	14995.4	17477.3	19022.1	20196.5	21176.9	21376.7	21126.3	20124.5	19170.3	18261.3	17395.4	16570.6
Western Europe and Australia	22528.4	26248.4	28562.9	30322.0	31163.6	30864.7	30533.3	29085.5	27706.3	26391.6	25140.2	23941.7
Japan	3783.9	4411.5	4750.5	5009.7	5118.1	5039.7	4975.6	4727.4	4491.5	4267.3	4054.4	3852.1
CEIT	3871.8	4524.8	4960.1	5879.8	5999.2	5930.9	5837.7	5560.5	5294.7	5040.1	4796.0	4562.2
Article 5(1)	33583.2	39859.7	44576.1	48976.9	52750.9	56931.1	60863.3	66166.5	72192.2	77846.4	80873.8	79733.8
TOTAL INVENTORY	78762.7	92521.7	101871.7	110384.9	116208.7	120143.1	123336.2	125664.3	128855.0	131806.7	132259.8	128660.4

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211 (Continued)

HALON 1211 SUMMARY (All quantities are metric tonnes) Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
ANNUAL PRODUCTION												
North America, Western Europe and Japan Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CEIT Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1) Production	6265.0	4278.0	3599.0	2954.0	2384.0	1568.0	165.0	165.0	0.0	0.0	0.0	0.0
TOTAL PRODUCTION	6265.0	4278.0	3599.0	2954.0	2384.0	1568.0	165.0	165.0	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	0.0	0.0	0.0
Western Europe and Australia	0.0	-3.9	-1.1	-1.3	-259.8	-180.9	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	0.0	0.0	0.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	6265.0	4278.0	3599.0	2954.0	2384.0	1568.0	165.0	165.0	0.0	0.0	0.0	0.0
TOTAL ANNUAL PRODUCTION ALLOCATION	6265.0	4274.1	3597.9	2952.7	2124.2	1387.2	165.0	165.0	0.0	0.0	0.0	0.0
ANNUAL EMISSIONS												
North America	785.7	748.5	713.0	679.2	647.0	616.3	587.1	559.2	532.7	507.5	483.4	460.5
Western Europe and Australia	1135.2	1081.4	1029.9	981.0	930.9	875.5	827.9	788.7	751.3	715.7	681.7	649.4
Japan	192.2	182.6	173.5	164.9	156.6	148.8	141.4	134.3	127.6	121.3	115.2	109.5
CEIT	224.1	214.8	205.8	197.3	189.0	181.2	173.6	166.4	159.5	152.8	146.4	140.3
Article 5(1)	9128.7	8689.0	8181.3	5053.3	4887.1	4686.0	4427.4	4114.0	3820.1	3539.2	3278.9	3037.8
TOTAL ANNUAL EMISSIONS	11466.0	10916.2	10303.6	7075.6	6810.6	6507.8	6157.5	5762.6	5391.2	5036.4	4705.7	4397.4
CUMMULATIVE PRODUCTION												
North America, Western Europe and Japan	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0
CEIT	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0
Article 5(1)	100703.7	104981.7	108580.7	111534.7	113918.7	115486.7	115651.7	115816.7	115816.7	115816.7	115816.7	115816.7
TOTAL CUMMULATIVE PRODUCTION	298798.7	303076.7	306675.7	309629.7	312013.7	313581.7	313746.7	313911.7	313911.7	313911.7	313911.7	313911.7

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211 (Continued)

HALON 1211 SUMMARY (All quantities are metric tonnes) Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CUMMULATIVE PRODUCTION ALLOCATIONS												
North America	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0
Western Europe and Australia	59109.0	59105.1	59104.0	59102.7	58842.9	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0
Japan	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8
CEIT	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8
Article 5(1)	179525.7	183803.7	187402.7	190356.7	192740.7	194308.7	194473.7	194638.7	194638.7	194638.7	194638.7	194638.7
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	298791.2	303065.3	306663.2	309615.9	311740.1	313127.2	313292.2	313457.2	313457.2	313457.2	313457.2	313457.2
CUMMULATIVE EMISSIONS												
North America	23626.1	24374.6	25087.6	25766.8	26413.7	27030.0	27617.1	28176.3	28709.0	29216.5	29699.9	30160.3
Western Europe and Australia	36302.5	37383.9	38413.8	39394.8	40325.7	41201.2	42029.2	42817.8	43569.1	44284.8	44966.5	45615.9
Japan	6192.9	6375.5	6549.0	6713.9	6870.5	7019.3	7160.7	7295.0	7422.7	7543.9	7659.1	7768.6
CEIT	6554.7	6769.5	6975.3	7172.6	7361.7	7542.8	7716.4	7882.8	8042.3	8195.1	8341.5	8481.9
Article 5(1)	102655.6	111344.6	119525.9	124579.2	129466.3	134152.3	138579.7	142693.7	146513.8	150053.0	153331.9	156369.7
TOTAL CUMMULATIVE EMISSIONS	175331.8	186248.1	196551.7	203627.3	210437.9	216945.6	223103.1	228865.7	234256.9	239293.3	243998.9	248396.4
INVENTORY												
North America	15784.9	15036.4	14323.4	13644.2	12997.3	12381.0	11793.9	11234.7	10702.0	10194.5	9711.1	9250.7
Western Europe and Australia	22806.5	21721.2	20690.2	19707.9	18517.2	17460.8	16632.9	15844.2	15092.9	14377.3	13695.5	13046.1
Japan	3659.9	3477.2	3303.7	3138.9	2982.2	2833.4	2692.0	2557.7	2430.1	2308.8	2193.6	2084.1
CEIT	4338.0	4123.2	3917.4	3720.1	3531.1	3349.9	3176.3	3009.9	2850.5	2697.7	2551.2	2410.9
Article 5(1)	76870.1	72459.2	67876.8	65777.5	63274.4	60156.5	55894.0	51945.0	48124.9	44585.7	41306.8	38269.1
TOTAL INVENTORY	123459.4	116817.3	110111.6	105988.6	101302.2	96181.6	90189.2	84591.6	79200.4	74164.0	69458.3	65060.9

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211 (Continued)

HALON 1211 SUMMARY (All quantities are metric tonnes) Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ANNUAL PRODUCTION												
North America, Western Europe and Japan Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CEIT Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1) Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL PRODUCTION	0.0	0.0	0.0	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	0.0	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	0.0	0.0	0.0
Japan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ANNUAL PRODUCTION ALLOCATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANNUAL EMISSIONS												
North America	438.6	417.8	398.0	379.2	361.2	344.0	327.7	312.2	297.4	283.3	269.9	257.1
Western Europe and Australia	618.6	589.3	561.3	534.7	509.4	485.2	462.2	440.3	419.4	399.5	380.6	362.5
Japan	104.0	98.8	93.9	89.2	84.7	80.5	76.5	72.7	69.1	65.6	62.3	59.2
CEIT	134.5	128.9	123.5	118.4	113.4	108.7	104.2	99.8	95.7	91.7	87.9	84.2
Article 5(1)	2814.4	2607.4	2415.6	2238.0	2073.4	1920.9	1779.7	1648.8	1527.5	1415.2	1311.1	1214.7
TOTAL ANNUAL EMISSIONS	4110.1	3842.2	3592.4	3359.4	3142.1	2939.4	2750.3	2573.8	2409.1	2255.3	2111.8	1977.7
CUMMULATIVE PRODUCTION												
N America, Western Europe, Japan	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0
CEIT	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0
Article 5(1)	115816.7	115816.7	115816.7	115816.7	115816.7	115816.7	115816.7	115816.7	115816.7	115816.7	115816.7	115816.7
TOTAL CUMMULATIVE PRODUCTION	313911.7	313911.7	313911.7	313911.7	313911.7	313911.7	313911.7	313911.7	313911.7	313911.7	313911.7	313911.7

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211 (Continued)

HALON 1211 SUMMARY (All quantities are metric tonnes) Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
CUMMULATIVE PRODUCTION ALLOCATIONS												
North America	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0
Western Europe and Australia	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0
Japan	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8
CEIT	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8
Article 5(1)	194638.7	194638.7	194638.7	194638.7	194638.7	194638.7	194638.7	194638.7	194638.7	194638.7	194638.7	194638.7
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	313457.2	313457.2	313457.2	313457.2	313457.2	313457.2	313457.2	313457.2	313457.2	313457.2	313457.2	313457.2
CUMMULATIVE EMISSIONS												
North America	30599.0	31016.8	31414.8	31794.0	32155.1	32499.2	32826.9	33139.1	33436.5	33719.8	33989.7	34246.7
Western Europe and Australia	46234.5	46823.8	47385.1	47919.8	48429.2	48914.4	49376.6	49816.9	50236.3	50635.8	51016.4	51378.9
Japan	7872.6	7971.4	8065.3	8154.5	8239.2	8319.7	8396.2	8468.9	8538.0	8603.6	8665.9	8725.1
CEIT	8616.4	8745.3	8868.8	8987.1	9100.6	9209.3	9313.5	9413.3	9509.0	9600.7	9688.6	9772.8
Article 5(1)	159184.0	161791.4	164207.1	166445.1	168518.5	170439.4	172219.1	173867.9	175395.4	176810.6	178121.7	179336.4
TOTAL CUMMULATIVE EMISSIONS	252506.5	256348.7	259941.1	263300.5	266442.6	269382.0	272132.3	274706.1	277115.1	279370.4	281482.2	283459.9
INVENTORY												
North America	8812.0	8394.2	7996.2	7617.0	7255.9	6911.8	6584.1	6271.9	5974.5	5691.2	5421.3	5164.3
Western Europe and Australia	12427.5	11838.3	11276.9	10742.2	10232.9	9747.6	9285.4	8845.2	8425.8	8026.2	7645.7	7283.1
Japan	1980.1	1881.3	1787.5	1698.3	1613.5	1533.0	1456.5	1383.8	1314.8	1249.2	1186.8	1127.6
CEIT	2276.4	2147.5	2024.0	1905.6	1792.2	1683.5	1579.3	1479.4	1383.7	1292.1	1204.2	1120.0
Article 5(1)	35454.7	32847.3	30431.6	28193.6	26120.2	24199.3	22419.7	20770.9	19243.4	17828.2	16517.1	15302.4
TOTAL INVENTORY	60950.8	57108.6	53516.2	50156.8	47014.6	44075.2	41324.9	38751.2	36342.1	34086.8	31975.0	29997.3

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211 (Continued)

HALON 1211 SUMMARY (All quantities are metric tonnes) Year	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
ANNUAL PRODUCTION								
North America, Western Europe and Japan Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CEIT Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1) Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL PRODUCTION	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
Western Europe and Australia	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
CEIT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Article 5(1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ANNUAL PRODUCTION ALLOCATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ANNUAL EMISSIONS								
North America	244.9	233.3	222.2	211.7	201.6	192.1	183.0	174.3
Western Europe and Australia	345.3	329.0	313.4	298.5	284.4	270.9	258.0	245.8
Japan	56.3	53.5	50.8	48.3	45.8	43.6	41.4	39.3
CEIT	80.7	77.3	74.1	71.0	68.1	65.2	62.5	59.9
Article 5(1)	1125.4	1042.6	965.9	894.9	829.1	768.1	711.6	659.3
TOTAL ANNUAL EMISSIONS	1852.5	1735.6	1626.4	1524.4	1429.0	1339.8	1256.5	1178.6
CUMMULATIVE PRODUCTION								
North America, Western Europe and Japan	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0	197055.0
CEIT	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0	1040.0
Article 5(1)	115816.7	115816.7	115816.7	115816.7	115816.7	115816.7	115816.7	115816.7
TOTAL CUMMULATIVE PRODUCTION	313911.7	313911.7	313911.7	313911.7	313911.7	313911.7	313911.7	313911.7

Table 8-2: HTOC 2006 Assessment of Current Estimates of Inventories for Halon 1211 (Continued)

HALON 1211 SUMMARY (All quantities are metric tonnes) Year	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
CUMMULATIVE PRODUCTION ALLOCATIONS								
North America	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0	39411.0
Western Europe and Australia	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0	58662.0
Japan	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8	9852.8
CEIT	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8	10892.8
Article 5(1)	194638.7	194638.7	194638.7	194638.7	194638.7	194638.7	194638.7	194638.7
TOTAL CUMMULATIVE PRODUCTION ALLOCATIONS	313457.2	313457.2	313457.2	313457.2	313457.2	313457.2	313457.2	313457.2
CUMMULATIVE EMISSIONS								
North America	34491.6	34724.9	34947.1	35158.7	35360.4	35552.4	35735.4	35909.7
Western Europe and Australia	51724.2	52053.2	52366.6	52665.1	52949.4	53220.3	53478.3	53724.1
Japan	8781.4	8834.9	8885.7	8933.9	8979.8	9023.3	9064.7	9104.0
CEIT	9853.5	9930.8	10005.0	10076.0	10144.1	10209.3	10271.8	10331.7
Article 5(1)	180461.7	181504.3	182470.3	183365.1	184194.2	184962.3	185673.9	186333.2
TOTAL CUMMULATIVE EMISSIONS	285312.5	287048.1	288674.5	290198.9	291627.8	292967.7	294224.2	295402.8
INVENTORY								
North America	4919.4	4686.1	4463.9	4252.3	4050.6	3858.6	3675.6	3501.3
Western Europe and Australia	6937.8	6608.8	6295.4	5996.9	5712.6	5441.7	5183.7	4937.9
Japan	1071.3	1017.9	967.1	918.8	873.0	829.4	788.0	748.7
CEIT	1039.3	961.9	887.8	816.8	748.7	683.5	620.9	561.0
Article 5(1)	14177.0	13134.4	12168.5	11273.6	10444.5	9676.4	8964.8	8305.5
TOTAL INVENTORY	28144.8	26409.2	24782.7	23258.4	21829.4	20489.6	19233.1	18054.5

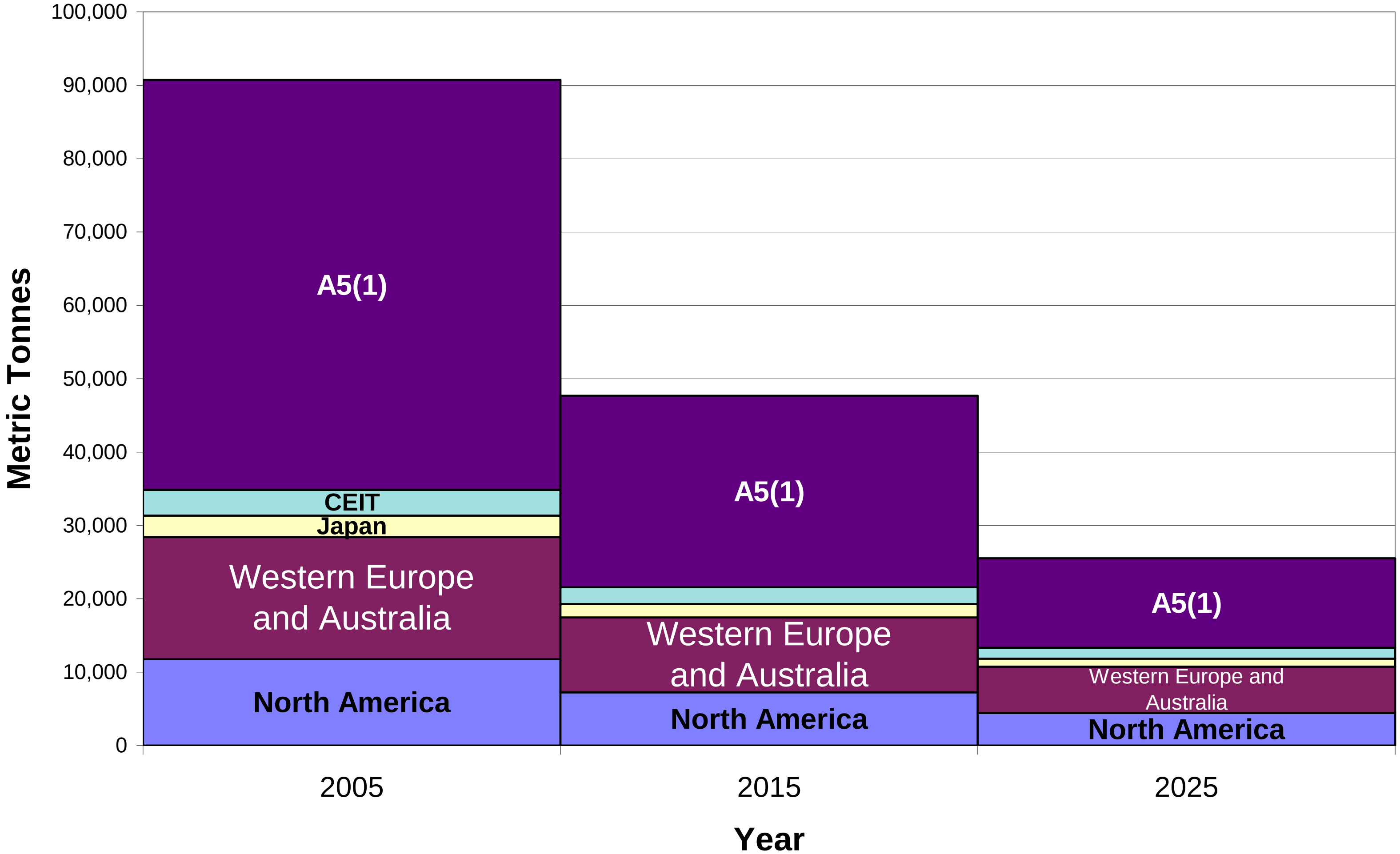

Figure 8-2: Breakout of Global Inventories (Bank) of Halon 1211 by HTOC Model Regions

8.3 Halon 2402

8.3.1 Estimated Local, Regional and Global Inventories of Halon 2402

Russian Federation: The largest user of halon 2402 remains the Russian Federation. According to the most recent data, the total amount of halon 2402 installed was estimated at 941 MT in 2009. The main users are the military sector, Gazprom, civil aviation and merchant shipping. The market can be estimated as currently well balanced with no surplus available for outside markets. No more than 20 MT of the halon 2402 were available as a free agent for purchase in 2009 (5 times reduction in comparison with 2006), and 12 MT from this amount was purchased from the US. Table 8-3 provides an estimate of the Russian installed base, recycling, and emissions from 2007–2015.

Table 8-3: Current Situation and Forecast for Russian Bank of Halon 2402

	2007*	**2009****	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Necessity in recycling, MT	80.0	120.0	160.0	50.0	50.0	30.0	30.0	30.0
Annual offer of free agent, MT	10.0	20.0	20.0	50.0	50.0	30.0	30.0	30.0
Possible losses, MT	8.0	10.0	16.0	5.0	5.0	3.0	3.0	3.0
Total bank, MT	947.0	941.0	899.0	894.0	889.0	886.0	883.0	880.0

* Data obtained by May 2008
** Data obtained by July 2010

As it follows from the Table 8-3, by 2010 about 160 MT of halon 2402 will need to be recycled annually. In fact, recovery and recycling of halon 2402, as well as halon 1211 and 1301, is of particular importance in the Russian Federation. It is also expected that in this period no more than 20 MT of the halon 2402 will appear in the market as agent ready for purchase. In conjunction with this, the spread between the annual offer of free agent and possible losses of halon 2402 will not exceed 4 MT in the period 2008–2010.

Ukraine: The most recent data on banks of halon 2402 contained in existing installed fire fighting systems in the Ukraine are shown in Table 8-4. During the preparation of a draft concept of the National Halon Management Strategy for the Ukraine for the period 2004-2030 (final version of the document was adopted by the Decision of the Ukrainian Government No. 256, 4th March 2004) it was concluded that the installed base of halon 2402 in the Ukraine ranges from 552 to 602 MT. According to some Ukrainian experts, the current Ukrainian bank of halon 2402 can be estimated at 300–340 MT (1.5–2 times reduction in comparison with 2003). As shown in Table 8-4, the main users are the military sector, oil – gas industry, transport system and telecommunication facilities.

Table 8-4: Installed Halon-2402 in the Major Sectors in Ukraine

Sector	Halon-2402, MT
Oil and gas industry	40.0
Metallurgy, engineering	30.6
Transport, communication	11.5
Public health, culture and education institutions	6.2
Commercial banks	27.2
Military	12.3
TOTAL	**128.1**

Fire suppression equipment contains approximately 128 MT. Based on this, the total bank of halon 2402 in the Ukraine is less than is required to support important uses – Ukrainian national regulations require a 100% reserve of halon to support existing fire suppression units. The market price for halon 2402 in the Ukraine is not known, but Ukrainian experts do not believe the situation is a problem for the country because it plans to accelerate the adoption of halon alternatives.

Armenia: The last survey of installed capacity of halon 2402 was carried out in 2005. Since then, the data have not been updated. The bulk of quantities of installed halon have not been identified and updated to provide a clear picture of the installed capacity and demand for halon 2402 in the country.

(*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 1–14).

Azerbaijan: Recent estimates indicate that 53 MT of halon 2402 is in Azerbaijan. The Centre on Climate Change and Ozone (CCCO) received information from the Caspian Sea Navigation indicating that the total quantity of fire fighting agent was 40.316 MT installed in fire suppression systems on 40 ships, including 1.0885 MT of Halon 2402. The communication from the Force Major Ministry, which is responsible for the Fire Fighting Service, reported that no halon was used in fire fighting systems in Azerbaijan. The evaluation team was unable to verify the present situation with regard to halon use in ships.

(*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 15–24).

Kazakhstan: Halon users were surveyed from 2002 until 2006, and a database of the halon type, quantity and location established. The database was not updated after 2006 because there was no financial support for this activity. It is estimated that 85 MT of halon 2402 has been stocked over the 4-year period.

Kyrgyzstan: In 2006, the installed base was estimated at 80.7 MT of halon 2402.

Poland: At the end of 2008, the installed quantity of halon 2402 in Poland was 6.549 MT, primarily used by the military sector for their applications and by some users in industry. At the end of 2009, halon 2402 installed in applications has risen to about 10 MT, while the stockpiled quantity for uses deemed critical by Poland, export, or destruction has more than doubled, being changed from 1 MT at the end of December 2008 to 2.8 MT at the end of December 2009. Poland believes that it has enough halon 2402 to support its projected needs.

(*Source*: Dr Janusz Kozakiewicz, Head of Ozone Layer and Climate Protection Unit - Industrial Chemistry Research Institute - 8, Rydygiera Street, 01-793 Warsaw, Poland).

Hungary: The amount of halons reclaimed from 1994 to 2008 was 66 MT, which was much less than 2,900 MT estimated to have been installed as of 1994. Fajro currently has strategic reserves of about 7 MT.

(*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 77–92).

In 2006, the representative of the Hungarian Ministry of Environment and Water reported that the inventory of halon 2402 in Hungary was less than 10 MT.

(*Source*: Róbert Tóth, "Halon-bank in Hungary", 5th Meeting of the Regional Ozone Network in Europe & Central Asia, 11-13 April 2006, Tbilisi, Georgia).

Czech Republic: For the 2006 reference period, the Czech Republic reported to EC Environment Directorate that the installed quantity of halon 2402 for applications considered critical by the EC was 5.09 MT.

Estonia, Latvia and Lithuania: Consumption of Halons in each of these three countries was difficult to quantify to any acceptable degree of accuracy. However, Table 8-5 shows the estimated status as of May 1999.

Table 8-5: Halon 2402 Data for Estonia, Latvia, and Lithuania (1999)

Country	Installed capacity, MT	Yearly Consumption, MT
Estonia	12.0	1.0
Latvia	15.0	1.5
Lithuania	8.0	0.5

There was no halon recovered in 2000 and 2001 from Estonia, but in 2007, the Reclamation Centre recovered and recycled about 0.8 MT of halon 2402 when all of the halon in the TV tower (about 1.8 MT) was replaced with an alternative. The quantities of halon 2402 recovered and recycled in Estonia from 2002 until 2008 are listed in Table 8-6. The quantities of halon 2402 sent by Latvia to the Estonian halon bank are shown in Table 8-7. So far, Lithuania has not sent any halon to the bank, as negotiations on the price for the halon failed.

Table 8-6: Halon 2402 Recovered and Recycled In Estonia from 2002 until 2008

Year	Halon 2402 Recovered, MT	Halon 2402 Recycled, MT
2002	1.200	1.200
2003	0.445	0.445
2004	2.472	1.777
2005	1.338	1.320
2006	1.182	1.182
2007	1.857	0.800
2008	0.442	0.142
TOTAL, MT	**8.936**	**6.866**

Source: GEF Impact Evaluation Information Document n. 18, 2009

Table 8-7: Halon 2402 Quantities Sent By Latvia to the Reclamation Centre in 2008

Year	Halon 2402 Recovered, MT	Halon 2402 Recycled, MT
2008	1.139	-

Source: GEF Impact Evaluation Information Document n. 18, 2009

Two MT of reclaimed halon were exported to the Indian Navy in 2006, and there have since been requests from India for Estonia to supply more halon from local or other sources (such as the Ukraine). In May 2009, the Reclamation Centre had stored about 1.5 MT of halon 2402. A certain amount of this was obtained from merchant ships. Determining the amount of halon from ships was problematic because data on halon were not recorded by the Maritime Administration. The NOU surveyed ship owners and as a result of the responses, estimated that the total halon on 463 ships was about 400 MT.

In Latvia, fire fighting use in 1995 was reported to be 5 MT of halon 2402. Once imports of halon systems stopped, the number of halon systems in the country dropped and consequently the annual use. Since 1993, some 45–50 large computer facilities protected by halon systems have been dismantled. The annual use estimate for halon 2402 is 1.5 MT. Annual use of “BF-2” (a mixture of 37% halon 2402 and 63% methyl bromide (Brometil)), typically used only on ships, was ignored since all ships were sold to other countries, and service to existing systems or a change to other alternatives was not within this mission’s scope. The status of such systems is questionable as to reliability, effectiveness, usage and compliance to fire and environmental standards.

In Lithuania the most widely used halon is 2402, including a mixture of 85% carbon dioxide with 15% halon 2402. The estimated amount of halon 2402 was about 8 MT. Determining the amount of halon on ships was problematic because no data were available at the time of the estimate. During 2006–2008, Lithuania decommissioned the halon systems on 28 ships and recovered 2.526 MT of halon including BF-2. According to information available to the Ministry of Environment, today there are no Lithuanian-flagged merchant ships using halons. One ship with 0.214 MT of halon 2402 changed flag State and is no longer under Lithuanian jurisdiction. Another ship is a special-purpose search and rescue ship with 0.420 MT of halon 2402 that was transferred to the military.

(*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 124–138).

The Environmental Ministry of Estonia, in collaboration with the Statistical Office, reported that 3.631 MT of halon 2402 were banked in 2004, and 0.124 MT of halon 2402 was sold at the end of the year. In total, about 1.280 MT of halon is contained in existing installed fire fighting systems.

(*Source*: GEF Impact Evaluation Information Document n. 18, *GEF Impact Evaluation of the Phase-Out of Ozone-Depleting Substances in Countries with Economies in Transition*, Volume Two: Country Reports, October 2009. pp 155–160).

Cyprus: 0.144 MT of halon 2402 are installed in aircraft (Mi-35P) protection, while no halon bank exists in this country.

(*Source*: Ministry of Agriculture, Natural Resources and Environment – Cyprus, 2008).

Italy: In 2007, Italy reported to EC Environment Directorate that about 7 MT of halon 2402 were available to satisfy the market needs – no data was available for 2008. According to information from the Italian Ministry of Environmental Protection, in 2002 the halon banks of some other EU Member States contained 1394 MT of halon 2402 – Netherlands (1100 MT), Italy (219 MT), Denmark (70 MT), Germany (5 MT). However, these quantities have not been confirmed and are not included in the HTOC assessment of global supplies of halon 2402.

India: Per 2004 estimates, India had a total installed base is 110 MT. However, their Army needs 50 MT over the next 15 years to support ground vehicles, their Navy and military aviation sectors are looking for 60 MT and 23 MT respectively for their servicing needs over the next 15–20 years. As a result, the annual demand to support important uses in India can be estimated at 7–9 MT/year. India received 9 MT of halon 2402 from the Russian Ministry of Defence. The HTOC has a growing concern over the capability of Russia and Ukraine to continue to support India's servicing needs of halon 2402.

Vietnam: In 2005, Vietnam estimated their total installed base of halon 2402 was 11.7 MT. An estimated reduction to 3.617 MT is anticipated for 2010.

Japan: Total installed halon 2402 has been estimated as 263 MT. With respect to the amount of halon 2402 in ships, aircraft and the military, it is estimated to be 4 MT as of December 2006. Japan does not have any surplus halon 2402 to support other Parties' needs.

United States of America: Confirmed amount of reclaimed halon 2402 in the US halon bank is about 11 MT. It is anticipated that most or all of this halon came from non-fire protection uses.

Based on the local and regional information above, the global inventory (or bank) of halon 2402 is estimated at approximately 2300 MT for fire protection uses. It must be noted that additional halon 2402 in non-fire protection applications, such as in thrust vector control in intercontinental ballistic missiles, may yet surface to increase the quantities that will be available for this sector in the future.

8.3.2 Modelling and Estimates of Halon 2402 Emissions

When the usage of halon 2402 as a process agent was stopped in Russia, it became possible to perform a rough estimation of its emissions from fire protection applications. According to a simplified approach proposed by Sergey Kopylov, current emissions of halon 2402 can be estimated as 10% of the amount of halon to be recycled annually. This model is based on the experience of the Russian market and covers the emissions of halon 2402 caused by accidental release, fire suppression and losses via recycling. Using this approach, the following forecast was made (see Table 8-8).

Table 8-8: Estimated Russian Inventory and Emissions of Halon 2402

	2007*	2008	2009	2010	2011	2012	2013	2014	2015
Necessity in recycling, (MT)	80	160	160	160	50	50	30	30	30
Annual offer of free agent (MT)	10	20	20	20	50	50	30	30	30
Possible losses (MT)	8	16	16	16	5	5	3	3	3
Total bank (MT)	947	931	915	899	894	889	886	883	880

*Data obtained May 2008

The predictions were confirmed for 2008: according to preliminary data, the bank of halon 2402 in the Russian Federation was estimated as 938–941 MT. The two times reduction in the predicted amount of recycled halon was mainly caused by the current economic crisis. Thus the emissions are approximately 8 MT, which is approximately 10% of the 80 MT of halon recycled in 2008.

For the years 2007–2009, the estimated emissions of halon 2402 in the Russian Federation are consistent with the halon 1301 and 1211 models that use 2% and 4% respectively, which also accounts for processing losses. Therefore, a global average emission rate of 3% for halon 2402 is recommended, which is an average of the 2% total flooding emission rate and of the 4% streaming rate, since halon 2402 is used in both of these applications.

Using the 3% average emission rate and a global installed base of halon 2402 for fire protection applications of approximately 2,300 MT, the estimated halon 2402 global emission for 2009 is 70 MT. This is approximately twice as high as previous HTOC estimates for halon 2402 emissions but still remains well below the estimates provided from the Scientific Assessment Panel based on atmospheric concentrations, i.e., two orders of magnitude below.

8.4 Local Banks and Emissions of Halon 1211 and Halon 1301

New and updated data on the emissions of halon 1211 and 1301 for NW Europe, using the methodology described in *Greally, B. R., et al. (2007), Observations of 1,1-difluoroethane (HFC-152a) at AGAGE and SOGE monitoring stations in 1994–2004 and derived global and regional emission estimates, J. Geophys. Res., 112, D06308, doi: 10.1029/ 2006JD007527)*, have been obtained in 2010. The data are multiplied by a factor of 1.6 based on Gross Domestic Product (GDP) to extrapolate from NW Europe to the whole of the European Union. The results are provided in Table 8-9 below and show that emissions of both halon 1211 and 1301 either remained relatively constant or increased during the period when non-critical halon systems had to be removed from service and halons properly disposed of in accordance with European Regulation (EC) No. 2037/2000, existing at that time. The regulation limited the use of halon to only very specific critical uses listed in Annex VII of that regulation.

Table 8-9: Estimated European Emissions, MT, using methodologies described by Greally, B.R., et al. (2007) and in the Decision XX/8 Task Force Report

Year	Halon 1301 (MT)	Halon 1211 (MT)
1995		960 ± 190
1996		930 ± 180
1997		790 ± 140
1998		750 ± 93
1999	380 ± 58	730 ± 100
2000	390 ± 77	660 ± 130
2001	380 ± 90	560 ± 77
2002	420 ± 120	540 ± 62
2003	560 ± 150	580 ± 80
2004	530 ± 240	560 ± 150
2005	310 ± 86	420 ± 62
2006	240 ± 29	400 ± 43
2007	250 ± 37	380 ± 54
2008	270 ± 48	360 ± 38

The installed quantities or bank of halons reported by the European Commission for all Critical Uses in all 27 EU Member States for the year 2006 total approximately 950 MT of halon 1301, 250 MT of halon 1211 and 60 MT of halon 2402. The average emissions of halon 1301 in Table 8-9 is 240 MT in 2006, 250 MT in 2007 and 270 MT in 2008. Assuming that only critical uses remain in the EU, all these emissions are from those critical uses. Comparing the emissions with the reported installed quantities in critical uses gives an average emissions rate for halon 1301 of 25% in 2006, 26% in 2007, and 28% in 2008 – extremely high and unsustainable emission rates. The same calculation cannot be performed for halon 1211, because the emissions in 2006, 2007 and 2008 are higher than the reported quantities of critical uses. Therefore, it appears that there are additional quantities of halons either installed, in storage and/or discarded that are also contributing to the estimated annual halon emissions.

It is possible to estimate the smallest size of the bank of halons that would lead to these emissions by using the lower end of the emission estimate from Table 8-9 and dividing that value by the higher end of the average emission rate previously reported. For halon 1301, the highest average emission rate is 3% based on the average of 2% ±1%. For 2006, the lowest emission is 211 MT (240 MT–29 MT), for 2007 it is 213 MT (250 MT–37 MT) and for 2008 it is 222 MT (270 MT–48 MT). The estimated smallest bank of halon 1301 is 7,000 MT in 2006 and 2007, and 7,300 MT in 2008 for all 27 EU countries. This is consistent with the HTOC model estimates of an average of approximately 6,000 MT for 2006–2008. Similarly for halon 1211, the highest average emission rate is 6% based on an average of 4%±2%. Performing a similar calculation for halon 1211 results in an installed base that much smaller than the 15,000 MT projected in the HTOC model. However, it is also possible to estimate the largest possible bank of halons that would lead to these emissions by using the higher end of the emission estimate from Table 8-9 and dividing that value by the lower end of the average emission rate previously reported. This yields a possible bank larger than the 15,000 MT projected in the HTOC model. Therefore, for both halon 1301 and halon 1211 the estimated installed base within Europe appears to be much larger than the reported quantities contained within the European Union Critical Uses.

A publication in the Journal of Environmental Science and Technology, provided 2004–2006 measurements of ODS and their alternatives from the US and Mexico. The results indicated that halon 1211 emissions from the U.S. were 600 (300–800) MT/yr. and Mexico were 100 (0–300) MT/yr. The results for the U.S. match well with the HTOC model estimate of 600 MT/yr. emissions. The emissions for Mexico appear to be in line with estimating techniques that calculate usage and emissions based on GDP. The results for halon 1301 were not able to be determined. These findings may point to the trend of reduced halon emissions where halon has it highest market value. This is consistent with the measured very low losses in Japan and the potentially higher emissions in Europe where halon in non-critical uses has lost market value and may in fact be a financial liability.

8.5 Conclusion

The HTOC 2010 Assessment indicates that at the end of 2010 the global bank of halon 1301 is estimated at approximately 42,500 MT, halon 1211 at approximately 65,000 MT and halon 2402 at approximately 2,300 MT. From this assessment, the HTOC remains of the opinion that adequate global stocks of halon 1211 and halon 1301 currently exist to meet the future needs of all existing halon fire equipment until the end of their useful life. However, there remains concern about the availability of halon 2402 outside of the Russian Federation and the Ukraine to support existing uses in aircraft, military vehicles, and ships. Much of the bank of halon 2402, which was intended to service fire protection needs for existing applications, was consumed within the Russian Federation as a process agent several years ago. In addition, a new product that encapsulates halon 2402 in a paint matrix is being commercialised in the Russian Federation that would further deplete supplies of halon 2402 to support existing uses. The HTOC is concerned that long-term, important users of halon 2402 will not have enough halon 2402 to support their needs if the bank continues to get depleted through use in non-fire protection uses and/or in new products

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 halons will obviously eliminate future availability of halons as a source of supply for many needs. As adequate global 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 particularly important application for halons 1211, 1301 or halon 2402.

9.0 Practices to Ensure Recycled Halon Purity

9.1 Halon Supply

Prior to the halt in production of halons, replenishment agent to recharge extinguishers and extinguishing systems had a fairly simple supply chain from manufacturer to servicing company to the end user. With such a short supply chain the quality assurance needs of all parties were readily achieved; or, in the rare case of out of specification agent, problems were easily traced back to the source and corrective action taken.

Today we no longer have newly manufactured halons and the fire protection industry has to rely on “used” halons for the recharge of extinguishers and extinguishing systems. The source of halon has thus shifted from a handful of agent manufacturers around the world to literally millions of end users who own halon extinguishers or extinguishing systems who may at some point offer the agent up for recycling. Furthermore, the condition of the agent at its entry (or re-entry) point into the market has shifted from newly manufactured agents with an extremely high level of purity to “used” agent that can have any of several types of impurities.

In the fire protection industry there are several terms used to describe the treatments of halons to prepare them for possible redeployment:

- **Reuse**: Remove halon cylinder or extinguisher from one application and install in another application
- **Recover**: To remove halon in any condition from an extinguisher or extinguishing system cylinder and store it in an external container without necessarily testing or processing it in any way.
- **Recycle**: To clean recovered halon for reuse without meeting all of the requirements for reclamation. In general, recycled halon is halon that has its super-pressurising nitrogen removed in addition to being processed to only reduce moisture and particulate matter.
- **Reclaim**: To reprocess halon to a purity specified in applicable standards and to use a certified laboratory to verify this purity using the analytical methodology as prescribed in those standards. <u>Reclamation is the preferred method</u> to achieve the highest level of purity. Reclamation requires specialised machinery usually not available at a servicing company.

For the purposes of this chapter, the expression “recycle” is intended to include both the “reclaim” and “recycle” treatments described above.

In order to have a credible halon resupply industry, the “used” halons must be properly processed in order to remove impurities and return the halon to a purity level consistent with newly manufactured agent. Furthermore, the participants in the halon resupply industry must have the technical ability to test and certify that the agents being offered for replenishment are indeed free of impurities. Without that ability rigorously applied, there can be no credible halon resupply industry.

9.2 Requirements

The requirements for halons 1211 and 1301 are contained in ISO 7201-1, see reference [1], and for halon 2402 are contained in GOST 15899-93, see reference [2], and are summarised in Table 9-1. In addition to these standards, there are several national standards for the halons with similar requirements.

Table 9-1: Requirements

Property	Requirements		
	Halon 1211[1]	**Halon 1301[1]**	**Halon 2402[2]**
Purity, % (mol/mol)	99.0 min	99.6 min	99.5 min
Acidity, ppm by mass	3.0 max	3.0 max	
Water content, ppm by mass	20 max	10 max	30 max
Non-volatile residue, % (mol/mol)	0.01	0.01	
Halogen Ion	Passes test	Passes test	
Suspended matter or sediment	None visible	None visible	

1 – according to ISO 7201-1.
2 – according to GOST 15899-9.

ISO 7201-1, ASTM and GOST describe in more detail the methods for testing for the requirements in Table 9-1:

- **Purity:** Determine the purity by gas-liquid chromatography (GC), using generally accepted laboratory techniques. If other tests indicate the presence of unidentified impurities, then determination by gas-liquid chromatography/mass spectrometry (GC/MS) is recommended.
- **Acidity:** Determine the acidity by the appropriate method specified in ISO 3363.
- **Water content:** Determine the water content by the orthodox Karl Fischer method or by any other method giving equivalent results.
- **Non-volatile residue:** Determine the non-volatile residue by the method specified in ISO 5789.
- **Halogen ions:** Mix 5 g of the sample with 5 ml of absolute methanol containing several drops of a saturated methanolic silver nitrate ($AgNO_3$) solution. The resulting solution shall exhibit no turbidity or precipitation of silver halide.
- **Suspended matter or sediment:** Examine the liquid phase of the sample visually.

9.3 The Problem

The Civil Aviation Section (7.2) of this report provides some specific information on extinguishers found with contaminated halon in that market. The presence of halons of questionable purity is an insidious problem that does not become apparent until an end user discharges an extinguisher or extinguishing system, often in a serious life safety or potential property loss setting. With an impure halon the performance can range from poor or no fire extinguishing effectiveness to one where the impure agent may actually intensify the fire in the case where the impurity is a flammable material.

Generally speaking, end users do not have the means to confirm the purity of halons they have employed in fire extinguishers or in extinguishing systems. Instead they have had to rely on the aftermarket supply chain to collect, process, test and certify that the halon agent is of acceptable purity. From the end user's perspective, it is that last step – the certification – that has been the ultimate basis for acceptance of the halon. Since there has been at least one instance where a certification was allegedly falsified by the agent supplier, it would seem that relying on a supplier's certification alone can introduce risk with respect to agent purity.

To understand how and/or why halon with impurities can be supplied to end users, one has to look at the circumstances under which the impurities can be introduced. For all practical purposes the impurities are usually introduced into the halon in three different manners. First, the impurities could already be present in the halon when the recycler or servicing company received the agent or the extinguisher containing the agent from an end user or intermediary. Second, the halon could become contaminated during processing by the recycler or servicing company when "good halon" is accidentally batched together with halon that is impure, thus causing the entire batch to become impure. This is referred to as 'cross contamination with other halocarbons.' Third, the failure to adequately purge the equipment when changing from processing a different halon or refrigerant will cause the introduction of impurities by cross contamination with other halocarbons or the introduction of other contaminants including oil, moisture, particulates or acids.

9.4 The Supply Chain

Figure 9-1 illustrates the parties involved in the supply chain for recycled halons.

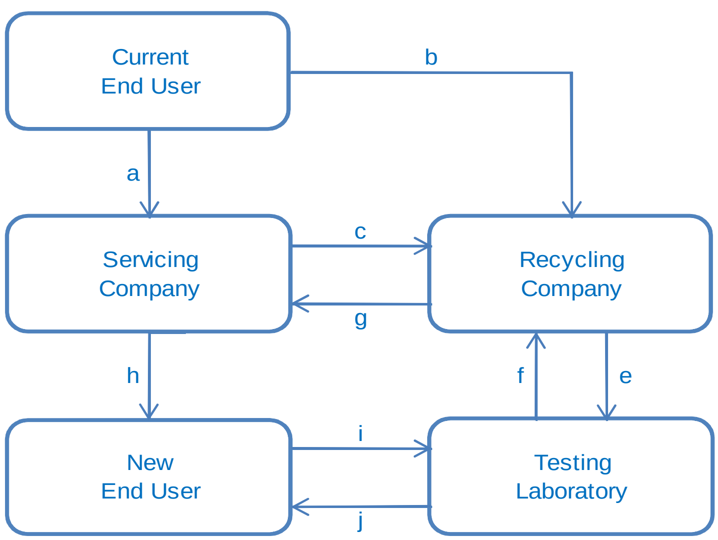

Figure 9-1: Supply Chain for Halon Recycling

In the trading of recycled halons, there are usually five parties involved in commercial transactions:

- The current end user of the agent or extinguisher sells the contents of its extinguishers or extinguishing systems. This sale is usually to either a servicing company (a) or to a recycling company (b).
- The recycling company buys the agent or extinguisher for processing the halon and returning it to the required purity level. The recycling company could buy the agent from the current end user (b) or from a servicing company (c).
- After processing the agent the recycling company has the agent purity confirmed by a testing laboratory (e to f). This laboratory is often a third party organisation and in other cases it is part of the recycling company.
- In most cases the recycling company sells the recycled agent to a servicing company (g) for use in recharging the extinguishers of a new end user (h). In some cases the current end user and the new end user could be the same with the halon being processed and then banked for the new end user. The banking service is sometimes provided by the recycling company and in other cases by the servicing company or by the new end user itself.
- From time to time the new end user may deal with the testing laboratory to have a sampling of its extinguishers contents tested to confirm that the halon therein is up to specification (i to j). In some cases the new end user employs the servicing company as an intermediary with the testing laboratory.

There are instances where the services of a recycling company and a testing laboratory are not part of the process. That is when the servicing company merely recovers halon from the extinguishers or extinguishing systems of a current end user and then uses that halon to recharge the extinguishers of a new end user (a to h) with little or no purification efforts and no testing. This is considered a bad practice because one is never certain about either the contents or the purity level in the current owner's extinguisher and there is no provision to identify any contamination introduced in the transfer process. Thus, extinguishers and extinguishing systems recharged with agent by this simple method have no credibility with regard to purity and thus performance effectiveness.

Recycling companies often use a 'halon identifier' instrument; see reference [3], to determine the percentage purity of newly received halon in order to prevent contamination of other halon when combined in a batch. Depending on the purity of the halon when received for recycling, reclamation efforts by the recycling company may be as simple as nitrogen separation. If, however, cross contamination with other halocarbons is found, then the halon mixture must be submitted to a distillation process to return the halon to a condition meeting the requirements of the appropriate standard. In some cases it may not be economically feasible to "clean" the halon depending on the type of halocarbon cross contaminants and / or the degree of contamination".

9.5 Mitigation Strategies

In reviewing the supply chain for recycled halon it is clear that the minimum mitigation strategies that can be employed to ensure agent purity are:

- **By the Recycler**: Employing robust quality assurance procedures that provide for (1) testing incoming agent to ensure that it is not contaminated before it is combined with other agent for the recycling process; (2) processing the batched agent in a manner to remove all impurities to the specified levels, ensuring that no new contaminants can be introduced into the processed agent up through and including its final storage condition (cylinders, drums, etc.)
- **By the Testing Laboratory**: In accordance with good laboratory practice, perform an analysis on samples of the recycled agent for each individual storage container (cylinder, drum, etc.) and provide written certification that the halon meets the required specifications. See Table 9-2 for a list of laboratories that may be considered for performing testing and certification.
- **By the Servicing Company**: Preparing and following established, good practices when recharging extinguishers and extinguishing systems to ensure no contaminants are introduced at this stage either by the halon transfer equipment or by improper cleaning and drying of the extinguisher cylinder.
- **By the New End User**: Periodically removing extinguishers from service and having the contents analysed by a testing laboratory to check for contaminants in the contents. This can be done in a cost effective manner by applying standard statistical sampling methods.

Table 9-2: Testing and Certification Laboratories

NIPPON EKITAN Corporation Kobe Gas Center 2-1-3, Murotani, Nishi-ku, Kobe, Hyogo 651-2241 Japan Phone: +81 78 991 7839 Fax: +81 78 991 7840 Website: http://www.n-eco.co.jp
Meridian Technical Services Ltd 14 Hailey Road, Erith Kent DA18 4AP United Kingdom Phone: +44 0208 310 3911 Fax: +44 0208 310 5687 Website: http://www.meridiantechnicalservices.com
Hudson Technologies (Headquarters)[1] PO Box 1541 One Blue Hill Plaza Pearl River New York, NY 10965 Phone: +1 845 735 6000 Website: http://www.hudsontech.com
Hudson Technologies Laboratory[1] 3402 North Mattis Avenue Champaign, Illinois 61821 Phone: +1 217 373 1414 Website: http://www.hudsontech.com

Table 9-2: Testing and Certification Laboratories (Continued)

National Refrigerants Laboratory[1] Inc. 661 Kenyon Avenue Bridgeton, NJ 08302 Phone: +1 800 262 0012 Phone: +1 856 455 2776 Website: http://www.refrigerants.com
RemTec International[1] 436 North Enterprise Bowling Green, OH 43402 Phone: +1 419 867 8990 Fax: +1 419 867 3279 Website: http://remtec.net
Intertek ETL Semko[1,2] 1717 Arlingate Lane Columbus, Ohio 43228 Phone: +1 614 279 8090 Website: http://www.intertek.com/hvac/refrigerants/halon-analysis

1 – These laboratories are AHRI (Air-Conditioning, Heating and Refrigeration Institute) certified to analyse refrigerant products, and because of product similarity, are also acceptable to the U.S. Department of Defense (DOD) for halon analysis.

2 – Although not identified as a certified laboratory, the U.S. DOD has utilised and accepted analyses provided by this laboratory.

9.5 References

1. "Fire Protection - Fire Extinguishing Media - Halogenated Hydrocarbons - Part 1: Specifications for Halon 1211 and Halon 1301", ISO 7201-1; Second Edition; pp. 12-15, 1989.

2. GOST 15899-93, Specification for 1,1,2,2-tetrafluorodibromethane (R-114B2).

3. One such instrument is shown at http://www.refrigerantid.com/halon/identifier.html

10.0 Halon Emission Reduction Strategies

10.1 Introduction

Releasing halon into the atmosphere is fundamental to the process of flame extinction and enclosed space inertion. However, these necessary emissions only use a small proportion of the available supply of halon in any year. Most countries have discontinued system discharge testing and discharge of extinguishers for training purposes resulting in emission reductions in some cases of up to 90%. Additional and significant reductions of halon emissions can be realised by improving maintenance procedures, detection and control devices, etc. as outlined in this chapter and in Technical Note #2 which can be downloaded from:

http://ozone.unep.org/teap/Reports/HTOC/index.shtml

It is becoming apparent that there are a number of non-technical actions that should be taken which have been shown to be equally important to the aforementioned technical actions. Non-technical steps include development of Codes of Conduct, implementing Awareness Campaigns, workshops, and training, Policies, and legislating regulations and ensuring enforcement. Halon Emissions Reduction Strategies are a combination of “responsible use” and political regulatory action.

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

- Alternative Fire Protection Strategies
- Halon Use Minimisation
- Maintenance Program
- Detection Systems
- Hazard and Enclosure Review
- Personnel Training And Documentation
- Halon Transfers And Storage
- Halon Discharging
- Awareness Campaigns and Policies
- Decommissioning, Transportation, and Destruction

10.2 Alternative Fire Protection Strategies

Do not use halons in new fire protection applications or new designs of equipment. Alternatives are available for virtually all applications with very few exceptions, e.g., some aircraft applications. Clearly halon emissions can be reduced if halon is not employed as the fire protection agent in the first place. In all cases, in determining whether or not a halon protection system is required or should be removed, a risk assessment should be performed.

Good engineering practice dictates that, where possible, hazards should be designed out of facilities rather than simply providing protection against them. Active fire extinguishing systems which perform the same function as halon systems should not be considered as the only alternative to halon systems. A combination of prevention, inherently safe design, minimisation of personnel exposure, passive protection, equipment duplication, detection, and manual intervention should be considered as follows:

1) Prevention

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

2) Inherently Safe Design

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

3) Minimisation Of Personnel Exposure

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

4) Passive Protection

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

5) Equipment Duplication

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

6) Detection

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

7) Manual Intervention

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

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

10.3 Halon Use Minimisation

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

1) Local Application

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

2) Reserve Systems

   Reserve systems should only be installed when:

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

If it is feasible to do so, consideration should be given to leaving reserve supplies unconnected, which can help avoid unwarranted release of the reserve supply. If possible, keep reserve agent in a single large storage tank to reduce the risk of accidental release and minimise the chance of leaking. Note, if the reserve halon is on site in a system of cylinders rather than a single large storage tank, then the chances of leaking and accidental discharge is increased by approximately the number of cylinders. Where there are no on-site capabilities for the storage and transfer of halon agent, or a contractor nearby with the capabilities, then consideration should be given to placing all reserve cylinders in an enclosure and installing an automatic halogen leak detector with remote and/or local alarms, or placing them on load cells and monitoring them for material loss.

1) Extended Discharge

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

2) Zoned Systems

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

10.4 Maintenance Program

Attention to maintenance programs can add years to a halon bank by reduced emissions. This represents money saved in two ways. It minimises the need to purchase recycled halon, and it prolongs the useful life of the existing fire protection system. Once emissions are minimised, funding for system replacement can be planned over longer periods, for example over the life of the program/equipment. Cost payback from maintenance, manufacturer improvements, and more frequent servicing can be realised almost immediately. A maintenance program includes; upgrading equipment to utilise improvements and new technology, scheduling equipment replacement, proper design, regular maintenance, and regular system checks.

1) Upgrade Equipment

Upgrade halon equipment to minimise leaks, prevent accidental discharges, and minimise false alarms/discharges. In some cases, the same equipment (with minor modifications) can be used for the halon replacements. In most cases, the alarm/detection system can be reused after halon system removal regardless of the method of fire protection. Thus upgrades to equipment represent a natural progression in an operation and maintenance program.

2) Scheduled Equipment Replacement

A well-developed maintenance program will include scheduled equipment replacement, based on the expected life of the equipment. The equipment life may be based on manufacturer's recommendations, local or national regulations, or previous history. Planning for replacement provides a basis for forecasting long term funding requirements.

3) Design and Regular Maintenance

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

Inadvertent discharges are mostly attributed to:

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

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

4) Regular System Checks

System checks and maintenance should be done on a frequent and regular basis. System cylinders should be visually inspected on a monthly basis for obvious damage to the cylinders, valves, leak detectors, etc. The contents of cylinders should be checked every six months to monitor losses. (Note: There are a number of methods for checking the quantity of halon in a cylinder. Check with the manufacturer for the optimum method.) Valves, hoses, manifolds, and fittings should be inspected at the same time using a local halon sensor such as those used to check refrigeration systems for leaks. Cylinders should only be replaced if more than 5% by weight of the initial contents has been lost or will be lost by the next service. Minor losses within this 5% can often be tolerated and will minimise unnecessary losses incurred in the process of rectifying such leaks. Bar coding methods have been successfully employed to record and track halon quantities and equipment condition.

The manager of a national halon bank has found that 90% of the halon discharges they are aware of are a result of "dirty smoke detectors and bad maintenance operations". The experience of HTOC members is this is a typical example seen world-wide. It is imperative in cases where halon is still being used that considerable effort is given to developing better maintenance methods for the equipment. Improved discharge system reliability is achieved through enhanced maintenance procedures and/or replacement with new technology. Development of a maintenance program should be done in parallel with performing a risk assessment of the facility and operations. Once a risk assessment has been performed on an operation, the fire protection needs are then determined. In cases where automatic fire detection or suppression is determined necessary, maintenance becomes a significant and integral part of the risk management.

10.5 Detection Systems

Automatic halon systems go hand in hand with sensitive detection systems. Poor design and improper maintenance of sensitive detection systems will almost always result in unwanted halon releases. It is therefore essential that:

1) Systems components not be mixed.

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

2) Halon is released only after positive confirmation of fire.

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

   Where the Authority Having Jurisdiction permits, and in facilities that are occupied continuously by trained personnel, the use of CCTV flame detectors will allow trained personnel to remotely, visually confirm the existence of a fire within a predetermined time when alerted by pop-up video. If no fire exists, then release of halon can be inhibited. Newer technology called video smoke & fire detection or video smoke detection (VSD) can provide even faster response than CCTV alone as it utilises computer software to analyze the smoke pattern for quicker identification.

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

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

Equipment chosen should conform to internationally or nationally accepted specifications incorporating suppression of airborne and electrical interference. For example, BS7273 2000 covers the electrical actuation of total flooding extinguishing systems, and was introduced to improve the reliability of control systems to reduce the likelihood of accidental discharges, see reference [1]. One of the major requirements is that the circuit design and equipment construction should be such that the system should not discharge because of the failure of a single component or the short circuiting of two current paths. In addition the equipment must be protected from EMI (cellular phones, etc.), e.g., EC Directive 2004/108/EC, see reference [2].

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

Experts in the field have determined that fires produce different types of stimulation that can be detected by sensors, e.g., molecular gases, condensed-phase aerosols, heat conduction, electromagnetic radiation, and acoustic waves. As a result there are a number of ways the fire can be detected. An example of upgraded technology in this area would be the use of early warning air sampling smoke detection systems. These types of systems employ a laser based light source, see reference [3]. Owing to particle size discrimination, a laser based light source requires no air intake filter which can clog over time and desensitise the system. In addition, a laser based light source requires no maintenance and no replacement on a periodic basis. Other examples are infrared optical sensors which have an advantage over sensors that depend on sunlight or operate in the ultraviolet range because they cannot be blinded by smoke or obscured by oil or other substances. Consequently, they are less likely to produce false alarms. Sensors using optical signal processing also achieve very rapid response times.

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

5) Trained service personnel are employed.

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

10.6 Hazard and Enclosure Review

Monitor and control the hazard. Check for enclosure modifications or changes to the configuration of the protected space. Halon system removal or redesign will likely be required where walls have been repartitioned, moved, the contents of the enclosure have been changed significantly, etc. During these types of changes it is also important to review impacts to the protection system which may include changes in the environmental control system. It is usually necessary to modify the halon system when heating, ventilation and/or air conditioning systems (HVAC) are added to the protected zone. Check with local/national fire regulations and manufacturers recommendations for specific requirements, which will include requirements to connect controls of the halon system into the HVAC system for automatic shutdown where the HVAC is not dedicated to the protected enclosure.

10.7 Personnel Training and Documentation

Where on-site maintenance will be performed, it is essential that the personnel performing the service be properly trained. It is equally important that the system user be competent in the proper operation of the system and aware of activities that could result in an unwanted discharge. Both groups should be educated on ozone depletion issues and the impact of halon releases, as well as the restrictions on future supplies. Encourage participation rather than demand compliance.

Where on-site maintenance personnel are not available, the user should take out a maintenance contract. Whether on-site personnel are utilised or a maintenance servicing contract, always insist on competent and licensed service engineers.

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

10.8 Halon Transfers and Storage

The component of halon emissions related to halon transfers can be substantially reduced by the use of approved filling rigs. Any operation relating to a high pressure gas must conform to the appropriate safety standards in line with all relevant local, national, and international regulations. The equipment used must be certified by a recognised standards organisation and be compatible for halon use.

Environmental and operator safety dictates that all filling procedures should be conducted by trained, and preferably licensed, personnel. Filling operations should be carried out in a well-ventilated area with all safety relief valves from the rig connected to a containment/recovery system. All equipment, particularly flexible connections, should be checked at monthly intervals for signs of deterioration. To avoid corrosion problems, it is essential that the halon not be allowed to come into contact with water. The filling rig must be leak tested to twice its normal pressure prior to its initial use, and constantly monitored for leaks during the filling operation. During filling and recovery operations, overall loss of halon should be minimised and under no circumstances should it exceed 5%.

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

Most safety standards require that portable halon extinguishers be emptied and refilled at regular intervals. This permits the operation of the appliance to be checked, and allows the cylinder to be inspected for signs of corrosion and to be subjected to pressure testing. In the past, frequently the halon was released to the atmosphere. Clearly such practices must be banned, and all discharging accomplished using approved recovery rigs.

Recovery rigs should be operated so as to avoid contaminating halon supplies. Cylinders containing halon should be emptied by pressurising with dry nitrogen or by use of positive displacement pumps. Vapours should be recovered if possible. Halons should never be mixed as this would significantly limit recycling possibilities. Halon 1211 recovery systems with an efficiency of >98% and halon 1301 recovery systems with efficiencies >96% are readily available today, see reference [5]. Table 10-1 provides an up-to-date list of halon recycling and reclamation equipment manufacturers known to the HTOC. Both Kidde and Neutronics stated that users would need to ship their units back to the manufacturer for servicing. HTOC members contacted some of the users of the halon reclamation equipment listed in Table 10-1. The users said it would be cost prohibitive to ship the units back, especially the Kidde and Neutronics units due to the size of the units. Both the Kidde unit and the Neutronics unit utilise step down refrigeration for nitrogen separation, a process which results in large, non-portable halon reclamation units. HTOC members are neither endorsing the use of the more portable units nor are they critical of the larger units, but rather we are pointing out a challenge encountered by some of the Parties to managing a national halon banking operation.

Table 10-1: Halon Recycling and Reclamation Equipment Manufacturers

Type	Product Name	Manufacturer	Country
Halon 1211 Halon 1301 Halon 2402	REcovery And Conditioning for Halon (REACH™) System REACH REACH	Kidde Aerospace Inc. 4200 Airport Drive, N.W. Wilson NC 27896 USA Tel: + 1 252 237 7004 Fax: +1 252 246 7185 **or** Kidde Graviner Ltd, Mathisen Way, Colnbrook Slough Berkshire, SL3 0HB United Kingdom Tel: +44 (0)1753 683245 Fax: +44 (0)1753 685126 Web Site: www.kiddegraviner.com	USA United Kingdom
Halon 1211 Halon 1211 & 1301 Halon 2402	Defender M-1 (Military) Defender C-1 (Commercial) Defender C700 (Commercial) Defender CM700M1 (Military) Defender C2402 NOTE: The MARS unit must be purchased with the Defender units to perform halon reclamation. MARS is a nitrogen separator.	RemTec International 1100 Haskins Rd. Bowling Green Ohio 43402 USA Tel: 800-372-1301 Fax: 419-867-3279 Web Site: www.remtec.net	USA
Halon 1211 Halon 1301	Halon 1211 Recovery System Halon 1301 Recovery System NOTE: The "Filtration System" must be purchased with these units in order to *RECYCLE* halon and the "Nitrogen Separator" must also be purchased to *RECLAIM* halon.	Getz Manufacturing 540 S Main Street North Pekin IL 61554, USA Tel: (309) 382-4389 Fax: (309) 382-6088 Web Site: www.getzmfg.com	USA

Table 10-1: Halon Recycling and Reclamation Equipment Manufacturers (Continued)

Type	Product Name	Manufacturer	Country
Halon 1211 and 1301 Halon 1301 and 2402	Halon 1211 & 1301 Reclamation Unit Halon 1301 & 2402 Reclamation Unit	Neutronics, Inc. 456 Creamery Way Exton PA 19341 Tel: (610) 524-8800 Fax: (610) 524-8807 Web Site: www.neutronicsinc.com	USA

In the past it has been common practice to install redundant or backup halon systems on-site for providing immediate protection once the primary system has discharged. This is no longer an encouraged practice. Where backup systems are not necessary, they should be removed from service and the halon recovered. The proliferation of relatively inexpensive, high efficiency halon recovery systems makes it easier to increase the longevity of an individual's halon bank. The manager of a national halon bank reported finding halon stored in improper cylinders resulting in slow leaks. By recovering all on-site halon that is not in use for fire protection purposes, the risk of accidental discharge or agent leakage is minimised. The halon can be recovered into large storage tanks and the tanks monitored for leaks.

The following practices should be observed:

- Store halon reserves in bulk storage where possible rather than in individual cylinders.
- Recover surplus halon from systems and appliances.
- Transfer and Store halon in system cylinders, extinguishers, and storage cylinders designed for halon use.
- Inspect and test (where appropriate) all cylinders prior to filling with halon.
- Provide good storage conditions for both in service systems/cylinders and backup systems or bulk agent, and install leak detection for storage atmospheres.

10.9 Halon Discharging

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

1) Systems

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

To address enclosure integrity a test, known as a "door fan" test, is conducted. The test uses air pressure, developed with a fan and measured with calibrated gauges, to determine the ability of an enclosure to hold the halon 1301 concentration. The calculations to interpret the gauge readings into halon 1301 hold time are usually performed with a small computer.

To address the other items, fire protection equipment standards play an important role. For example, UL 1058, *Standard for Halogenated Agent Extinguishing System Units*, see Reference [7], provides an indication of the level of reliability for the proper operation of detector/control devices, guidelines for the proper installation of nozzles to achieve sufficient agent distribution, and a test for verifying a manufacturer's flow calculation methodology. Only systems with complex piping arrangements should require additional agent distribution testing. If you must test, use a surrogate gas. HFC-125 has been proposed as a candidate alternative to halon 1301 for such tests, but it should be noted that this gas has a fairly high global warming potential (GWP), which may restrict its use in some countries.

Although the exact decrease in emissions, caused by the reduction in discharge testing using halon 1211, halon 2402, or halon 1301, is not known, it is estimated through the modelling of emissions and inventories to exceed 3500 MT per annum. The Committee therefore believes that eliminating discharge testing on a global basis should be effected immediately and could be effected without major impact on protection system integrity.

2) Portable Fire Extinguishers

Do not discharge manually operated halon fire extinguishers for training purposes.

The Committee believes that it is now possible to virtually eliminate this source of halon emissions. Discussions within the industry suggest that fire training organisations are now only demonstrating the use of portable halon extinguishers and have stopped using them during training. Thus, where three or four extinguishers may have been discharged in the past, now none are discharged during training sessions. With the increase in awareness of the environmental problems associated with halon, many users are switching to carbon dioxide, dry chemical, Aqueous Film Forming Foam (AFFF), Water Mist, or other acceptable zero or low ozone depleting substance (ODS) clean agent extinguishers. Thus, the demand for training and the reliance on the use of portable halon extinguishers is rapidly declining. A pressurised water extinguisher system has been developed for the US military for fire fighter training. The handling behaviour is similar to a halon 1211 system, see Reference [8].

Video demonstrations of halon 1211 appliances in use compared to alternatives would assist in building user confidence without the actual use of halon 1211 in every training session. Interactive video training has also been developed for US military applications and can be developed for most other needs, see reference [8]. The UK military in conjunction with the Civil Aviation Authority has also developed and utilises interactive video training, see reference [9]. Therefore, it is reasonable to assume that the use of halon 1211 for training purposes can be virtually eliminated.

Similar to the halon system cylinders, UL 1093, *Standard for Halogenated Agent Fire Extinguishers*, see Reference [10], provides requirements for the construction and performance of portable halon type fire extinguishers.

10.10 Awareness Campaigns and Policies

This section covers non-technical steps that can be taken to reduce halon emissions. These steps have been shown to be as important as the technical steps discussed in the previous sections of this chapter in achieving halon emission reductions. The non-technical steps are discussed only briefly in this section; however, references within this section are provided at the end of this chapter and should be consulted for in depth coverage of each subject. The HTOC, various governments, and the fire protection community have worked diligently to provide guidance documents on all aspects of halon phase-out. The value of the references should not be underestimated.

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

- Policies, Regulations, and Enforcement
- Awareness Campaigns
- Standards and Code of Practice
- Record keeping

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

10.10.1 Policies, Regulations, and Enforcement

Policies should be in place to meet the country obligations under the Montreal Protocol. Each country has a National Ozone Unit (NOU) tasked with implementing policies, programs, and regulations in support of those obligations under the articles of the Montreal Protocol specific to their country. Some countries have elected to utilise the concept of a Steering Group to formulate plans for ODS phase-out, to draft policies and regulations, and to provide periodic oversight. This is especially effective where resources are limited and actions might otherwise be delayed. It also serves to involve those entities directly affected by the phase-out. It is advisable that a Steering Group be made up of stakeholders from the following sectors, see Reference [11]:

- Public fire service
- Fire equipment trade association
- Insurance company
- Halon user company
- Environmental advocacy groups (NGOs)
- Environment Ministry
- Customs officials
- Defence ministry

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

While penalties can increase venting of halon and black market trading, many halon bank managers have cited lack of enforcement of halon control regulations as limiting the success of their operations. Without enforcement and incentives, national halon banking functions, especially those operated by industry or commercial entities, are unlikely to be financially viable. Several national halon bank managers have reported to HTOC members little or no activity in halon recycling which they attributed directly to lack of policies, regulations, and enforcement. In those cases, the bank either shuts down or the recycling operators will need retraining in the event decommissioned halon does become available.

10.10.2 Awareness Campaigns

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

Involve the stakeholders, who include the NOU delegate, Ministry of Environment, halon users, code enforcing authority, military branches, maritime and airline industries, research and testing laboratories, and the fire protection community. In all countries one or more of the following organisations exist and comprise the fire protection community:

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

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

In those countries where there is still no comprehensive halon management programme, no national halon bank, and no clearinghouse, it is quite likely there are halon installations that are inappropriate for the application and should be replaced with an alternative, see reference [11]. Workshops and Training are an excellent way to implement an Awareness Campaign while meeting with the fire protection community.

10.10.3 Standards and Codes of Practice

The fire protection community should:

- Adopt or develop technical standards on the design, installation, testing, and maintenance of extinguishers and fire suppression systems both for halons and their alternatives.
- Ensure users have training in place for the occupants and site manager of a halon protected enclosure.
- Develop or adopt a Code of Practice, see References [11–15]:
    - Target groups may include insurance, system manufacturers and distributors, fire protection system operators, service technicians, and state fire services.
    - Enforce the standards and codes. Various methods of enforcement may include command and control measures (e.g., regulations), market-based measures (e.g., taxes or permits) or voluntary agreements. Command and control approaches, the most common approach, require an effective legal framework and enforcement.
    - Incorporate standards and Codes of Practice in regular training. National training workshops should teach and explain the Code of Practice.

The fire protection industry has a goal of reducing the risk to people and property from the threat of fire while minimising non-fire emissions of fire protection agents. With the aim of ensuring both of these goals are achieved, the fire protection industries in many countries have developed or adopted a Voluntary Code of Practice (VCOP) that is intended to focus the industry's efforts on minimising emissions of gaseous fire protection agents, see reference [11]. The VCOP is distributed throughout the fire protection community and members are encouraged to voluntarily follow the emission reduction strategies. The following are typical strategies outlined in a VCOP:

1. Regulations and Standards: Follow applicable technical standards for the agent.
2. Emissions: Minimise emissions during storage, handling, and transfer.
3. Equipment: Utilise equipment appropriate for the agent and maintain it regularly according to step 1.

4. Discharge Testing: Eliminate discharge testing of halon and minimise discharge testing for all replacement agents to “essential” tests only.

5. Decommissioning, Servicing, and Disposal: Prohibit venting or release of agent to atmosphere, recycle or destroy agent, follow manufacture instructions for operation and maintenance of recycling equipment, and assure purity of agent.

6. Technician Training: Require that technicians who test, maintain, service, repair or dispose of halon containing equipment are trained regarding responsible use to minimise unnecessary emissions, see Reference [14]. Training should include:

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

7. Communications and Outreach: Ensure dissemination of information designed to minimise emissions and enable phase-out of halons.

8. Record keeping and Reporting: Develop a verifiable data tracking system on stockpiles, installed base, transfers, and emissions.

In most countries, fire equipment distributors belong to an industry association or are registered with a government agency. That agency or the government agency responsible for ODS phase-out could develop a Code of Practice (COP) and require compliance with the COP, in that case it would not be called voluntary. Requiring compliance would assure compliance with recognised and acceptable levels of safety and quality, thereby reducing liability concerns and building confidence in the viability of recycled material. This is very important where international transfers are concerned to ensure compliance with the provisions of the Basel Convention, see Reference [12].

There are Codes of Practice available in many countries. It may be that another country’s Code of Practice is suitably applicable to your situation and can be translated and adopted. This is what was done in Georgia (refer to Chapter 4 of this Report).

10.10.4 Record keeping

Record keeping should be an integral part of managing halons from the system user to the national halon bank. Record keeping can include any or all of the following:

- User should have accurate information on site regarding system/extinguisher manufacturer, service provider, drawings, specifications, maintenance schedule, operator manual, etc., see reference [13] for an extensive list.

- Users, service providers, halon recycling facilities, and national banks should all implement inventory control, maintain detailed halon transfer records, and emissions data. This provides insight into why leaks or discharges occur, better long range planning for transition to alternatives, proactive capabilities for managing reserves, improved financial planning, and better enforcement of applicable regulations.
- Service providers and fire equipment distributors should keep records of customers' installed base, replenishment rates, and decommissioning plans especially where there is no national halon bank and no clearinghouse. This is also a tool to forecast future halon needs, surplus halons that will become available, and for assisting in the emissions quantifications.

Coordinate the development of a verifiable data tracking system on the emissions of halons and alternatives across the fire protection industry in your country.

The manager of a national halon bank reported personal knowledge of halon cylinders being vented to make them lighter and easier to handle when decommissioning the systems. The manager emphasised the need to provide information to users, operators, and service technicians explaining the damage that is done to the ozone layer as a result of halon venting and discharges. The incidents reported here were provided to the HTOC committee this year (2010) and is a reminder of the continued need to implement Awareness Campaigns.

10.11 Decommissioning, Transportation, and Destruction

Decommissioning is the process of removing a halon system from service. This must be done in order to recover the halon so it can be made available for other uses. Safety is an important aspect of decommissioning and transportation. Halons are pressurised gases. Therefore, the cylinders containing them are under pressure and must be handled with great care. If the pressure is released in an uncontrolled way not only will it result in unwanted halon emissions, but more importantly it can become a projectile that can cause serious injury or death. Two ways this can occur is damage to the valve or activation of the discharge mechanism. Service technicians should always follow the manufacturer's guidelines for cylinder valve disassembly, see Reference [15].

The rate of decommissioning has increased significantly as production of halon has ceased. As a result, there is the potential for a correlating increase in injury and unwanted emissions. Safe decommissioning guidelines are available from numerous sources and are applicable to all halon users, see References [11,15,16].

Transportation of halon occurs during decommissioning, servicing, and transfers to other users, vendors, banking facilities, or destruction facilities. It is important to develop guidelines and ensure they are properly followed so that halon is handled, transported, and stored in such a way that its physical property values are not degraded or emitted, see Reference [16].

Destruction of halon is a final disposition option that should be considered only if the halons are cross-contaminated and cannot be reclaimed to an acceptable purity. There are six processes that have been identified as suitable for halon destruction by the Parties to the Montreal Protocol. These are (1) liquid injection incineration, (2) reactor cracking, (3) gaseous/fume oxidation, (4) rotary kiln incineration, (5) cement kiln, and (6) radiofrequency plasma destruction, see Reference [14]. For up-to-date information on halon transportation and destruction refer to www.unep.fr/ozonaction under "Topics/Disposal & Destruction".

10.12 Conclusions

Avoidable halon releases account for greater halon emissions than those needed for fire protection and explosion prevention. Clearly such releases can be minimised. In reviewing reduction strategies, the UNEP Halons Technical Options Committee recommends the following:

- Do not use halon in new fire protection applications unless absolutely necessary.
- Take advantage of maintenance opportunities to replace existing halon systems or extinguishers with suitable alternatives where it is technically and economically feasible to do so.
- Encourage the application of risk management strategies and good engineering design to take advantage of alternative protection schemes.
- Implement a regular maintenance program.
- In protected areas that are occupied continuously by trained personnel, consideration should be given to manually activated systems or automatic systems that are activated via CCTV flame detectors.
- Encourage users of automatic detection/release equipment to take advantage of the latest technology.
- Verify system design and requirements when changes in hazard have occurred.
- Improve maintenance and system configuration documentation.
- Educate and train personnel on system characteristics.
- Introduce the use of halon recycling equipment to recover all surplus or reusable material.
- Utilise well-managed central storage for halon reserves and install automatic leak detection.
- Discontinue protection system discharge testing using halon as the test gas, and amend any existing regulations which mandate such testing.
- Discontinue the discharging to the atmosphere of portable halon extinguishers and system cylinders during equipment servicing.
- Discontinue the discharge of portable halon fire extinguishers for training purposes.
- Enact laws, develop policies, and ensure enforcement to support the managed phase-out of halons.
- Implement national Awareness Campaigns on ODS environmental concerns.
- Develop or adopt Technical Standards and Code of Conduct
- Develop database and implement record keeping on halon base, transfers, and emissions.
- Develop halon management plan – include end of useful (halon) life considerations.
- Ensure "Responsible Use" of halons using all of the tools from this chapter.

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11.0 Destruction

11.1 Introduction

Since the end of halon production for fire protection uses in 1994 in non-Article 5 countries, many Parties have used recycled halons to maintain and service existing equipment. This has allowed users to retain their initial equipment investment, allowed halons to retain a comparably higher market value to other ozone depleting substances (ODSs), and has resulted in very little halon being destroyed compared to other ODSs. With the end of halon production for fire protection uses worldwide, global inventory management and responsible disposal practices become important considerations to prevent emissions during a critical period of ozone layer recovery. The options for avoiding emissions of unwanted stockpiles of halons include destruction and transformation (also referred to as conversion) to useful chemical products.

Since the 2006 Assessment, considerable interest has focused on the potential ozone and climate benefits from the avoided emissions of ODS still remaining in equipment, products, and stockpiles. While the Montreal Protocol has been successful in ending production and consumption of ODS worldwide, it does not explicitly control emissions. The fear is that without additional incentives, there could be significant releases of these unwanted ODS from the millions of items of equipment each year that reach the end of their useful life or from stockpiles no longer needed.

ODS also have high global warming potentials (GWPs), and therefore their destruction has the potential to earn carbon credits through global carbon markets, broadly divided into the compliance market and the voluntary market. The compliance market for greenhouse gases (GHGs) is based on a legal requirement where, at an international (e.g., Clean Development Mechanism (CDM)) or national and regional level (e.g., European Union Emission Trading Scheme (EU ETS)), those participating countries and/or states must demonstrate that they hold the carbon credit equivalents to the amount of GHGs that they have emitted in order to meet their GHG reduction targets or commitments. Presently, the voluntary market operates outside of the compliance market where individual companies or organisations voluntarily commit to actions and projects to offset their GHG emissions.[4] Currently, only the voluntary carbon market has established standards for ODS destruction as carbon offsets projects. As of February 2010, there are two voluntary standards that recognise and/or have established credits for ODS destruction, but neither provides credits for halon destruction under their protocols. These are discussed further below.

This chapter considers the current issues related to these final options for halon disposal. Since much of the information with regard to halon destruction has remained unchanged since the 2006 HTOC Assessment (e.g., halon destruction technologies, halon transformation/conversion chemistry), some of this information is briefly summarised below and the reader is referred to the 2006 HTOC Assessment for more details.

[4] In the United States, the state of California plans to pursue a compliance market that would accept credits generated from a voluntary carbon market that includes credits for ODS destruction projects.

11.2 Destruction Technologies

In their 2002 report, the UNEP Task Force for Destruction Technologies (TFDT) developed screening criteria for technologies for use by Parties to the Protocol to dispose of surplus inventories of ODS. These technologies were assessed on the basis of:

- Destruction and Removal Efficiency (DRE)
- Emissions of dioxins/furans
- Emissions of other pollutants (acid gases, particulate matter, and carbon monoxide)
- Technical capability

Destruction of halons presents some unique considerations. A number of the technologies screened by the TFDT satisfied the criteria for the destruction of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), but had not been tested for halon destruction. The TFDT, therefore, could not recommend such technologies for halon destruction, since the presence of bromine in halons can significantly alter the process parameters. In particular, molecular bromine tends to be formed and is very difficult to remove from the exhaust gases. Technologies that are recommended for CFC and HCFC destruction, but have not been tested for halon destruction, are described as potential technologies for halon destruction.

Based on the TFDT evaluation, 5 technologies were approved by the Parties for destruction of halons:

- Liquid injection incineration
- Gaseous/fume oxidation
- Rotary kiln incineration
- Argon plasma arc
- Inductively coupled radio frequency plasma

More information on these approved technologies may be found in Chapter 3 of the TFDT report.

11.3 Reported Destruction of Halons

Under Article 7 of the Montreal Protocol, Parties are required to report annual destruction of halons. Historically, very little halon has been reported as destroyed, supporting the findings in Chapter 8 of this report showing a significant global inventory of both halon 1301 and halon 1211. As discussed earlier in this report, this situation is attributable to the fact that the demand for halons has largely been met through the availability of substitutes and alternative technologies and to a limited extent halon recycling. Table 11-1 below lists the amounts of halons destroyed and reported under Article 7.

Table 11-1: Article 7 Reporting for Halon Destruction

HALON	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1211 (MT)	1	0	6.5	0	3.9	1.1	14.2	265	184	84.4	332	307	112	13
1301 (MT)	0	6	3.7	29	50	22	18.5	242	296	29.8	32.9	168	47.7	6.3
2402 (MT)	0	0	0	0	0	0	0	0	0	0	0	0.1	1.3	0
TOTAL (ODP MT)	**3**	**60**	**37**	**290**	**512**	**223**	**227**	**3218**	**3514**	**551**	**1325**	**1089**	**819**	**102**

(UNEP, 2010)

11.4 Transformation of Halons

The term "transformation" refers to the conversion of halon into useful, commercially viable products. Ideally this transformation would produce environmentally friendly products that could be sold for profit. More information on the reaction chemistry for transformation of halons 1211 and 1301 can be found in Chapter 9 of the 2006 HTOC Assessment report.

The Chemicals Technical Options Committee (CTOC) has determined that halon 1301 is a very useful feedstock for the preparation of bioactive compounds. In particular, halon 1301 has been used for many years in the preparation of Fipronil, a broad-spectrum insecticide. In order to support Fipronil production, halon 1301 feedstock production in France has averaged approximately 400 MT per annum since the mid-1990s and more recently approximately 500 MT in China. As the demand for Fipronil (or other bioactive compounds) grows worldwide, it is conceivable that other manufacturing facilities may restart production of halon 1301 to support the feedstock needs. As yet, no Party has used this process to transform existing stocks of halon 1301.

CTOC has received information on one technology, the Newcastle process, covered by a US patent 0036719 (2009) to Kennedy, et al., which has processed halons and CFCs on a pilot scale. Operating at 25kg/hour, the process has a 99.8% conversion efficiency with vinylidene fluoride as a major product. At higher temperatures, the conversion efficiency is over 99.99% for halons and CFCs. No dioxins have been detected with this process. CTOC continues to review information on emerging technologies for potential transformation and destruction of halons and other ODS.

11.5 Carbon Credits for ODS Destruction

11.5.1 Avoiding Emissions of Unwanted ODS

Since the 2006 Assessment, there has been a renewed interest by the Parties to address the issue of continued emissions of ODS and the option of destroying unwanted ODS to avoid emissions altogether. The Parties have requested a number of reports and studies and held a number of workshops related to this issue. A recent study by the World Bank considered how ODS destruction could be financed through the voluntary carbon market (ICF, 2010) as ODS also have high GWPs. The study confirmed a limited window of opportunity over the next two decades in which ODS could potentially be available for destruction for credits as long as the appropriate incentives could be created to encourage increased recovery of ODS at equipment end-of-life. Even with increased recovery from a diminishing, accessible bank of ODS for credits, it is expected that ODS destruction projects will be a small percentage of the overall voluntary market in the coming years. The avoided emissions, however, could be significant and timely for ozone layer recovery and avoided emissions of GHGs.

11.5.2 Voluntary Market Standards for ODS Destruction

According to the World Bank study mentioned above, the global carbon market is comprised of two key segments – a compliance market and a voluntary market. The Bank estimated that the global carbon market represented US$126 billion of total traded value in 2008, of which the voluntary market represented less than 1%. The markets can be further broken down into allowance-based and project-based markets. The project-based, voluntary market is the primary focus for ODS destruction projects where individual projects that demonstrate additional, verifiable, and permanent decreases in GHG emissions earn emission reduction credits that are tradable.

As of February 2010, ODS destruction is eligible for carbon credits under the following two standards: the Climate Action Reserve (CAR) and the Voluntary Carbon Standard (VCS). Neither of these standards provides credits for the destruction of halon under their protocols.

11.5.3 Considerations for Halon Destruction

The availability of carbon credits for ODS destruction raises some specific issues with regard to halons which need further consideration. Halons, more than some of the other ODS, are readily accessible for collection, storage, and disposal, making them very attractive for potential ODS destruction projects under a carbon credit protocol. However, there are a number of issues with regard to the destruction of halons, in general, and as an offset credit project specifically.

- **Continued Demand**: Owing to the continued global demand for halons, the HTOC has recommended that destruction as a final disposition option should be considered only if the halons are cross-contaminated and cannot be reclaimed to an acceptable purity. The global phase-out of halons has been planned based upon halons being reclaimed and reused until the end of the useful life of the systems they are employed in and until there are no longer any important uses. Early destruction of halons undermines the long-range plan set by the Parties, imposes significant financial burdens on users who invested in their halon systems, and puts at risk uses that generally have the potential for significant loss of life in a fire scenario. The actual amounts of the global halon inventory potentially available for destruction are highly uncertain due to business planning and economic considerations by users, potential local and regional imbalances of supply and demand, the availability of destruction technologies and facilities, inventory management approaches, and applicable disposal regulations.
- **Uncertain Climate Impact**: A number of the voluntary standards have cited uncertainty with the actual global warming impact of halon destruction as the reason for its current exclusion from their protocols. The HTOC recommends that the Parties may wish to

consider requesting the Scientific Assessment Panel to clarify the extent of the climate benefits, if any, resulting from destroying banked halons.

- **Avoiding Perverse Incentives**: There are concerns that the availability of carbon credits for halon destruction may inadvertently lead to the wrong incentives – to actions that actually lead to more environmental harm and, worse, to potentially illegal activities. With halons, one concern is that the continued new production of halon 1301 used as a feedstock for a pesticide product may lead to production simply for destruction credits since newly produced halon is technically indistinguishable from recycled halon. In fact, there exists the potential under the Montreal Protocol for a Party to produce halons or any other ODS and destroy equivalent amounts of the same ODS in the same year, resulting in a net zero production and consumption profile for the Party. The Protocol definition of "production" subtracts the amount of ODS destroyed from any amount produced, so a Party reporting net zero production and consumption is in compliance with the Protocol. Further consideration by the Parties and the voluntary standards should be given to highlight this issue and consider if additional measures are needed to ensure that new production of halons or any other ODS for the sole purpose of destruction for carbon credits is avoided.
- **Avoiding New Production**: The HTOC maintains the opinion that adequate global stocks of halons currently exist to meet the future service and replenishment needs of existing equipment until the end of their useful lives. However, the HTOC continues to be concerned of reported regional imbalances where excess agent supply in some regions reportedly cannot be used to meet shortages in other regions due to challenges presented by national or international regulations. Tipping this balance in supply and demand for halons by destroying unwanted but needed material too early concerns the HTOC, because this could result in an essential use exemption (EUE) nominations coming to the Parties and would represent an unacceptable step backward in the halon phase out under the Protocol.

11.6 Conclusions

Halons, more than some of the other ODSs, are readily accessible for collection, storage, and disposal or reuse. Owing to the continued global demand in applications such as aviation, the HTOC has recommended that destruction as a final disposition option should be considered only if the halons are cross-contaminated and cannot be reclaimed to an acceptable purity. Approved ODS destruction technologies and facilities can be found in many countries, and some already have experience destroying some types of ODS including, to a very limited extent, halons. The recent introduction of carbon credits for ODS destruction creates a limited window of opportunity to increase ODS recovery at equipment end of life and to avoid potential emissions altogether by destroying unwanted material. Halon destruction is currently eligible for credits under one voluntary standard, however there are other serious considerations with regard to halon destruction in general. The Parties may wish to consider asking TEAP/HTOC to investigate the issues related to halon destruction further in order to better understand the full implications to the halon phase out under the Protocol, and the impacts to ozone layer recovery and climate protection.

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Appendix A List of Acronyms and Abbreviations

AAAV	Advanced Amphibious Assault Vehicle
AAWG	Advanced Agent Working Group
ABC	Dry Chemical Powder
AFFF	Aqueous Film Forming Foam
APU	Auxiliary Power Unit
ASTM	American Society for Testing and Materials
BSI	British Standards Institute
BTP	Bromotrifluoropropene
CCTV	Close Circuit Television
CEFIC	European Chemical Industry Council
CEIT	Countries with Economies in Transition
CEN	European Committee for Standardisation
CFC	Chlorofluorocarbons
CO_2	Carbon Dioxide
CTOC	Chemicals Technical Options Committee
DE	Destruction Efficiency
DRE	Destruction and Removal Efficiency
DOD	US Department of Defense
EC	European Commission
EEAP	Environmental Effects Assessment Panel
EFV	Expeditionary Fighting Vehicles
EPA	US Environmental Protection Agency
EU	European Union
EUN	Essential Use Nomination
FEPN	Fire and Environment Protection Network
FIC	Fluoroiodocarbon
FK	Fluoroketone
FRP	Fibreglass-Reinforced Plastic
GEF	Global Environment Facility
GWP	Global Warming Potential
HARC	Halon Alternatives Research Corporation
HRC	Halon Recycling Corporation
HBr	Hydrogen Bromide
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HTOC	Halons Technical Options Committee
HVAC	Heating, Ventilating, and Air-Conditioning
HWC	Hazardous Waste Combustors
IASFPWG	International Aircraft Systems Fire Protection Working Group
ICAO	International Civil Aviation Organisation
IMO	International Maritime Organisation
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
ITEQ	International Toxic Equivalency

kg	kilogrammes
LAV	Light Armoured Vehicles
LAVEX	Lavatory Extinguishing
LCG	Liquefied Compressed Gas
LOAEL	Lowest Observed Adverse Effect Level
MAP	Monoammonium Phosphate
MEC	Minimum Extinguishing Concentration
MFS	Multilateral Fund Secretariat
MLF	Multilateral Fund
MOD	UK Ministry of Defence
MPS	Minimum Performance Standards
MRLS	Multiple Launch Rocket System
MSDS	Material Safety Data Sheets
MT	Metric Tonnes
NATO	North Atlantic Treaty Organisation
NFPA	National Fire Protection Association
NGP	Next Generation Fire Suppression Technology Program
NOAEL	No Observed Adverse Effect Level
NOO	National Ozone Officer
NOU	National Ozone Unit
OBIGGS	On-board Inert Gas Generating Systems
ODP	Ozone Depletion Potential
ODP tons	Weight of the ODS in metric tonnes multiplied by its ODP
ODS	Ozone Depleting Substance
PBPK	Physiologically-based Pharmacokinetic
PCBs	Polychlorinated Biphenyls
PCDDs	Polychlorinated Dibenzodioxins
PCDFS	Polychlorinated Dibenzofurans
PFCs	Perfluorocarbons
PGA	Pyrotechnically Generated Aerosols
PICs	Products of Incomplete Combustion
POHCs	Principal Organic Hazardous Constituents
SA	Southern Africa
SAP	Scientific Assessment Panel
SNAP	Significant New Alternatives Policy
SOLAS	Safety of Life at Sea
TEAP	Technology and Economic Assessment Panel
TFDT	Task Force for Destruction Technologies
TRI	Toxic Releases Inventory
TSP	Total Suspended Particles
UK	United Kingdom
UL	Underwriters Laboratories Inc.
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
US	United States

USSR	Soviet Union
VCD	Video Smoke Detection
VCOP	Voluntary Code of Practice
VNIIPO	The All-Russian Research Institute for Fire Protection

Appendix B Definitions

Article 5 Parties: Parties to the Montreal Protocol whose annual calculated level of consumption is less than 0.3 kg per capita of the controlled substances in Annex A, and less than 0.2 kg per capita of the controlled substances in Annex B, on the date of the entry into force of the Montreal Protocol, or any time thereafter. These countries are permitted a ten year "grace period" compared to the phase out schedule in the Montreal Protocol for developed countries. The Parties in this category are known as "countries operating under Article 5 of the Protocol".

Atmospheric Lifetime: The total atmospheric lifetime or turnover time of a trace gas is the time required to remove or chemically transform approximately 63% (i.e., $1-1/e$) of its global atmospheric burden as a result of either being converted to another chemical compound or being taken out of the atmosphere by a sink.

Consumption: Production plus imports minus exports of controlled substances.

Controlled Substance: Any ozone depleting substance that is subject to control measures under the Montreal Protocol. Specifically, it refers to a substance listed in Annexes A, B, C or E of the Protocol, whether alone or in a mixture. It includes the isomers of any such substance, except as specified in the relevant Annex, but excludes any controlled substance or mixture which is in a manufactured product other than a container used for the transportation or storage of that substance.

Countries with Economies in Transition (CEITs): States of the former Soviet Union, and Central and Eastern Europe that have been undergoing a process of major structural, economic and social change, which has resulted in severe financial and administrative difficulties for both government and industry. These changes have affected most areas of community life, as well as implementation of international agreements such as the phase out of ODS in accordance with the Montreal Protocol. CEITs include both Article 5 and non-Article 5 countries.

Country Programme (CP) A national strategy prepared by an Article 5 country to implement the Montreal Protocol and phase out ODS. The Country Programme establishes a baseline survey on the use of the controlled substances in the country and draws up policy, strategies and a phase out plan for their replacement and control. It also identifies investment and non-investment projects for funding under the Multilateral Fund.

Decommissioning: Decommissioning is the physical process of removing a halon system from service. This must be done to recover the halon so that it can be made available for other uses. Effective decommissioning requires knowledge of good practices related to technical procedures and safety measures.

Decomposition products: When certain gases are used to extinguish a fire they break down (decompose) into a range of chemicals, some of which can be toxic. The types of decomposition products and the quantity produced depend on the chemical composition of the fire extinguishing gas.

Essential Use: In their Decision IV/25, the Parties to the Montreal Protocol define an ODS use as "essential" only if: "(i) It is necessary for the health, safety or is critical for the functioning of society (encompassing cultural and intellectual aspects) and (ii) There are no available technically and economically feasible alternatives or substitutes that are acceptable from the standpoint of environment and health". Production and consumption of an ODS for essential uses is permitted only if: "(i) All economically feasible steps have been taken to minimise the essential use and any associated emission of the controlled substance; and (ii) The controlled substance is not available in sufficient quantity and quality from existing stocks of banked or recycled controlled substances, also bearing in mind the developing countries' need for controlled substances".

Essential Use Nomination (EUN): Decision IV/25 of the 4th Meeting of the Parties to the Montreal Protocol set the criteria and process for assessment of essential use nominations.

Feedstock: A controlled substance that undergoes transformation in a process in which it is converted from its original composition except for insignificant trace emissions as allowed by Decision IV/12.

Fine solid particulate **technology:** A category of new fire fighting technologies to replace halons that includes fine solid particulates, aerosols, and gelled halocarbon/dry chemical suspensions. These take advantage of the well-established fire suppression capability of solid particulates.

Fluoroiodocarbons (FICs): A molecule that contains fluorine, iodine, and carbon atoms (in some cases FICs also contain hydrogen). FICs are highly-effective fire extinguishing agents and are alternatives to halons in some applications.

Global Warming Potential (GWP): Global warming potential is defined as a cumulative radiative forcing effects of a gas over a specified time horizon resulting from the emission of a unit mass of gas relative to CO_2. The TEAP has proposed the following classification: High >1000, Moderate 300 – 1000, and Low < 300, which has been used in this Assessment report.

Halocarbons: Halocarbons are compounds derived from hydrocarbons, where one or several of the hydrogen atoms are substituted with chlorine (Cl), fluorine (F), bromine (Br), and/or iodine (I). The ability of halocarbons to deplete ozone in the stratosphere is due to their content of chlorine, bromine, and/or iodine and their chemical stability). CFCs, HCFCs and HFCs are examples of halocarbons.

Halocarbon Fire Extinguishing Agents: Halocarbon chemicals used as alternatives to halons for fire fighting applications. These agents include HCFCs, HFCs, PFCs, and FICs. They share several common characteristics, including: all are electrically non-conductive, all are clean agents (vaporize readily and leave no residue), and all are liquefied gases or compressible liquids.

Halon: The halon terminology system provides a convenient means to reference halogenated hydrocarbon fire extinguishants. Halogenated hydrocarbons are acyclic saturated hydrocarbons in which one or more of the hydrogen atoms have been replaced by atoms from the halogen series (that is, fluorine, chlorine, bromine, and iodine). By definition, the first digit of the halon numbering system represents the number of carbon atoms in the compound molecule; the second digit, the number of fluorine atoms; the third digit, the number of chlorine atoms; the fourth digit, the number of bromine atoms; and the fifth digit, the number of iodine atoms. Trailing zeros are not expressed. Unaccounted for valence requirements are assumed to be hydrogen atoms. For example, bromochlorodifluoromethane – CF_2BrCl - halon 1211.

Halons exhibit exceptional fire fighting effectiveness. They are used as fire extinguishing agents and as explosion suppressants.

Halon 1211: A halogenated hydrocarbon, bromochlorodifluoromethane (CF_2BrCl). It is also known as "BCF". Halon 1211 is a fire extinguishing agent that can be discharged in a liquid stream. It is primarily used in portable fire extinguishers. Halon-1211 is an ozone depleting substance with an ODP of 3.0.

Halon 1301: A halogenated hydrocarbon, bromotrifluoromethane (CF_3Br). It is also known as "BTM". Halon 1301 is a fire extinguishing agent that can be discharged rapidly, mixing with air to create an extinguishing application. It is primarily used in total flooding fire protection systems. Halon 1301 is an ozone depleting substance with an ODP of 10.

Halon 2402: A halogenated hydrocarbon, dibromotetrafluoroethane ($C_2F_4Br_2$). Halon 2402 is a fire extinguishing agent that can be discharged in a liquid stream. It is primarily used in portable fire extinguishers or hand hose line equipment, and fire protection for specialised applications. Halon 2402 is an ozone depleting substance with an ODP of 6.0.

Halon Bank: A halon bank is all halons contained in fire extinguishing cylinders and storage cylinders within any organisation, country, or region.

Halon Bank Management: A method of managing a supply of banked halon. Bank management consists of keeping track of halon quantities at each stage: initial filling, installation, "recycling", and storage. A major goal of a halon bank is to re-deploy halons from decommissioned systems. Halon banks can be managed by a clearinghouse, i.e. an office that facilitates contact between halon owners and halon buyers.

Halon Management Strategy: The Parties to the Montreal Protocol through Decision X/7 (November 1998) reinforced the need for a comprehensive strategy to manage halon stocks. They requested all Parties to "develop and submit to the Ozone Secretariat a national or regional strategy for the management of halons, including emissions reduction and ultimate elimination of their use".

Halons Technical Options Committee (HTOC): An international body of experts established under the Technology and Economic Assessment Panel (TEAP) to regularly examine and report to the Parties on the technical options and progress in phasing out halon fire extinguishants (see TEAP).

Hydrochlorofluorocarbons (HCFCs): A family of chemicals related to CFCs that contains hydrogen, chlorine, fluorine, and carbon atoms. HCFCs are partly halogenated and have much lower ODP than the CFCs.

Hydrofluorocarbons (HFCs): A family of chemicals related to CFCs that contains one or more carbon atoms surrounded by fluorine and hydrogen atoms. Since no chlorine or bromine is present, HFCs do not deplete the ozone layer.

Inert Gases: Fire extinguishing agents containing one or more of the following gases: argon, carbon dioxide, and nitrogen. Inert gases are zero ODP halon alternatives that extinguish fires by reducing oxygen concentrations in the confined space thereby "starving" the fire.

Inert Gas Generator: A fire fighting technology that replaces halons. Inert gas generators use a solid material that oxidises rapidly, producing large quantities of carbon dioxide and/or nitrogen. The use of this technology to date has been limited to specialised applications such as engine nacelles and dry bays on military aircraft.

Montreal Protocol (MP): An international agreement limiting the production and consumption of chemicals that deplete the stratospheric ozone layer, including CFCs, halons, HCFCs, HBFCs, methyl bromide and others. Signed in 1987, the Protocol commits Parties to take measures to protect the ozone layer by freezing, reducing or ending production and consumption of controlled substances. This agreement is the protocol to the Vienna convention.

Multilateral Fund (MLF): Part of the financial mechanism under the Montreal Protocol. The Multilateral Fund for Implementation of the Montreal Protocol has been established by the Parties to provide financial and technical assistance to Article 5 Parties.

National Ozone Unit (NOU): The government unit in an Article 5 Party that is responsible for managing the national ODS phase-out strategy as specified in the Country Programme. NOUs are responsible for, inter alia, fulfilling data reporting obligations under the Montreal Protocol.

Non-Article 5 Parties: Parties to the Montreal Protocol that do not operate under Article 5 of the MP.

Ozone Depleting Substance (ODS): Any substance with an ODP greater than 0 that can deplete the stratospheric ozone layer. Most of ODS are controlled under the Montreal Protocol and its amendments, and they include CFCs, HCFCs, halons and methyl bromide.

Ozone Depletion Potential (ODP): A relative index indicating the extent to which a chemical product destroys the stratospheric ozone layer. The reference level of 1 is the potential of CFC-11 and CFC-12 to cause ozone depletion. If a product has an ozone depletion potential of 0.5, a given mass of emissions would, in time, deplete half the ozone that the same mass of emissions of CFC-11 would deplete. The ozone depletion potentials are calculated from mathematical models, which take into account factors such as the stability of the product, the rate of diffusion, the quantity of depleting atoms per molecule, and the effect of ultraviolet light and other radiation on the molecules. The substances implicated generally contain chlorine or bromine.

Ozone Layer: An area of the stratosphere, approximately 15 to 60 kilometres (9 to 38 miles) above the earth, where ozone is found as a trace gas (at higher concentrations than other parts of the atmosphere). This relatively high concentration of ozone filters most ultraviolet radiation, preventing it from reaching the earth.

Ozone Secretariat: The secretariat to the Montreal Protocol and Vienna Convention, provided by UNEP and based in Nairobi, Kenya.

Party: A country that has ratified an international legal instrument (e.g., a protocol or an amendment to a protocol), indicating that it agrees to be bound by the rules set out therein. Parties to the Montreal Protocol are countries that have ratified the Protocol.

Perfluorocarbons (PFCs): A group of synthetically produced compounds in which the hydrogen atoms of a hydrocarbon are replaced with fluorine atoms. The compounds are characterised by extreme stability, non-flammability, low toxicity, zero ozone depleting potential, and high global warming potential.

Phase Out: The ending of all production and consumption of a chemical controlled under the Montreal Protocol.

Pre-Action Sprinkler: A sprinkler system whose pipes are normally dry and are charged with the extinguishing agent (e.g., water) only when the fire detection system actuates.

Production: The amount of controlled substances produced, minus the amount destroyed by technologies to be approved by the Parties and minus the amount entirely used as feedstock in the manufacture of other chemicals. The amount recycled and reused is not to be considered as "production".

Reclamation of Halons: To reprocess halon to a purity specified in applicable standards and to use a certified laboratory to verify this purity using the analytical methodology as prescribed in those standards. Reclamation is the preferred method to achieve the highest level of purity. Reclamation requires specialised machinery usually not available at a servicing company.

Recovery of Halons: To remove halon in any condition from an extinguisher or extinguishing system cylinder and store it in an external container without necessarily testing or processing it in any way.

Recycling of Halons: To extract halon from an extinguisher or system storage container and clean the halon for reuse without meeting all of the requirements for reclamation. In general, recycled halon is halon that has its super-pressurising nitrogen removed in addition to being processed to only reduce moisture and particulate matter.

Total Flooding System: A fire extinguishing system that protects a space by developing a critical concentration of extinguishing agent.

Water Mist: A halon alternative that uses relatively small droplet sprays under low, medium, or high pressure to extinguish fires. These systems use specially designed nozzles to produce much smaller droplets than are produced by traditional water-spray systems or conventional sprinklers.

Appendix C Halon Bank Management Programmes

Additional Examples of Halon Banks that are functioning successfully in Article 5 Countries (or former CEIT/Article 5 Countries) – continued from Section 4.2.1

Algeria: Algeria established a national halon bank with the assistance of an MLF project and began operations in 2006–2007. Initially the halon recycling centre was located at a commercial gas supplier's facility where they have recovered approximately 1 MT of halon. The national halon bank which will ultimately be tasked to provide halon recovery, recycling, and destruction, to facilitate the management of halons currently installed in the national territory, and to ensure environmentally safe and sound practices in the effective recovery, storage, management and destruction of halons will be the responsibility of a different commercial entity. Algeria expects to be in a position to export recovered halons outside of the country in the future as a result of the recycling centre and national legislation promulgated in 2007; however, the exportation of halon is only approved for the purpose of "utilising destruction technologies approved by the Parties to the Montreal Protocol". The legislation also regulates the use of all halons, of their mixtures, and of the products containing them. Additionally, the legislation (Executive Decrees) prohibits discharge of halons into the atmosphere and forbids the use of halons in new installations and equipment. Measures are being taken to prevent and minimise the leakage of controlled substances particularly in fire protection systems. All halon systems designated non-critical by Algeria are to be removed by a deadline to be established by a joint decree from several national Ministries. The joint decree is also expected to provide full details on the management and operation of the national halon bank.

Argentina: The Argentina national halon bank began operations in 2004 with the assistance of an MLF project. The national bank is government managed and includes a halon analysis laboratory, storage cylinders, halon recovery and recycling equipment, and a depository for the cylinders. The State Fire Services, a branch of Instituto Nacional de Tecnología Industrial (INTI), operates the national bank. They conducted workshops to disseminate information regarding the halon bank and developed a Halon Guide for owners of halon systems/extinguishers. A regulatory framework was established for designation of INTI as responsible for the bank operations and for the establishment and updating of guidelines that govern the banks operations. Multiple coordination meetings were held between entities that would be affected by the banking operations, including government, commercial, and insurance. The Armed Forces are managing their halon bank independently. While the INTI reclamation equipment can purify halon back to 95%, they see the need for destruction capabilities and plan to purchase a catalytic incinerator for the unrecoverable substances. The INTI provides a virtual halon clearinghouse for maritime uses (see Table 4.2). The Argentina halon bank manager's experience to-date is that the national law on halon uses provides sufficient legal support for the banking operations.

Croatia: The halon bank in Bosnia and Herzegovina is run by a commercial entity and the program is managed by the government. Croatia enacted a Regulation on Substances that Deplete the Ozone Layer in 1999. The Croatian Ministry of Environment first conducted a workshop in 2000 involving all stakeholders to inform them of the new regulations on ODS and in particular halons. They then applied for and received MLF assistance to establish their national halon bank. They received halon recycling equipment; however, they did not receive enough equipment for halon reclamation. They do not yet have bulk storage cylinders or the equipment necessary to analyse the halon. The halon bank is operated by a company that specialises in the handling and treatment of liquefied and pressurised gases in the fire protection sector. Croatia also has a service provider and halon 1211 and 1301 available for maritime uses (see Table 4.2).

Croatia updated their ODS regulation in 2005 to be more restrictive and comprehensive. Once they become a member of the European Union, their status will change from a developing country to a developed country. One consequence of EU accession will be the requirement to remove all halon from systems deemed non-critical by EU regulations in order to become compliant with the EU.

Czech Republic: The halon banking programme in the Czech Republic was initiated in 1994 by ESTO Cheb ltd. in cooperation with the Czech Ministry of Environment. The Czech Republic ratified all significant international documents on atmosphere protection. Several other related acts, decrees, and standards applying to the atmosphere protection may be in need of harmonisation with new requirements of EU countries. The Czech Republic among others initiated the changes to Regulation (EC) No 2037/2000 (now Regulation (EC) No 1005/2010) regarding some of the extinguishing agents from the former USSR, used in the Army of the Czech Republic. This Regulation focuses on banning the import, production, selling, and consumption of virgin halons (1211,1301), requiring the safe dismantling and decommissioning of EU defined non-critical halon systems by 31.12.2003, restricting the use of HCFCs for halon replacement (avoiding future HCFC dependency), and encouraging member states to help with the recovery, stockpiling, and destruction of halons. The national Standards, Acts, and Rules were also adopted; one of the most significant of those is the Czech National Standard CSN EN 27201, which is the Czech version of ISO 7201. ISO 7201 specifies the conditions for storage of halon in the halon bank. Also of significance were the national Acts and Rules No.338/1991, 86/2002, 92/2004, 117/2005. These last four established the “Polluter Pays” principle, developed a register of air polluters, banned the production, import and use of halons, made mandatory dismantling of halon systems by 31.12.03, made mandatory recovery of halons (banned venting), specified a technology for halon recovery, and established an exception for applications considered critical by the EU.

The Czech halon bank was established by ESTO Cheb ltd. in 1995 with the support of the State Environmental Fund. The Environmental Fund was established by an Act of Parliament, and the Czech Minister of Environment is responsible for the Fund allocations. This Fund is supplemented by taxes and fines from the illegal production/import of ODS and the Fund is intended to support the national halon bank. The national halon bank was established to meet the requirements of the Montreal protocol and its amendments, the EU legislation and laws, and legislation prepared by the authorised institutions and bodies in the Czech Republic. The project provided a complete solution for collection, depositing, extraction, storage, detection, release, monitoring, transportation, recycling, reclamation, and ecological disposal of halons. According to the bank manager, the halon bank has also become a place of international cooperation as well as the centre for monitoring the existing users, monitoring types and quantities of halon alternatives in the Czech Republic, and for providing training to users and organisations servicing fire equipment.

The Czech halon bank is a private, profit-oriented company. A number of sources provided the funding and support needed to establish the national halon bank, which began operations in 1996. Support came from an ODS phase-out project funded by the Global Environment Facility, the European PHARE programme (pre-accession instrument) which allowed for the purchase of a certified halon reclamation unit (REACH), the State Environment Fund which provides co-financing of operations and covers the costs of destruction (free for the halon owners) and maintaining the inventory of halon users, data collection and reporting, and income from the sales of reclaimed halons (10 Euros / kg). No investments were needed for analytical equipment because of a cooperative agreement with an accredited university laboratory.

Halon bank operations are only part of the overall business activities. In addition to the banking operations, Esto Cheb Ltd. also runs an information centre on fire protection and industry safety services, runs a training centre, operates the reclamation system on halons and other chemicals used in fire protection, provides supervision of substance storage and certification of halon delivery, performs pressure and leak testing of cylinders, and coordinates destruction services (free for halon owners, out-sourced).

To achieve the best possible results the company is also networking with several stakeholders. The company works with an accredited university laboratory for analysing and testing, with a German supplier of Advanced Fire and Explosion Technologies in the Czech Republic, and it cooperates and performs some research with the Czech Army Research Institute. It maintains close cooperation with the National Ozone Unit (data collection & reporting)

In 2007, co-financing from the State Environment Fund ceased – since that time the halon bank has become more flexible in order to adjust to changing business conditions. The bank started charging halon owners for destruction of their used halons, for data collection and reporting, and for consulting services, and it discontinued non-profitable business activities. "Nowadays the halon bank is still running all the activities it was established for", assured the bank manager.

Egypt: Egypt established a national halon bank in late 2008. Their banking operations are industry run while the government provides the program management and regulatory support. They are currently in the process of collecting halons and working regulatory issues in support of the halon bank including regulations on the collection, storage, and recycling of halon. Egypt has established a list of "critical" users, an approval process for becoming a critical user, and guidelines for those users to acquire halon from the national bank. Egypt has regulations requiring all halon users to turn in their excessed halon to the national bank and for all halon users regarding new installations (approved alternatives). They also have regulations on leakage monitoring systems, prohibiting venting, and safing systems for transportation. The national halon bank is required to provide services without profiting; the user is responsible for the costs of transportation and recycling. Egypt has designated two facilities as service providers of halon for maritime uses (see Table 4.2).

The Egyptian Environmental Affairs Agency produced a book and DVD about the national halon bank, they conducted workshops and a training program in support of the bank, and they are currently in the process of implementing an Awareness Campaign regarding minimisation of accidental releases of halons during system maintenance and leakage prevention. While their Halon Bank Management Plan includes considerations for the eventual phase-out of all halons, there are no fixed dates for the phase-out of halon for users considered critical by Egypt.

<u>Estonia</u>: The halon bank in Estonia was established in 2002 under the UNDP project *Regional Halon Management Scheme* and was one of the 4 projects belonging to Estonia's Country Programme for the Phase-out of ozone depleting substances. The halon bank that was set up in Tallinn and run by the National Ozone Office was also meant to serve as a regional base for receiving, reclaiming and storing halon 2001, 2402 and 1301 that had been decommissioned from the fire protection equipment held in Estonia, Latvia, and Lithuania. The halon recycling and reclamation equipment as well as chromatography equipment for chemical analyses to determine the purity of reclaimed halon arrived in May 2002. After the project was complete, the government of Estonia provided funds to run the halon bank and increase the volume of storage capacity. In addition to halons the centre also handles refrigerants.

During 2002-2009, the centre has recovered 14 MT of halon (mainly halon 2402), from a variety of sources including museums, factories, ships, and a TV tower. Many ships had been equipped with 'BF2 halon' (27% halon 2402 and 73% ethyl bromide or halon 2001). This blend cannot be reclaimed and needs to be destroyed.

In addition to satisfying national needs halon was exported to the Indian Navy in 2006, and there have since been requests from India for Estonia to supply more halon from local or other sources. The Estonian halon bank has also received several MT of halons (mainly BF2 halon mix) from Latvia.

As of May 2009, in Estonia only halon deemed as vital remains in-service, e.g., in aircraft and military equipment. Critical uses (as defined by the EC) in Estonia involve only halon 1301 and 1211.

<u>Georgia</u>: Georgia established their national Halon Recovery & Recycling Centre in 2007 with MLF financial assistance. Their banking operations are industry run with government management and regulation. They translated two UNEP DTIE manuals into Georgian; "Eliminating Dependency on Halons: Case Studies" and "Standards and Codes of Practice to Eliminate Dependency on Halons: Handbook of Good Practices in the Halon Sector". They also conducted an awareness and training workshop which included participants from the field of fire safety and protection including importers of fire extinguishing systems, state organisations, and private companies. Georgia implemented several legislative policies regarding halons covering the import, export, transport, use, and production of ODSs. In order to ensure sustainability of the national halon banking operations, the Georgian NOU incorporated the halon bank into the Refrigerant Recovery & Recycling Centre which is a private company working in the refrigeration field. They noted the halon banking programme is not operating as planned - there had been no halons recovered or supplied as of late 2009 which they attribute to no halons being removed from service or discharged since the establishment of the bank.

<u>Hungary</u>: Hungary's national halon bank has been in operation since 1997. The halon bank facility and reclamation equipment were acquired under a GEF project. The national halon bank primarily serves Hungary but has provided some services to neighbouring countries.

Hungary entered the European Union in 2004. According to the EU legislation (Regulation (EC) No 2037/2000 and currently Regulation (EC) No 1005/2009) they were required to decommission all halon systems and extinguishers not defined as critical by the legislation. From

2003 to 2005 the bank decommissioned and collected this halon. A portion of the decommissioned halon was exported, some of it was destroyed, and the remainder was placed in storage as part of the so-called strategic stock.

Indonesia: Indonesia officially launched their halon bank in 2003 and completed it in 2006. They received fully automated halon reclamation equipment through an MLF project; the halon bank manager said the equipment is functioning as intended. Their plan is to receive halon from less important uses in order to supply reclaimed halon to vital uses. The halon bank is industry run. One problem cited is that they are operating the bank without government management and regulation. They have developed internal guidelines which restrict the sales or provision of halon to users considered critical by Indonesia.

While "critical" users have been identified, the regulations defining "critical user" had not been finalised as of late 2009. The Indonesian government has finalised their "Halon Act" (effective 2010) which will also include the process for becoming a "critical user", the guidelines for acquisition of halon from the national bank, regulations on new installations, regulations regarding monitoring systems for leakage, a prohibition on venting of halons, and regulations requiring halon users to turn in their excessed halon to the national bank. When turning in excessed halon, users will be required to pay the transportation fees and follow the "Dangerous Goods Transportation" guidelines regarding safing the systems.

There are only three companies that have been given an Indonesian "critical listing", one of which is in the aviation sector. It is estimated that half of the country's installed base has been identified and that 99% of the installed base is halon 1301. If more halon 1211 is not identified and turned in for reuse, then they anticipate purchasing halon 1211 from outside of the country for the aviation sector.

The halon bank manager has a halon decommissioning procedure in place. There are currently no national plans in place for eventual phase-out of all halons and no requirements or dates set for halon phase-out. The bank manager has a Business Plan in place for selling halon to "critical users", but the bank operating costs are currently absorbed by the commercial entity that operates the bank and such an arrangement is not considered financially sustainable. In spite of the financial uncertainty, the Indonesian halon bank appears to be a model bank in that it consists of a dedicated bank manager, it is located in an aircraft servicing facility (close to one of the primary important users) with state of the art cylinder hydrostatic testing and re-certification equipment, ample conditioned storage space for the halon cylinders, a dedicated, well-maintained room for the reclamation equipment, and trained staff. They also have a website for the bank:

www.indonesiahalonbank.org

Macedonia: Macedonia does not have halon banking operations. The NOO reported that almost all halon systems have been replaced with non-ODS alternatives. Halon is not being imported. They do not believe they have a need for recycled halons in the country. They currently have approximately 150 kg of "waste" halon 1301 awaiting final disposal.

Poland: In 2005 the Ministry of the Environment established a system under which three companies were authorised to store halons, including equipment containing halons, designated for satisfying the uses considered critical by EU regulation, with the option of exporting halons outside the EU territory or destruction. Two of the three companies provide halon for maritime needs (see Table 4-2).

Syria: Syria received MLF assistance in establishing their national halon bank which included procuring halon recovery and recycling equipment and a storage facility. They conducted numerous workshops during this time. Syria's national halon bank is operated and managed by the Syrian Civil Defence, and all halon must now go through them. A nation-wide survey was conducted, but it is incomplete as some "important" users would not release their information to the contractor conducting the survey. Despite the lack of information on the installed base, they believe there is enough halon nation-wide to meet future country needs. Syria released regulations covering the fire protection sector and developed a "Code of Conduct". These new regulations and guidelines require all personnel working on fire protection systems become certified on said systems and related environmental issues. They require monitoring and record-keeping on all fire protection systems. They prohibit the import, export, sales and purchasing of all halons outside of the Civil Defence bank. The Civil Defence was tasked with identifying important users and issuing a list of those users who should report their use and requirements for halon to the halon bank. Users are also required to report any incidents involving halon to the halon bank. In addition, penalties for not meeting the aforementioned requirements were established in order to discourage system owners and technicians from undermining the halon management programme. The bank is tasked with performing annual inspections of all halon users' systems. They have expressed some concerns regarding sustainable funding for the banking operations. In particular, they are concerned that the users relinquishing their halons not be financially burdened such that the halons become vented or traded on the black market. The halon bank management programme has been established with sound principals and within an organisational structure well suited to operate the bank.

Vietnam: Vietnam issued regulations and quotas for halon imports, and as of 1 January 2010 they banned the importation of virgin CFCs and halons. No newly produced halon has been imported to the country during the last 5 years; all demand was met by the importation of recycled halon from Russia, the United States, and several other countries. Halon banking for halon 2402 was included in the original scope of their national ODS phase-out plan; however, as a result of limited resources they decided not to establish a national halon bank. As a national focal point, the NOU is responsible for and involved in the preparation and implementation of all regulations relative to the Montreal Protocol. According to the NOU, the only halons in use in the country are halon 1301 and 2402. The known halon use is limited to the petroleum sector; specific applications are oil platforms and oil vessels. The demand for halon has reduced significantly over the past several years. The halon users are phasing out their halon fire protection systems with CO_2 based systems. The remaining users meet the current demand for halons through importation of recycled halons and existing stockpiles. The NOU reported the remaining users are trying to import recycled halon to stockpile it for future uses.

Additional Examples of Halon Banks that are experiencing difficulties in Article 5 Countries (or former CEIT/Article 5 Countries) – continued from Section 4.2.2

Dominican Republic: The Dominican Republic established a government managed national halon bank in 2006 after receiving halon recycling equipment from an MLF project. However, they did not receive all equipment necessary, so as of late 2009 they were still not fully operational. They have been able to recover some halon 1301 and have it in storage for resale or servicing. Several technicians were trained in the operations, and they have sufficient funds to complete training and to purchase a halon analyser for quality certification. They do not have a halon leak detector nor do they know whether practices have been implemented to minimise discharges and leaks. They have not been able to identify the halon in service throughout the country so they cannot project future halon needs or quantities that may become available. The Ministry of Environment and the State Fire Services are jointly responsible for the national halon bank management program; they provide the manpower and cover the operational costs. The Ministry of Environment was working on the draft regulations to support the halon management program as of late 2009.

Libya: The Libyan government received financial assistance from the MLF in 2005 to establish a halon bank and as of late 2009 they were still working on identifying a "host" for the halon banking equipment.

Mexico: The Mexican halon bank was declared operational in 2002. The bank includes bulk storage cylinders, and portable halon analysis equipment to test the halon quality. While the bank is capable of the recycling and reclamation of halons 1211 and 1301, they have seen little activity since becoming operational. The commercial entity managing the halon bank indicated there has only been a small quantity of halon turned in and attributes the lack of activity to several factors such as halon users recognise halon is a valuable commodity and are unwilling to turn it in at their own expense with no recompense, the international companies are sending their halon to sources outside of Mexico, and small users may have vented their halon rather than incurring the cost of turning it in. Additionally, one of Mexico's largest industries will not turn in the halon they remove from service because they need or want monetary compensation for the halon and can get it elsewhere. The government has met with that particular industry several times with no success. The government has promulgated national regulations in support of the halon banking programme; however, the regulations have not been effective in getting users to turn their decommissioned halons into the national halon bank either because the regulations are not being enforced or are considered unenforceable. Some awareness training was provided, but the bank manager believes significantly more awareness of the environmental concerns with ODS is needed. The halon recycling equipment has also been problematic. While the operators were trained on use of the equipment, it is considered difficult to operate. Additionally some of the parts for the equipment were not functioning and the company managing the bank could not afford the replacement parts.

Nigeria: Nigeria established a national halon bank in 2005 with MLF assistance. Their facility included recovery and recycling equipment, 15 storage tanks for recovered halon, and various support equipment. The halon banking, recovery, and recycling centre is located in Lagos and is operated by a commercial entity. They conducted two workshops in support of the national halon bank and participants included delegates from other countries within their region.

Nigeria expects they have sufficient halons within the country for all future Nigerian needs if their halon base is larger than was reported (they believe it may be as much as 30% larger) and if the decommissioned systems are not vented. As of 2009 they had legislation drafted to support the banking efforts as well as a Code of Conduct for halon decommissioning, recycling, and storage. They conducted numerous training workshops, involving some 300 fire operators and other personnel, on halon decommissioning and design of fire protection systems using halon alternatives. Major halon users were identified and visited with the purpose of monitoring compliance with the halon phase-out in Nigeria. The Nigerian NOU established a Steering Committee consisting of members drawn from the major halon users.

While their halon bank is considered a regional bank, Nigeria is not receiving halon from other countries in the region with the primary reason being attributed to the requirement that costs for transportation, testing, storage, and destruction being absorbed by the halon users. The halon users in Nigeria are also reluctant to turn in their decommissioned halon because of the aforementioned costs associated with doing so and for that reason the NOU has "grave" concerns that the halon decommissioning will not be successful.

Pakistan: Pakistan laid the groundwork to establish a national halon bank, a halon clearinghouse, and halon steering committee in early 2000. They received MLF assistance in 2003 and after lengthy difficulties with suppliers received halon recycling equipment in 2006. During this period, the halon bank manager said that it appears most of the major halon users such as Glaxo, Shell, and BP replaced their halon systems with alternatives. The halon banking operations are managed by a commercial entity in the business of fire extinguishing systems. The bank manager approached the remaining halon users that had been identified during the national survey to encourage them to replace their extinguishers/systems with halon alternatives. The halon users reportedly wanted the replacements to be done at no cost to themselves and, without such incentive, indicated they will wait to replace their systems after a fire event depletes them. As a consequence, the bank manager said he has had negligible quantities pass through the bank (the small amount of halon that was collected and recycled was sold). Another consequence of low throughput was the release of the trained technicians due to lack of work and resources. The bank manager also suggested that venting of halon systems may have occurred prior to bringing the national halon bank on-line. Pakistan has restrictions on the import of halons including recycled halons (due to a lack of a separate tariff classification for recycled halons). The bank manager said there are no known legislative actions in place regarding halon use, collection, or storage. Furthermore, there are no regulations on minimising leakage of halon or accidental discharges and no national guidelines. Pakistan has no national definition of "critical use" nor is there a list of "critical users". The bank manager said there appears to be a general lack of awareness regarding the importance of maintenance, methods for safing halon systems, and halon emission impacts. There is a strong need for supportive legislation, an extensive Awareness Campaign, a re-evaluation of the installed base nation-wide, and training/workshops.

Serbia: Serbia established their national halon bank in 2004 with MLF assistance. They also conducted one regional and two national workshops, set up a webpage, and produced and aired television commercials as part of their Awareness Campaign. The halon bank serves both Serbia and Montenegro and is located in Belgrade at a commercial facility. A commercial entity with experience in high pressure systems and fire fighting equipment was given responsibility for the management and operations of the national halon bank. The banking operations include halon

1211 and 1301 recycling equipment, portable equipment for recovery of halon from remote sites, laboratory equipment, cylinder refurbishment equipment, storage and recovery tanks, leak detector, scales, air compressor, software and database development, and training. The bank manager indicated the quantities of halon 1211 and 1301 recovered have been lower than expected due to the lack of government regulations restricting halon imports and prohibiting the use of any facility other than the designated national halon bank. Many of the halon systems are being serviced or replaced with alternatives by commercial entities other than the national halon bank. There appears to be little known regarding the quantities of halon in fixed installations and mobile fire extinguishing equipment throughout the country, possibly a result of not having someone in the NOO specifically responsible for the national halon bank management programme. While they feel they have been successful in setting up the national halon bank and in implementing an Awareness Campaign, they do not believe they have been successful in banking the decommissioned halon.

South Korea: The halon manufacturing facilities in South Korea closed down in 2009 and no new halons have been produced since. There is no government run halon clearinghouse. In 2010, the South Korean government promulgated a regulation that restricts halon retrieval, recycling, and banking to companies that are "qualified" to provide halon recycling and analysis. The HTOC member from South Korea indicated this new system and regulation are not working as well as expected and attributes the challenges to a lack of regulatory enforcement and penalties.

West Asia, Eastern Africa, and Western Africa: There was MLF assistance provided to establish regional halon banking projects in these three regions; the project for Western Africa was subsequently cancelled. Recycling and recovery equipment were purchased for two of the three regions, but centres have not been set up for any of the three regions. Implementation has not been successful. The recycling and recovery equipment for West Asia and Eastern Africa was shipped to Bahrain and South Africa where national recycling centres have been established as reported in sections 4.2.2 and 4.2.1 respectively. Nigeria, as reported in this section, set up a national bank with MLF assistance and the intent of providing services for the Western Africa region. Delegates from the Western African countries participated in Nigeria's halon bank workshops, but they have not turned in any halon nor formalised procedures to do so.

Appendix D Airworthiness Directives (AD)

AD	Title	Release Date	Effective Date	Comp.	Remark
EASA 2009-0251-E	FFE H1211 – Handheld	25.11.09	26.11.09	2 days	483 units
EASA 2009-0262	FFE H1211 – Handheld-	23.12.09	29.12.09	30 days	FFE ASB-26-115 2,317 units
EASA 2009-0262 R1	FFE H1211 – Handheld	27.01.10	10.02.10	30 days	SB ASB-26-115 Revision C for S/N list – 1 more S/N
EASA 2009-0278	SICLI H1211 – Handheld	22.12.09	05.01.10	30 days	1,422 units
EASA 2009-0276	ATR – H1211 – Handheld – L'Hotellier	23.12.09	06.01.10	36 days	SB 863521-26-001 origin issue 21.12.09 1,582 units (L'Hotellier total)
EASA 2009-0276 R1	ATR – H1211 – Handheld – L'Hotellier	05.02.10	05.02.10	4 months	SB 863521-26-001 revision 1, 28.01.10
EASA 2010-0061	ATR – H1211 – Handheld– L'Hotellier	31.03.10	14.04.10	4 months	SB 863521-26-001 revision 2, 04.02.2010
EASA 2009-0277	ECF– H1211 – Handheld – L'Hotellier	23.12.09	06.01.10	36 days	SB 83520-26-001 origin issue 21.12.09 1,582 units (L'Hotellier total)
EASA 2009-0277 R1	ECF– H1211 – Handheld – L'Hotellier	05.02.10	05.02.10	6 months	SB 83520-26-001
EASA 2010-0012	SOCATA– H1211 – Handheld – L'Hotellier	05.02.10	12.02.10	3 months	SB 83520-26-001, dated 21.12.09 SB 70-183(26), Jan 2010 1,582 units (L'Hotellier total)
EASA 2010-0062	FFE H1211 – Handheld	31.03.10	14.04.10	4 months	ASB 26-116 3,694 units
EASA 2010-0062R1	FFE 1211 - Handheld	17.05.10	31.05.10	4 months	ASB 26-116 issue B 2,586 units

AD	Title	Release Date	Effective Date	Comp.	Remark
FAA 2010-01-03	FFE H1211	28.12.09	20.01.10	90 days	Covers 2009-251-E and 2009-262
FAA 2010-04-16	SICLI H1211	04.02.10	08.03.10	90 days	Covers 2009-278
FAA 2010-05-01	ATR H1211	25.02.10	12.03.10	90 days	Covers 2009-277R1
FAA 2010-11-15	TBM 700 H1211	19.05.10	06-07-10	90 days	Covers 2010-0012